With the Authors' Compl

A MANUAL

OF

VETERINARY HYGIENE.

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BY

VETERINARY CAPTAIN F. SMITH, M.R.C.V.S.,

PROFESSOR IN THE ARMY VETERINARY SCHOOL, ALDERSHOT;

FELLOW OF THE INSTITUTE OF CHEMISTRY;

AUTHOR OF 'A MANUAL OF VETERINARY PHYSIOLOGY,' 'A MANUAL OF SADDLES AND SORE BACKS.'

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PREFACE TO THE SECOND EDITION.

SINCE the first edition of this book appeared, the question of Veterinary Hygiene has received greater attention both in and out of the profession, and it is probable that before long, systematic instruction on this important subject will be given in our veterinary schools as part of the regular course.

For the advancement we have made in this direction we are indebted to the intelligence of our Body Corporate, and the impetus given to the science by the meeting in London of the International Congress of Hygiene.

The only important alterations which this edition has undergone are in the chapter on Ventilation. The previous calculations of the amount of air required by horses were based on some early foreign observations; more recent ones, including my own, have produced a modification in the figures.

Although I have published a separate manual on 'Saddles and Sore Backs,' I have not considered it necessary to remove this chapter from the present edition.

The claims of Mr. Charles Hunting as a pioneer in veterinary sanitary science, which were regretably overlooked in the first edition of this book, have been acknowledged in the present edition. His publications on 'Food and Work,' 'The Feeding and Management of Colliery Horses,' etc., should be read by all interested in these important questions.

Several errors occurring in the first edition have been corrected; in other respects the book practically remains unchanged.

F. S.

Army Veterinary School,
Aldershot,
September, 1892.

PREFACE.

The importance of Veterinary Hygiene, both to the profession and agriculturist, must be my apology for producing this book. No one is more conscious than myself of its imperfections and shortcomings; my duties as an army veterinary surgeon have brought me of necessity more in contact with the horse than with other domesticated animals, and hence it may appear more of an equine than general hygiene; the principles, nevertheless, remain the same, though I have dealt, so far as lies in my power, with the other animals of the farm.

I have endeavoured to place before the profession, in a manner suited to its importance, a subject of considerable interest which has daily to engage its attention, and thus to assist as far as possible in the prevention of disease and saving of life amongst the lower animals.

Having been permitted to work in the Laboratory of Hygiene founded by the late Dr. Parkes, and further being privileged to work under his talented successor, Professor de Chaumont, I have had exceptional opportunities afforded me for practical observation and research. I desire to express to Professor de Chaumont the deep sense of my obligations to him for his instruction and help, and to thank him for his invariable courtesy and kindness.

In the article on 'Transport by Sea,' I have been greatly assisted by notes kindly furnished me by Mr. Duck, Army Veterinary Department.

Some of the chapters of this book have appeared in the *Veterinary Journal* and *Quarterly Journal of Veterinary Science in India.* They have been re-written. compressed, and modified where necessary.

The majority of the plates have been borrowed, for which I desire to express my thanks to the following firms: Messrs. Boyle and Son, Ventilating Engineers, Holborn, for the Ventilation plates; Messrs. F. and A. Dickson, Seedsmen, Chester, for the plates of Grasses; Messrs. Musgrave, Belfast; Stevens, London, and St. Pancras Iron Works Company, for the plates illustrating Stables and Stable-Fittings; Messrs. Stiff and Doulton, London, for plates of Drain-Pipes, etc.; Messrs. McDougall, London, for the plates of Bot Flies, and Mr. L. Casella, Holborn, for those illustrating Meteorological Instruments.

I believe that all sources of information are acknowledged, and elsewhere will be found a list of works consulted.

I have adopted, as the best method of dealing with the subject, the plan followed in that work to which I owe so much, Parkes' 'Manual of Practical Hygiene.'

Aldershot,
March 1887

WORKS CONSULTED.

HYGIENE AND STATE MEDICINE.

'Practical Hygiene' . . . . *Parkes.*
'Lectures on State Medicine' . . *De Chaumont.*
'Hygiene and Public Health' . . *Buck.*
'Hygiène Vétérinaire Générale' . *Magne.*
'Veterinary Sanitary Science and Police' . . . . . . *Fleming*
'Sanitary Engineering' . . . *Eassie.*
'Report of Barrack and Hospital Improvement Commission'

PHYSIOLOGY.

'Human Physiology' . . . *Hermann.*
'Traité de Physiologie Comparée des Animaux' . . . . . *Colin.*

STABLE MANAGEMENT.

Stable Economy' . . . . *Stewart.*
'Horses and Stables' . . . *Fitzwygram.*
'Stable Management in India' . . *Meyrick.*
" " " . . *Poyser.*

Chemistry.

'How Crops Grow'	*Johnson.*
'Chemistry of the Farm' . . .	*Warrington.*
'Rothamstead Experiments' . .	*Lawes and Gilbert.*
'Volumetric Analysis' . . .	*Sutton.*
'Agricultur-Chemie' . . .	*Wolff and Knop.*

Food and Feeding.

'Diseases of Field and Garden Crops'	*Smith.*
'Permanent and Temporary Pastures'	*Sutton.*
'Encyclopædia Britannica' . .	*Letheby.*
'Food and Dietetics' . . .	*Pavy.*
'Food and Feeding' . . .	*Letheby.*

Saddlery and Draught.

'The Horse'	*Youatt.*
'Applied Mechanics' . . .	*Rankine.*
'Animal Mechanics'. . . .	*Haughton.*
'Seats and Saddles'	*Dwyer.*
'The Horse in Motion' . . .	*Stillman.*
'Royal Engineer Aide Mémoire' .	*Cooke.*

Various.

'Elementary Meteorology' . .	*Scott.*
'Text-Book of Geology' . . .	*Page.*
'Geology, Science Primer' . .	*Geikie.*
'Physical Geography' . . .	*Skertchly.*
'Instructions in the use of Meteorological Instruments . .	*Scott.*

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INTRODUCTION.

THE study of physiology teaches almost intuitively the necessity of practising Hygiene. Hence it is that for three-quarters of a century the profession has been unanimous in urging its adoption, and pointing out the ill consequences of its neglect.

It required, however, practical demonstration to convince the public of its utility, and the severe lessons taught them by the various epizootics which from time to time have attacked the animals of these islands, have, in a slight degree, impressed upon them the necessity of observing the laws which govern health, and ward off disease. That a decided impression has been made on the general public no one will deny; hot, steaming, dark stables, filled with putrid and irritating gases, are certainly no longer regarded as adjuncts to health; the veterinary profession has steadily, and in spite of great opposition, brought about considerable sanitary reform, but much more yet remains to be done.

Our greatest hygienic triumphs have been won where our advice has been assisted by law. The most noted example of this has occurred in the army, where, supported by authority, we have practically eradicated diseases which years ago carried off whole regiments of horses. Glanders, a disease which existed in every regiment of the British army, occasioning enormous losses, is now practically unknown; canker and grease are almost as equally uncommon.

We have practised Hygiene in the army since 1796, the principles of which were laid down by the immortal **Coleman**, and have existed with very little modification unto the present day. The magnificent results we have obtained have strengthened our hands and established our position in the service; for it has been publicly recognised that we have practically banished diseases which before our time decimated regiments, that we have prolonged the useful life of the horses of the army, and have placed them at the head of all others for freedom from disease and general fitness for work.

Following on Coleman we had **William Percivall** and **John Stewart**; the latter produced in his 'Stable Economy' the first work on Veterinary Hygiene published in this country. It is difficult to value this excellent work of Stewart's, but it must have been productive of immense good; written in clear and simple language, it directly appealed both to the professional man and to horse-owners.

Charles Hunting for forty years has been identified with sanitary reform, stable management, and food and feeding, especially of colliery horses; to him the profession owes much for his persistent endeavours to enforce a system of rational feeding.

Lastly, we have **Fleming's** 'Veterinary Sanitary Science and Police,' and **Fitzwygram's** popular work on 'Horses and Stables'; a section of the latter is devoted to Elementary Hygiene, such as the horse-owner can readily comprehend.

It is often difficult to value sanitary reform, particularly in human hygiene; where, however, every unit represents money, as is the case in veterinary hygiene, we can show in actual gold the value of the services we are capable of rendering if allowed. When sanitary reform was introduced into the French army, it effected a saving of £90,000 per annum in *the purchase of horses alone.*[1]

The cost to the country of maintaining an efficient army veterinary staff is exceedingly small; including medicines, etc., it only amounts to £1 3s. 2d. per horse per annum; *this is less than half the amount paid for the shoeing.*

Passing away to civil life, we find that our sanitary reform is bearing fruit, though not so luxuriantly as in the army. The chief reason of this is, that up to a certain point a man is at liberty to do what he likes with his own property; the law, excepting in the case of certain diseases, cannot interfere, and it possesses no power of enforcing hygiene. My opinion is, that it is no interference with public liberty to prevent a man overworking, under-feeding, and shutting up in a non-ventilated, filthy hovel animals which unfortunately happen to be his property. The prevention of this state of affairs can only be satisfactorily accomplished by establishing a Veterinary Sanitary Police, aided by the law; such a scheme might well receive the support of the Society for the Prevention of Cruelty to Animals.

The severe lesson taught the country during the last outbreak of cattle-plague, a lesson which they could have entirely avoided had they listened to the profession, or one which would not have proved so costly had they followed its advice, led to the establishment, on a sound basis, of that great sanitary reform, the port inspection of all animals entering the country.

Our insular position is particularly favourable to the exclusion of disease from foreign sources, and the excellent manner in which our port inspection, and the other branches of our Veterinary Department of the Privy

Council perform their work, speaks volumes for the efficiency of our sanitary service.

Owners of stock throughout the country are slowly appreciating the value of the advice on sanitary matters given them by the civil profession; but the work of the latter is often only accomplished by personal influence, and the respect in which their opinion is held by the educated stock-owner. Our progress is therefore slow amongst this, by far the largest class.

It must be acknowledged that much of the hygiene we have practised has been exercised as an art and not as a science. I have endeavoured, in the following pages, to combine the subject as an art and science; we must know how our guiding principles in sanitary science act, and if our knowledge is to be based on a scientific foundation, we must understand the methods by which such subjects as air, food, water, soils, etc., are examined; how ventilation, drainage, disinfection, etc., act; and clearly appreciate by what agencies diseases are spread, and how these are best arrested: a careful study of these subjects places us in the position of determining how diseases are best *prevented*.

Edmund Alexander Parkes, the founder of Modern Hygiene, a man whose magnificent work has startled us by its simplicity and yet completeness, and who has contributed more to the saving of life than words or figures can express, tells us that 'if we had a perfect knowledge of the laws of life, and could practically apply this knowledge in a perfect system of hygienic rules, disease would be impossible'; that such a perfect knowledge of these laws is not likely to be obtained, or rather if obtained is not likely to be acted upon, we can have no reasonable doubt; the value of health will never be generally appreciated, and the serious losses occasioned by disease seem only too readily effaced from the public mind.

Parkes has defined Hygiene as the art of preserving health : '*It aims at rendering growth more perfect, decay less rapid, life more vigorous, death more remote.*' So comprehensive and beautiful is this definition, that I have felt compelled to place it in italics, to give it, if possible, more emphasis.

We have, in dealing with this subject, to consider, with regard to animals, the air they breathe, the water they drink, the food they are fed on, the stables they are placed in, the soils they live on, the saddle and harness they wear, the exercise and labour they undergo ; their individual care and management must occupy our attention, and lastly, the prevention and eradication of epizootic diseases from which they suffer ; still more extensive would be our subject if we included the hygiene of breeding, but we have already covered as much ground as falls within the personal experience of one man.

Veterinary State Medicine is so comprehensive that it requires dealing with separately ; we have touched upon it in the briefest possible manner. Detailed information on this point can be obtained in Fleming's 'Veterinary Sanitary Science and Police,' where the subject of Epizootic Diseases —Prevention and Eradication, Meat and Milk Inspection, Slaughter-houses, Acts of Parliament relative to Animal Diseases, and other matters connected with State Medicine, will be found fully described.

VETERINARY HYGIENE.

CHAPTER I.

WATER.

It is only within recent years that the necessity for the supply of pure and wholesome water for man has been recognised. Before the light of scientific investigation into obscure causes of epidemic diseases was brought to bear, but little attention had been paid to the subject. People drank surface water from polluted rivers or ditches, or from wells in close vicinity to cesspits and other receptacles for decomposing organic matter, and such a thing was considered by no means dangerous. Science, however, has shown that a large body of people cannot with impunity drink water containing the essence of their own excreta, and considerable light has of late years been thrown upon the diseases which are introduced by the agency of impure water. Respecting the part played by impure water in the production of disease amongst the lower animals, we have at present very little evidence. I think it is undoubted that man suffers from more diseases as the result of this than do the lower animals, but I am equally convinced that the horse, no less than his master, requires for the most perfect bodily condition a pure and wholesome supply of water. However that may be, as a simple matter of hygiene, it is our duty to obtain for animals a supply as pure as is consistent with circumstances.

The following points naturally arise in dealing with the subject of water-supply : 1. The quantity of water required for healthy and sick animals; 2. The collection, storage, and distribution of water; 3. The quality of drinking water; 4. Its purification; 5. The effect of an insufficient or impure supply; 6. The chemical examination of water for hygienic purposes.

The Quantity of Water required.—From experiments made in 1866 the War Office fixed the daily supply for Cavalry horses at 8 gallons, and Artillery at 10 gallons per horse. This quantity was to be inclusive of all stable purposes, and in the Artillery was to include washing carriages. If these amounts had to be adhered to they would certainly be found too small, particularly during the summer. In the month of October a horse 16 hands high and doing 8 miles a day of carriage-work was found to drink $7\frac{1}{2}$ gallons; a second horse drank nearly the same amount. In a stable of Cavalry horses doing very little work, and at a cool time of the year, the amount per horse was found to average $6\frac{1}{3}$ gallons. The amount used for washing was 3 gallons daily. Such are the observations made by Parkes, who, from a careful consideration of facts, came to the conclusion that 16 gallons per day per horse for all purposes was not an excessive amount. When we consider the flushing of drains and that used for washing purposes, we must agree that the amount stated is not too large. From experiments I made in India I found that during the month of February a horse consumed on an average $8\frac{1}{2}$ gallons daily.* In the Abyssinian Expedition

* The experiment was carried out on ten horses. The average quantity consumed was:

The morning water - - -	1·9 gallons.
At midday - - - -	3·4 „
At evening - - - -	3·15 „

The amount consumed during very hot weather would be rather larger than this.

the following was the calculation for the daily expenditure of water per head on board ship. Elephants, 25 gallons; camels, 10 gallons; draught bullocks, 6 gallons; pack bullocks, 5 gallons; horses, 6 gallons; mules and ponies, 5 gallons. The quantity of water required per head for infirmary purposes is difficult to estimate, so much depends upon circumstances, such as fomenting, irrigations, enemata, etc.

The quantity of water used by human beings for all purposes is a question which has excited considerable inquiry, as it is considered an important point in the social economy of nations. It is therefore desirable that as sanitarians we should be able to answer the question for the animals committed to our charge, both from an economic and official point of view.

The collection of water is obtained naturally by rivers and streams, or artificially by tanks and wells. The collection of water which has not penetrated the soil is desirable, but a process has been proposed to use both surface and subsoil water, obtaining the latter by means of pipes, and thus drying the soil as well as obtaining water. All water from below the surface of the ground is called subsoil; this is obtained by means of wells or borings. All the rain which falls on the soil cannot of course be recovered for the purposes of water-supply; much depends on the nature of the ground and the amount of evaporation; the loss arising from these causes has been stated to be from $\frac{1}{2}$ to $\frac{7}{8}$.

An inch of rain delivers a little over $4\frac{1}{2}$ gallons of water to every square yard, or 22,617 gallons per square acre; this equals 101 tons by weight. A knowledge of this may be of importance in calculating the length of time a supply will last in places where water is scarce, particularly in India, when the question of water-supply during long hot weather, or after successive dry seasons, becomes one of extreme urgency.*

In cases of standing camps, or where large bodies of mounted troops are likely to be stationed for any length of time, the question of a permanent supply of water is an important one. Camping-grounds are not always selected with a due regard to this point. A mile to water is a trying thing for both men and horses, and the latter suffer as a result.

Of the STORAGE OF WATER we have little to say; reservoirs such as are used in England are carefully guarded by the sanitary authorities. In India, where the supply for horses is often from tanks, the question as to the proper conservation of such tanks would certainly fall within our province. The deeper they are the better, as evaporation is to an extent prevented and the water kept cooler. As the water subsides during the hot weather, the opportunity should be taken to clean the sides, removing all dead vegetable matter. The removal of *living* vegetable matter from the surface of the water should not be indiscriminately carried out, for many water-plants give out a large amount of oxygen, and thus assist in oxidizing or destroying organic matter in the water. A general order was issued some years ago in India for the clearing out of all the water-plants from tanks; the result was that water which before this was good and wholesome became unfit for use. There are, however, certain species of duck-weed which impart an unpleasant taste to the water. Where doubt arises as to the wholesomeness or not of water-plants, the simple

* The yield of a spring can be roughly estimated by observing how long it takes to fill a measure of known capacity; and that of a well is ascertained by noticing how long it takes the water to rise to a certain level.

experiment of placing them in water and observing whether any smell or taste is imparted to it would settle the point. It is certain that decaying vegetable matter should not be allowed to remain in tanks.* Water-troughs, as a means of temporary storage, demand hygienic attention as to their cleanliness, scraping, and washing out.

The distribution of water is usually effected through iron pipes; leaden ones were formerly used, and many cases are on record of lead-poisoning in man from the action of the water on the pipe. There are certain waters which act on lead more than others; those containing carbonic acid and salts of calcium and magnesium have but little effect on lead pipes; the immunity is due to the carbonic acid they contain forming an insoluble lead carbonate. Water containing organic matter, or even water exceedingly pure, has a great solvent action on lead. The protection of lead pipes is accomplished by a tin lining, or a bituminous or coal-tar coating.

As rain falls through the air it carries down with it certain ammoniacal salts, nitrous and nitric acids; it also becomes highly aërated. It often contains dust and organisms. As a source of supply it is healthy and pleasant.

Rain falling on the ground is variously distributed; most of it sinks into the earth and is returned through springs, wells and borings; part of it is collected into brooks and rivers, and part of it evaporates. Water which has passed into the earth does not remain at rest: it is constantly traversing the cracks which exist in the underground formations; if it arrives at a pervious bed like sand, it readily passes through; if at an impervious bed like clay, it is turned aside and has to find another line of

* The singular effect on animals in South Australia partaking of water in which a quantity of scum like green paint was growing is remarkable. The case is detailed later on.

escape. No matter how dense rocks may be, there are generally some cracks or joints through which the water is enabled to circulate. The origin of SURFACE SPRINGS may be thus described: They are the result of a pervious and impervious stratum. Water will pass readily through a layer of porous material such as sand or gravel, and continue to do so until it meets with some impervious layer such as clay; the effect of this is to turn the current aside, the water escaping at some hollow or valley in the form of springs.

DEEP SPRINGS are produced by that portion of the underground water which sinks a great depth, perhaps for several miles, into the earth; it flows through the cracks in the rocks for a considerable distance, until it meets with a rock through which it cannot pass. The pressure of that water which is descending from the surface forces it to find another passage, and it is driven up and down until it comes to the surface again as a gushing spring. ARTESIAN wells are deep springs made artificially. In the case of those existing in London the water-bearing rock is the chalk which comes to the surface both north and south of London, but is found at a depth of 300 feet below that city; its form is evidently that of a trough, hence geologists speak of the London Basin. Water coming in from both sides collects under London at great pressure, so that when the water-yielding bed is tapped, the water rises with great force (Skertchly).

Water containing carbonic acid, such as ordinary water obtains by passing through the ground, has a remarkable effect on many rocks, even on some of the hardest. It dissolves and carries away the lime in solution, and this power of dissolving lime is the cause of hardness.

Spring water may be pure or impure; the general notion of spring water being always pure is not correct. Some are so highly charged with mineral matter as to be quite unfit for any but medicinal purposes.

River water is of very variable composition, depending upon the amount of contamination the river has to endure. So long as rivers are converted into open sewers, so long must disease be present amongst the people living on their banks, who have to drink a solution of their own excreta.

A well may be deep, shallow, or Artesian. A deep well is anything over 50 feet; anything under 50 feet, *unless it pass through an impermeable stratum such as a stiff clay or rock*, is classed as shallow.

Sutton tells us that it is evident that no very definite distinction can be drawn between deep and shallow wells. There are many considerations which qualify the definition of a deep well. It may be considered essentially as one the water in which has filtered through a considerable thickness of porous material, and whether the shaft of such a well is deep or shallow will depend on circumstances. If the shaft passes through clay or other impervious stratum, and the surface water is thus rigidly excluded, the well should be classed as deep, even if the shaft is only a few feet in depth, because the water in it must have passed for a considerable distance below the clay. On the other hand, however deep the shaft of the well is, it must be considered as shallow if water can enter it near the surface, or large cracks or fissures give passage to surface water through the rock in which the well is sunk. Every care should be taken to exclude surface water from passing into deep wells. Much may be done in shallow wells by making the upper part of the shaft water-tight, and it is desirable that the surface for some distance around the well should be puddled with clay or otherwise rendered impervious, and so increase the thickness of the soil through which the water passes.

Shallow wells are always suspicious, as they afford a natural drainage to the upper soil, and are liable to have during heavy rain organic matter washed into them. A well drains a surface, roughly speaking, of four times its depth. The drainage into it is not equal throughout the whole length of its shaft. At one time it was described as being that of an inverted cone; it is now stated to be that of a parabola to the surface, extending for some distance along the surface of the ground. All wells should be protected from surface-washings by a stone coping, and be lined for part of their depth by brick or stone.

The following classification of waters is given by the Rivers Pollution Commissioners:

Wholesome.	1. Spring water.	Very palatable.
	2. Deep well water.	
	3. Upland surface water.	Moderately palatable.
Suspicious.	4. Stored rain water.	
	5. Surface water from cultivated land.	Palatable.
Dangerous.	6. River water to which sewage gains access.	
	7. Shallow well water.	

Hygienically the classification would be as follows: 1. Pure and wholesome water; 2. Usable; 3. Suspicious; 4. Impure. The characteristics of a pure water are absence of colour, taste, smell, or extreme hardness; the more a water deviates from this, so will it pass into the other classes named.

The impurities found in water are of various kinds, but may be generally stated to be organic and inorganic. The organic impurities are animal and vegetable substances in all forms, from disease-producing matter to harmless vegetable growths. The inorganic impurities are the salts of the metals. These impurities obtain entrance into the water in various ways, either at its source or during its passage through rivers, canals, or pipes, or even after its delivery to the place of consumption. The impurities obtained at its origin will depend upon the geological formation of the soil in which the source is situated. If the ground is charged with the products of animal excreta and refuse, the water derived from it will contain these products in solution; but it is evident that some soils or formations are more impure than others, and this difference in the degree of soil impurity depends upon the power the ground possesses of oxidizing or destroying the filth which is carried into it. Where rapid destruction of this occurs, there we may expect to find a purer water than in formations where it does not occur. Moreover, the porosity of the soil, especially when of great depth, will considerably assist in purifying the water by acting as a natural filter.

It is evident that in deep porous soils, where rapid oxidation and destruction of organic matter occurs, we may look for water of a pure type, and the more we depart from these conditions the more impure will the water be. Again, the presence of the salts of metals in great abundance in the formation will affect the purity of a water; for we find that these substances, such as lime, magnesium, soda, potash, iron, and alumina, are very readily acted upon by the water passing through the soil, and rapidly taken up in solution.

In gravel formations we usually expect to find a pure water, particularly away from towns. Where clay exists the water is usually impure; in alluvial formations it is generally bad; in limestone and chalk districts the water is usually organically pure, but contains a large amount of mineral substances, as lime and magnesium, rendering it exceedingly hard. Surface waters, especially from cultivated lands, and marsh waters are usually very impure, from the amount of organic matter they contain.

During the passage of water through rivers or canals the principal impurities which obtain an entrance are sewage and manufacturing refuse; the latter is derived from bone-boilers, bleach-works, tanneries, etc. The importance of this class of impurities is very considerable.

The impurities found in wells are derived from surface-washings and soakage through soil impregnated with organic matter; from pipes or cesspits containing animal excreta leaking, and the leakage finding its way into the soil to be carried into the nearest well. Shallow wells near buildings, or stables, or close to manure-pits, are simply receptacles for filth. In India the contamination of tanks from washing clothes, and from the direct introduction of excreta, is perfectly abominable.

Examination of Water for Hygienic Purposes.*

A water analysis is made with the object of finding if any deleterious matter is present which may affect the health of the animals drinking such water. The deleterious matter looked for is organic and inorganic. The information revealed by a water analysis requires great care to interpret its real meaning and significance, as we shall have later to point out.

The inquiry consists of a physical, chemical, and micro-

* Some care should be exercised in collecting samples of water for analysis. Quart bottles should be used, thoroughly cleaned out with the water to be analysed. If water be drawn from a tap, some of it should be allowed to run off, and so clear the pipe before the collection is made. The same remark applies to a pump. In collecting water from a river or stream, fill the bottle below the surface of the water. Glass stoppers, and not corks, should be used for the bottles.

scopical examination. By the PHYSICAL EXAMINATION we determine the colour, clearness, sediment, lustre, taste, and smell of the water. The *colour* of a water is obtained by putting it in a tall glass vessel, placed upon a piece of white paper, and then looking down through the depth of water, which should, if possible, be not less than 18 inches. Any marked colour by this means is readily detected. Water should have a bluish tinge; yellowish is perhaps the most common tint, and is probably due to fine sand or clay. Brown waters are suspicious of sewage or other organic contamination. The *clearness* of the water is judged of in the manner above described. The *sediment* forms usually after the specimen has stood for twelve or twenty-four hours; to obtain it the clear water is drawn off by a syphon, and the remaining water and sediment poured into a conical glass. It will usually be found to consist of vegetable debris, in which may be detected low forms of organic life, ova of insects, parasites, etc. A microscopical examination is the only satisfactory method of dealing with the sediment. The *lustre* of a water is its degree of brilliancy. The chalk waters have an exceedingly brilliant appearance, from the amount of carbonic acid they contain. The brilliancy of a water may be great, slight, or nil. No good water should have a decided *taste;* taste is a difficult thing to define, but whatever taste good water does possess is not due, as Professor de Chaumont has shown, to the salts existing in it, but entirely to the dissolved carbonic acid. Iron is the only substance which can be tasted in small quantities in water.

A good water should certainly have no *smell;* the best method to determine the presence of smell is to heat the water, when such gases as sulphuretted hydrogen are given off, and smell becomes apparent.

The opinion to be formed of the purity of a drinking water from the physical examination alone might be misleading, as a very unpromising *looking* water may be perfectly pure, and *vice versâ*. We are, however, justified in considering, in the absence of anything more definite, that a water possessing no colour, taste, or smell, with but a slight sediment and brilliant lustre, is perfectly fit for drinking purposes.

The object of a MICROSCOPICAL EXAMINATION of water is to determine the nature of the suspended matter. This, as we before stated, is organic and inorganic; vegetable matter, dead or living; animal matter, as epithelium, hairs, portions of tissue, ova of insects or parasites; also those organic substances which lie between the animal and vegetable kingdom, as bacteria, vibriones, etc.; inorganic substances, as sand, chalk, and other mineral matter.

The indication which these substances afford, particularly the organic, is evidence of pollution. Respecting the innumerable living organisms which may be found, it is difficult to say that these are direct evidence of pollution, for algæ, diatomes, and desmids are found in most running streams.

Much larger organisms, as the water-flea, are probably quite harmless in themselves, though for all we know they may be the intermediate bearers of certain parasites. Respecting the latter, there can be no doubt that many forms of parasite are conveyed through the ova being in the drinking water. The filaria which affects the blood of man develops in water within the body of the mosquito, and in the relapsing fever of equines, described by Mr. J. H. Steel as produced by a spirillum, there was certain evidence to point to the drinking water as the source of the organism.

It should be clearly understood that in all analyses of water the dissolved solids only are referred to; all suspended matter is referred to the microscopical examination, and where the water contains much, it should be filtered before being subjected to analysis.

DISSOLVED SOLIDS.

We have now to consider the chemical examination of the water for dissolved solids. These consist of lime, magnesia, soda, potash, ammonia, iron, alumina, combined with chlorine and sulphuric, carbonic, phosphoric, nitric, and nitrous acids (Parkes). Let us clearly understand before we proceed further what the object is of determining the presence of these substances in water. We may rightly argue that the addition of them to drinking water would, in the small quantities in which they are found, be utterly unproductive of harm. Perfectly true ! We might add all these substances in the proportion in which they are found in bad water, viz., only fractional parts of grains, and yet not in the least impair the purity of drinking water. Why, then, does the chemist lay such stress upon their presence, and what is the object of the careful and often tedious process for isolating each substance and estimating its quantity ? The object is this, that the elements, as we obtain them, are indications of the compounds in which they exist, and are undoubted proofs of the entrance into the water of substances containing these elements.

If we look back at the whole range of organic and inorganic substances, we will find that there are but few of them which do not contain the elements and acids we have named. Take lime, magnesia, soda and potash, and consider the number of totally different bodies of which these may form an integral part. They may be found in the earth, and in animal or vegetable bodies. Their presence, therefore, in water is from either one or all of these sources; it remains with the chemist to decide which. Take ammonia as another example. Consider how few substances there are in nature which do not contain either ammonia or the elements which form it. Rain water collected before it reaches the earth contains a distinct amount of it; nearly all organic substances contain either it or its elements, nitrogen and hydrogen. Would we, therefore, be justified (considering for the moment that ammonia is a dangerous thing in water) in rejecting uncontaminated rain water because it contains ammonia? Certainly not, for we know its source and origin. What is it, then, which renders us suspicious of ammonia in water? It is not its quantity, for even in sewage it does not reach more than $\frac{1}{2}$ to 1 grain per gallon, and we know that therapeutically we can give it, combined with a carbonate, in the quantity of drachms; it is evident therefore that it is not ammonia as ammonia which we fear, but it is the undoubted indication which the presence of ammonia affords us of *organic contamination.* We cannot isolate fæces, urine, or putrid organic substances in water in the form in which they entered, for they have become dissolved or suspended; their elements have undergone change; the nitrogen has broken up or combined with hydrogen, and thus formed ammonia. In ammonia, therefore, we have our index of the amount of organic nitrogenous substances in drinking water, and in speaking of ammonia we are actually speaking of organic nitrogenous matter.

The presence of ammonia in water is therefore a most important point to determine, and, owing to its ubiquitous nature, very great precautions have to be adopted to prevent its entry into the water under examination; the chemist possesses such extremely delicate tests for this body, that the opening of an ammonia bottle during the time an analysis is being made would, if discovered, be the cause of the whole analysis being repeated; and if undiscovered, would probably be the means of condemning a water which was perhaps entirely free from nitrogenous organic matter. We have named chlorine as a substance to be sought for; now chlorine in the form of a gas, or dissolved in water, is certainly a powerful germicide, and consequently it might be argued that in the very small proportion in which it is found it would be beneficial rather than otherwise. But the chemist shows us clearly that the presence of chlorine in drinking water is a most valuable aid in determining its purity, for the chlorine found there comes only from two sources, viz., chlorides of the metals, potassium, calcium or sodium, or chlorides of organic substances containing the same bases. It is certain that chlorine derived from the chloride of sodium of inorganic substances is quite harmless, and it has been suggested that 30 to 40 grains per gallon might be added to drinking water with positive advantage. But, on the other hand, chlorine derived from the chlorides of sodium of urine and fæces would be a very serious thing. We determine the chlorine, therefore, to see whether urine or other organic matter has obtained an entry into the drinking water; we know the normal amount of chlorine which should exist, and all over and above this must either be derived from organic matter or from a salt stratum. Phosphoric acid is another substance sought for, because the phosphates in good waters are small; and if they are found in large quantities they generally indicate organic matter, vegetable or animal. Nitric and nitrous acids are also sought for, not for the harm they do in the very minute quantities in which they exist, but for the indications they afford of nitrogenous organic matter; for we know that when this latter is undergoing change, various nitrogen acids are formed, and of these nitric and nitrous are the most important.

We therefore sum up all that has been said on this point by stating that the object in examining water for the substances already named is to utilize their absence as an index of the organic purity of the water, or their presence as a proof of its impurity.

There are two distinct analyses of water which we can make, viz., either to ascertain the simple presence of the substances; or, secondly, not only to ascertain their presence, but estimate their amount. The first is called qualitative, the second quantitative analysis. The first is open to everyone with the aid of a few reagents and test-tubes; the second requires much care, manipulative skill, and apparatus. I regard it as quite unnecessary that a veterinary surgeon should be able to make a quantitative analysis of water. The process requires continual practice to keep both eye and hand in, and experience shows that men who have gone through a course of quantitative analysis very soon forget it unless always at it; but I do consider it necessary that a veterinary surgeon should be able to apply an examination which does not last more than a few minutes, and which will enable him to pass an opinion as to the purity or otherwise of the water supplied to the animals under his professional care. If anything more elaborate is required, the water can be sent to an expert.

QUALITATIVE EXAMINATION.

Having noted the physical character of the water, such as colour, taste, smell, lustre, etc., we proceed to note the *reaction* of the water under examination, and this is done with ordinary litmus-papers. Good water is usually neutral in its reaction. If it is acid, and the acidity disappears on boiling, it is due to carbonic acid. If it is alkaline, and the alkalinity disappears on boiling, it is due to ammonia; this reaction is, however, very rare. If it remains alkaline after boiling, the alkalinity is due to carbonate of soda.

Lime is present in the form of calcium carbonate, sulphate, chloride or nitrate. To test for this substance we apply the well-known reaction between lime and oxalic acid, producing the white precipitate of oxalate of lime. The oxalate used is the oxalate of ammonium. The amount of precipitate obtained may vary from a faint haze to a well-marked turbidity; as the amount of precipitate depends entirely on the amount of lime in the water, and not on the oxalate used, we can roughly estimate the amount of lime by the eye. Thus 6 grains of lime per gallon gives a marked turbidity, 16 grains a considerable precipitate. Six grains of lime per gallon is found in the best waters; some are even softer than this, such as the water supplied to the Aldershot camp, which I find contains only 3 grains per gallon. A water may contain more than 6 grains per gallon consistent with organic purity; thus, water from the chalk and lime strata is very hard, containing 12 to 16 grains per gallon. The question constantly arises in connection with hard waters, Can this water be softened in any way? The chemist by a simple test can answer the question readily.

Hardness in water is due to lime; but, as mentioned, there are four forms in which it may exist, viz., carbonate, sulphate, chloride, and nitrate. Which of these, therefore, is most concerned in the question of hardness? Before this is answered, attention must be drawn to the fact that hardness is of two kinds, *permanent* and *temporary*. These terms require no explanation; one hardness can be got rid of, the other cannot. Temporary hardness is due to calcium carbonate, whilst permanent hardness is due principally to calcium sulphate. As the hardness due to calcium sulphate cannot be got rid of, we regard the presence of this salt as extremely objectionable when it exists in large amounts; whereas, calcium carbonate hardness is not regarded with anything like the objection. We can determine between these hardnesses by a very simple test. Water containing calcium carbonate hardness is softened by boiling, for by this process we drive off the carbonic acid which holds it in solution, and the calcium carbonate, being no longer soluble, becomes deposited; calcium sulphate is quite unaffected by this process. Let us suppose, therefore, that our opinion is asked, about a specimen of water, as to what its hardness is due to. We first of all apply the test for lime, viz., the oxalate of ammonia; we find, say, that it produces a considerable precipitate, which we judge to be between 12 and 16 grains per gallon. We allow this to stand aside in a test-tube, and taking another sample, boil it for a few minutes and allow it to cool. We next pass this through a small filter made of blotting-paper into another test-tube, and a clear liquid results. To this add oxalate of ammonia, and compare the precipitate given by this with the precipitate first formed; if it is considerably less, we may be sure that much of the hardness is temporary and due to calcium carbonate, whereas, if there is very little difference between the precipitates, it is sure to be calcium sulphate. By the process of quantitative analysis the amount of lime in water may be determined with accuracy by the so-called soap test, where the well-known reaction between soap and water is made use of. No lather can form in water until the lime is thrown down, hence, the amount of soap which it takes to make a lather is the amount of lime which it has precipitated. To obtain accurate results a solution of soap of known strength has to be made up, but for qualitative analysis the ordinary soap liniment of the Pharmacopœia may be used.

I have made some experiments with this soap liniment, and I find that 1 drop added to half an ounce of water is equal to about $1\frac{1}{2}$ grains of lime per gallon. In other words, if we take half an ounce of water and add 1 drop of the liniment, and on shaking a lather is produced, we would know that about $1\frac{1}{2}$ grains of lime per gallon existed. We are thus in possession of a most useful test. If half an ounce of water required 4 drops to produce a lather, there would be about 6 grains of lime per gallon; if 6 drops, 9 grains; if 12 drops, 18 grains; and so on. We know the amount of lime per gallon in good water should not exceed, if possible, 6 grains, and the greater the deviation from this, the greater the hardness.

Thus, in a rough way, we may estimate the hardness of the water. Exactly the same process may be applied to it after it has been boiled. If, for example, it takes 12 drops of soap liniment to produce a lather before boiling, and 3 drops to produce one after boiling, we would know that calcium carbonate hardness was principally present. The next substance to be looked for is chlorine.

Chlorine.—We have before described the sources of chlorine in water; its presence is determined, by taking advantage of the delicate reaction which occurs between silver nitrate and a soluble chloride. If we add a solution of nitrate of silver to water containing chlorine, a white precipitate falls. The precipitate may be a mere haze, or a considerable opacity; depending entirely upon the amount of chlorine present. 'One grain of chlorine per gallon gives a haze, 4 grains a marked turbidity, 10 grains a considerable precipitate' (Parkes). We must remember that silver also precipitates phosphoric acid in the water; so in order to prevent any mistake in judging the phosphate and chloride precipitates together, we add dilute nitric acid, which dissolves the phosphate precipitate should any be present, but has no effect on the chloride. After being exposed to the light the white precipitate becomes lead-coloured.

Sulphuric Acid.—This acid is generally found in combination with lime; from what we just said, it will be remembered that the sulphate of lime in water is objectionable, owing to its producing permanent hardness. The test employed to detect its presence is the chloride of barium, which gives a white precipitate insoluble in nitric acid. 'One and a half grains of sulphate per gallon gives no precipitate until after standing; 3 grains gives an immediate haze, and after a time a slight precipitate' (Parkes). Sulphuric acid in large quantity, with but little lime, indicates that sulphate of soda, and usually much chloride and carbonate of soda, are present in the water; the latter if evaporated will under these circumstances be found alkaline.

Nitrous Acid.—The object of this test is to ascertain the presence of nitrogenous organic matter. We have said that when nitrogenous substances undergo oxidation they give off ammonia, nitrous, and nitric acids. The first acid formed is nitrous, hence nitrous acid in water tells us that the organic matter has commenced to undergo change; in other words, the contamination of the water is *recent.* To detect nitrous acid, add a solution of iodide of potassium and starch to the water, and then dilute sulphuric acid; if nitrous acid is present we get an immediate blue colour. But the solution of starch and iodide keeps very badly, and often instead of getting a blue colour we get a yellow one.

There is another substance used as a delicate test for nitrous acid; it is known as metaphenylenediamine. A few drops of this and sulphuric acid, added to water containing nitrous acid, produces a yellow colour which becomes almost red on standing; so delicate is this test for nitrous acid that it is capable of detecting half a part of nitrous acid in 10,000,000 parts of water. There is another substance termed naphthylamine capable of detecting 1 part of nitrous acid in 1,000,000,000 parts of water. The presence of nitrous acid is an indication of recent organic contamination; it should, therefore, be entirely absent from water.

Nitric Acid is produced from nitrous by oxidation. This acid is tested for by means of a solution of brucine. Add a solution of brucine to the water to be tested, and pour gradually down the tube strong sulphuric acid, so as to make it fall to the bottom; if nitric acid is present a red-coloured zone forms at the margin of the acid and water, the depth of the colour varying with the amount of nitric acid present. This is a very delicate test; $\frac{1}{100}$th of a grain per gallon may thus be detected. Nitric acid in the water indicates old contamination, or at any rate, it is a proof that oxidation of organic matter is taking place.

The test with brucine may not be obtainable, but the presence of nitric acid may be ascertained by means of a solution of sulphate of iron and sulphuric acid applied in just the same way; a brown colour forms.

Ammonia.—The importance of determining the presence of ammonia we have previously dwelt upon. In water it exists in two forms, viz., as *free* or saline ammonia, such as would be found were urea introduced into the water; and secondly, as *albuminoid* or organic ammonia. Qualitative analysis makes, however, no distinction between these forms, that come under the head of quantitative, and special methods have to be adopted to obtain them. For ordinary qualitative analysis we are content to know that ammonia is present, and take no cognizance of the form in which it may exist. The test employed is known as Nessler's, which is a compound of mercuric chloride, potash, and iodide of potassium; this possesses, in the most remarkable manner, the power of detecting, even in very minute quantities, the presence of ammonia. On adding a drop of this solution to water containing ammonia, it strikes a yellow colour which deepens on standing. A water may contain both free and albuminoid ammonia, and yet give no evidence of it when the test is applied in the usual qualitative way.

The explanation of this is, that in spite of the delicacy of Nessler's test for NH_3, yet (unless the water be concentrated by distillation) we do not get the reaction, unless it is found in large amounts. Therefore, if on applying Nessler's test to water which has not been distilled we get a markedly yellow colour form, there need be no hesitation in rejecting such water for drinking purposes, as the amount of organic matter present must be very large to give such a deep reaction. Should there be only a pale delicate tint of colour, it will render us very suspicious of the water, and exceedingly careful over the analysis. In order to perceive the colour formed by Nessler's test, we look through a certain depth of the fluid placed over a white surface; an inch or so in a test-tube is sufficient; the least yellow tint can then be detected at once. It is of supreme importance in applying this test that the test-tube be perfectly clean and free from ammonia. Add to a test-tube, one-quarter full of the water under examination, one or two drops of Nessler's solution; shake the tube: if ammonia is present there will be a yellow colour struck at once, or it will come up after standing a few minutes.

The **oxidizable matter** which exists in water, viz., the organic matter there, which will absorb oxygen, is important to determine. We have, under the head of ammonia, nitrous and nitric acids, dealt with the subject of the determination of organic matter; but it must be remembered, that the organic matter spoken of in every case contained the element nitrogen. We have, however, organic matter which contains no nitrogen; we must, therefore, have a test which will enable us to judge of the amount of the substances in water, both nitrogenous and non-nitrogenous, which are capable of absorbing oxygen and undergoing change; the oxygen absorbed is the measure of the organic matter present. The agent used for this purpose is a solution of chloride of gold. A few drops of this solution are added to the water and boiled for twenty minutes. If organic matter is present, the yellow colour turns to pink, violet, olive, dark violet, or even a black precipitate, depending entirely on the amount of organic matter present. The usual colour is violet, more or less deep, and it deposits itself on the side of the glass or vessel. The solution of silver chloride, resulting from the chlorine test, may also be a guide in judging of organic substances; where these are largely present it rapidly darkens in colour. A very weak solution of permanganate of potassium may also be used—1 grain to 4 ounces of water. A few drops of this are added to the water just to give a delicate pink tint. If much organic matter is present the colour soon goes, varying from a few minutes to an hour. Two drops of this solution added to 2 ounces of water should keep its colour at least 1½ hours if the water is good.

Phosphoric Acid.—Pure water contains no phosphate; water containing vegetable, and particularly animal matter, such as urine and fæces, contains a considerable quantity of phosphoric acid. The test is really a valuable one when carefully considered with the others. The presence of this substance is detected by adding to the water a little dilute nitric acid, and then molybdate of ammonium. If phosphoric acid is present in large quantities, an immediate yellowish-green colour appears; if in small quantities, it shows itself on boiling the liquid.

Sulphuretted Hydrogen is found in exceedingly bad waters; the objectionable smell of this gas may be perceived on boiling the water, or by the addition of a salt of lead, which gives a black precipitate.

Lead, Copper or Iron may be present. The former is dangerous, the copper is rare, the iron unobjectionable. The test for these three is the sulphide of ammonium. Place the water in a white dish and stir with two or three drops of ammonium sulphide. A dark colour is produced, which disappears on the addition of a drop or two of hydrochloric acid if due to iron, or remains permanent if due to lead or copper.

Such are the qualitative tests used in water analysis. So valuable are they as indications of the quality of water, that they are never omitted even when a detailed quantitative analysis is being made. It may be said that in ordinary practice it would be impossible to put them in operation; that oxalate of ammonium, chloride of barium, brucine, Nessler's solution, chloride of gold and sulphide of ammonium, are not agents in common use. To an extent this is true, but the cost of these reagents is trifling, and the difficulty of obtaining them would not be great where their method of application is known, and their value appreciated. Both chlorine and hardness may, however, always be approximately determined by agents found in most Pharmacies, viz., nitrate of silver and soap liniment. The inferences to be derived from the qualitative tests are, according to Parkes, as follows:

If chlorine be present in considerable quantity, it either comes from a strata containing salt, from impregnations of sea-water, or from the admixture of liquid excreta of animals or man. If from the first cause, viz. salt strata, the water would be alkaline from carbonate of soda; there would be an absence, or nearly so, of oxidizable organic matter as determined by the tests for nitric and nitrous acids, ammonia, and the chloride of gold tests; and there would probably be a large amount of sulphuric acid present. If the chlorine be derived from calcium chloride, there would be a large precipitate with ammonium oxalate after boiling. If from sea-water, the chlorine would be found in very large quantities; there would be much magnesia, and very little evidence of oxidized products of organic matter. If it be from sewage the chlorine is marked, the nitric, nitrous, phosphoric acids and ammonia largely present; and if the contamination be recent, the organic oxidizable matter would be large. A stream fouled by excreta may thus show at different times of the day different amounts of chlorine, and this in the absence of rain will certainly indicate contamination.

Ammonia is nearly always present, but in minute quantities in good water. If it can be detected without distillation it is exceedingly suspicious. If nitrates and nitrites are present they are likely to be from excreta. Nitrates, viz. nitric acid, found in water indicate previously existing organic matter, probably animal; but nitrites, viz. nitrous acid, indicate recent contamination. The coincidence of readily oxidizable matter, of ammonia, and chlorine, indicates an animal origin.

If a water gives the test for nitric and not nitrous acids, and there is almost an absence of ammonia, the origin of the nitric acid is not from organic matter, but probably from potassium, sodium, and calcium nitrate, derived from a soil impregnated with organic matter at some previous date. Large evidence of nitric acid, with little evidence of organic matter, indicates old contamination. If nitrous as well as nitric acids and organic matter be present, the pollution is recent. Phosphoric acid indicates an origin from phosphatic strata, or from sewage impregnation.

Lime in large quantities indicates a very hard water; if boiling removes it, it is calcium carbonate; if it has but little effect upon it, it is calcium sulphate or chloride. If sulphuric acid is large, it is in combination with lime; if the latter is small, it is combined with soda. If the water is acid, and the acidity disappears on boiling, it is due to carbonic acid; if it is alkaline and remains so after boiling, it is due to carbonate of soda.

In forming an opinion as to the quality of a water, it is most essential that the collective tests, and not a single one, should be our guide. As an example of this, the subjoined table from Parkes (see p. 27) will be found most useful.

It would be beyond the scope of this work to give an account of the methods adopted in making a quantitative analysis of water. Full information on this point can be obtained from Parkes' 'Practical Hygiene,' and Wanklyn's 'Water Analysis.' All we have to note is, that in order that the results of a quantitative analysis may be appreciated, we should know the quantities of the various substances which are admissible in a good drinking water. We already know the significance of each substance; it only remains to state the proportion in which they should exist.

The substances dealt with in a quantitative analysis are:

The solids: *a*, total; *b*, fixed; *c*, volatile.
Chlorine.
Hardness: *a*, total; *b*, fixed; *c*, removable.
Free ammonia.
Albuminoid ammonia.
Oxygen required for total oxidizable matter.
" " " organic matter only.
Nitrous acid.
Nitric "

TABULAR VIEW OF INFERENCES TO BE DRAWN FROM QUALITATIVE EXAMINATION.

Chlorine.	Oxidizable Matter.	Nitrates.	Nitrites.	Ammonia.	Phosphates.	Sulphates.	Classification.	
Slight	Slight	Nil	Nil	Nil	Nil	Trace	Good	A perfectly pure water.
Marked	Nil or trace	Nil	Nil	Marked	Present	Trace	Good	A good water probably from a deep well.
Marked	Slight	Marked	Nil or trace	Trace	Trace	Trace	Usable	Probably old animal contamination.
Large	Slight	Nil or trace	Nil	Nil	Nil or trace	Marked	Usable	Probably some contamination with sea water.
Slight	Well marked	Marked or large	Nil	Nil	Nil or trace	Nil or trace	Usable	Probably vegetable impurity—peat.
Marked	Nil or trace	Marked	Nil or trace	Marked	Marked	Marked	Suspicious	Probably a shallow well contaminated with urine.
Slight	Marked	Present	Present	Marked	Trace	Trace	Impure	Probably water contaminated by sewer gas.
Marked	Large	Marked	Marked	Marked	Marked	Marked	Impure	Water contaminated with sewage.

The analyst shows his results as either grains per gallon (equivalent to parts per 70,000), or he expresses them in the metrical system, and describes them as parts per 100,000, or parts per 1,000,000.

So many conditions influence the quantity of each of the substances found in good drinking water, that no hard and fast rule can be drawn in the case of any but one substance, and that is nitrous acid.

The following are approximately the quantities which are found in a good water :

	Grains per gallon.	
Solids.		
Total	5·0000	The solids in chalk waters may be as high as 30 grains per gallon.
Fixed	4·0000	
Volatile	1·0000	
Chlorine	1·0000	
Hardness.		
Total	6·0000	
Fixed	2·0000	
Free Ammonia ...	·0014	
Albuminoid Ammonia	·0035	
Organic Oxygen ...	·0200	
Nitrous Acid ...	Nil	
Nitric „	·0226	

The FILTERING of water for horses is a process never likely to assume important proportions ; nevertheless, I can conceive certain conditions where a water-supply being impure, and expense no object, our opinion might be asked with regard to the process.

The essentials of a good filter, as laid down by Dr. de Chaumont, may be stated in a few words :

1. Every part of the filter should be readily got at for the purpose of cleaning.

2. The filtering medium must have a sufficiently purifying power.

3. The filtering medium must yield nothing to the water.

4. The filtering material must not clog.

Of the many articles in the market, only one fulfils the required conditions, and that is spongy iron. This substance, not unlike animal charcoal in appearance, is obtained by roasting hæmatite iron ore in porous metallic iron. Its action on water is mechanical and chemical, for it arrests suspended matters, and oxidizes organic matter in solution. It is the most powerful filtering medium ever introduced. The whole water-supply for cavalry and artillery horses at the station of Bangalore is filtered. The filter-beds are of sand.

To purify water from suspended matter **alum** has a marked effect; it produces a film which carries down with it all suspended matter, and clarifies water in a remarkable manner. The quantity added is about 6 grains per gallon.

To SOFTEN water is a process we may certainly be called upon to advise. Hardness due to carbonate of lime can be removed; that due to the sulphate, chloride, and salts of magnesium cannot be removed. To soften water due to calcium carbonate hardness, the process known as Clark's is used. It is simply the addition of lime-water, which, by combining with the carbonic acid in the water, causes nearly all the calcium carbonate to be thrown down. The process is done on a large scale in many parts of England.

The water-supply to army animals is a point to be noticed. In barracks our attention is confined to the regular cleaning out of water-troughs, and observing that the golden rules of stable management, in respect to time of watering and quantity, are carried out. During marches, particularly abroad, horses have to put up with whatever supply is most convenient, irrespective of quality. In camps where the supply is from a running stream, it is a recognised principle to tell off the river or stream into three parts; at the upper part is drawn the supply for the men, below this that required for animals, and lower still that for washing and bathing purposes. Lord Wolseley tells us that in the Crimea, where the supply was from springs, a series of half-barrels were arranged, one slightly below the other, connected by a tin gutter, so that the overflow from each barrel filled the one next below it, the fall being just sufficient to allow for this; so that if twenty-five of these barrels were arranged, fifty horses could be watered at one time. If animals are to be watered at very shallow streams, dams should be constructed to deepen them, as horses drink much better when the water is 4 or 5 inches deep. I have known many instances where horses refused to drink at running water.

It takes a horse about two and a half minutes to drink and make way for another; but when there are many animals to be watered, about five minutes each will be occupied. Each horse occupies about 1 yard in length of trough, therefore 1 foot of trough will water four horses an hour. There is a portable horse-trough known as the Aldershot manœuvre pattern; it is made of wood; each trough holds 24 gallons; the weight, with legs complete, is 40 lb. There is one pump to every three troughs, and each trough will water three horses at a time. Lord Wolseley recommends these troughs to be made 1 foot 6 inches broad and 8 or 12 inches deep. A small canvas water trough is now on trial; it appears most satisfactory.

Let us suppose our opinion is asked as to what should be the capacity and size of a trough for watering one hundred horses three times a day. The least amount we could calculate for would be 3 gallons per head at each water, so that the capacity of the trough should be 300 gallons. One cubic foot will contain 6·25 gallons of water, so that 300 gallons would occupy a space of 48 cubic feet. The trough should, therefore, contain 48 cubic feet of water; the size would be 2 feet wide, by 1 foot deep, by 24 feet long.

The process of boring for water has often to be adopted; the rationale of the method is boring through the ground, following this down with tubes which keep the earth from falling in, and afford the means of escape for the water, which is pumped up. The principal pumps so used are the American or Norton's Tube Well, and Bastier's Chain Pump. The tube well in a porous strata will yield as much as 600 gallons per hour. It can be sunk in the ground at the rate of from 10 to 20 feet per hour.

Effects of an Impure Supply of Water.

We are in almost absolute ignorance as to the effects of an impure supply of water on the health of animals; the general impression, that any water is good enough for horses and cattle to drink, has perhaps to account for this state of affairs; there can, however, be no doubt that as precise investigations proceed, and greater care is shown in the inquiry into, and accuracy of examination of the causes operating in producing disease amongst animals, impure water will have its legitimate share allotted to it. Of one thing I am convinced, that however inert impure water may have been to animals in a wild state, the more we subject them to an artificial existence as the result of civilization, the more we remove from them the immunity they may have possessed against common causes of disease, and the greater the liability is there for causes which originally may never have existed to become developed.

What are the substances in water which are liable, then, to provoke disease? We have animal organic matter, vegetable organic matter, particularly that of marshes, the germs of specific diseases, and some of the salts.

Commencing with the latter first, we know the result on the digestive organs of horses receiving a large quantity of lime in their water. Hard water undoubtedly produces a derangement of the intestinal canal, and sympathetically of the skin; the harsh staring coat of horses receiving hard water rapidly disappears when a softer water is supplied. The amount of hardness in water which will produce this derangement of the intestinal canal has not been accurately determined; but from 8 to 10 grains of lime per gallon has, in many cases, been found injurious.

Water impregnated with sulphurous acid gives rise in cattle to a number of serious symptoms and to diseases of the bones. Rossignol states that water highly charged with calcium carbonate and sulphate was found to give rise to exostoses in horses, and that pure water being given the disease ceased. In the *Veterinarian* Dudfield states that young horses have been attacked by bony tumours on their limbs, the result of using water charged with calcareous salts.

An excess of sulphate of lime in some well water is supposed to have caused an epizoötic amongst the horses of a French regiment of cavalry. On changing the water-supply the disease ceased.

Butyric acid, one of the results of the decomposition of organic substances, has been known, in combination with lime, to produce diarrhœa in man and animals. During the cattle-plague in Dresden, some animals were buried at from

10 to 12 feet in depth. During the next year water from a well 100 yards away had a putrid odour, and contained butyrate of lime.

Cystic calculi amongst animals, particularly sheep, have been attributed to the excessive hardness of the water. Calculus disease is more common in the limestone districts than in any other. Ulcers of the skin in man, particularly that known as Delhi boil, have been supposed to be produced by the drinking water. I have had reason to believe that Bursattee, the analogy of Delhi sore in man, has been produced by the agency of water, though in what way this acts I am not prepared to explain. Goitre has been observed amongst horses and mules in France, from drinking waters well known to produce goitre in man.

The impregnation of water by sewage has undoubtedly some effect upon animals. Mr. Stevenson, veterinary surgeon of Newcastle-on-Tyne, regards it as the most prolific source of abortion in cows, and abortion in ewes has been attributed to the same cause.* We have no idea how much it may be answerable for cases of intestinal irritation, such as diarrhœa; or of obscure outbreaks of disease which we read of from time to time. It seems, at least, only rational to assume that it must have some evil effect, and as our knowledge progresses we shall have outbreaks of disease clearly attributable to this cause.

We have, at least, very clear grounds for stating that most of the specific diseases from which animals suffer may certainly be communicated through the water-supply. I need only instance glanders, foot-and-mouth, cattle-plague, anthrax, and even perhaps pleuro-pneumonia. I have before alluded to the singular form of relapsing fever in equines, so thoroughly worked out by the late Vety.-Surg.

* 'Journal of the Royal Agricultural Society of England.'

J. H. Steel, which he considers to have been introduced by impure water. All the animals attacked were watered at one tank, and any fresh ones brought to it were certain to be affected.

How far cases of sore throat, particularly that known as malignant sore throat, may be due to impure water we have no knowledge.

Lastly, water may be the medium, and perhaps in animals the most common medium, for the conveyance of the ova of parasites; tape-worms, liver-fluke, round-worms, and thread-worms are undoubtedly conveyed in this manner. Leeches may find their way into an animal's nostrils through water, producing great inconvenience and hæmorrhage. V.-Major R. Poyser has told me of some well-marked cases due to this, and in Algeria the French soldiers have at times suffered severely from this cause. V.-Captain Pringle observed in the Zoab Valley Expedition the frequency of leech-bites in the nostril, from drinking at streams infested with these creatures.

Some wells near the sea are brackish and unfit to drink. In places on the East African coast this is the general state of affairs, and neither animals nor vegetation are to be found.

The amount of organic matter in water given to animals to drink is often very high. I need only allude to the water-supply of farmyards from pools and ditches; the water is stagnant, putrid, swarming with animal and vegetable organisms, the result of the impregnation with animal excreta and farmyard refuse. The flesh and milk from animals receiving water of this description has often a bad taste and peculiar odour.

The poisoning of animals from drinking the water of an Australian lake is recorded in vol. xviii. of *Nature.* A protococcus forms a scum, like green paint, from 2 to 6 inches thick on the surface of the lake. Cattle will not drink the water after it has been standing some time, as it gives off a stench of urine and butyric acid. It produces stupor and convulsions. Sheep die in one to eight hours; horses, eight to twenty-four hours. Post-mortem appearances were not remarkable for any great change; the blood was black and uncoagulated, the brain congested.

I have entered rather fully into the subject of water, for the reason that I am persuaded we have many diseases affecting horses and cattle, particularly, I think, the latter, which are due to its influence.

There can be no doubt that for the full enjoyment of health an unlimited and pure supply of water is necessary; and though the effects of a bad supply may not produce in many cases any positively prejudicial effect such as we can see, yet it must be a means of exposing the health of animals to risk, by lowering the tone of the system, and rendering them more susceptible to contract zymotic poisons when these are present.

CHAPTER II.

AIR.

Composition of the Atmosphere.

THE air may, generally speaking, be stated to be a mixture of one-fifth oxygen and four-fifths nitrogen in one hundred parts. The exact composition of pure air has been variously stated, but the following may be accepted on the authority of Dr. Angus Smith:

Nitrogen	78·98
Oxygen	20·99
Carbonic Acid	0·03
	100·00

In addition to these, air is found to contain a certain amount of watery vapour, which varies with the temperature, traces of ammonia, and a variable quantity of ozone, organic matter, and mineral substances.

Oxygen.—A pure air will contain 20·99 per cent., an average air 20·96 per cent., whilst very bad air begins at 20·6 per cent. Under contaminating influences, the oxygen diminishes; the air from cow-houses and stables, taken after the buildings had been open in the morning, gave from 20·70 per cent. to 20·82 per cent. (Angus Smith). A closed stable in the Ecole Militaire gave 20·39 per cent., and the same stable, ventilated by casements, 20·71 per cent. (Leblanc).

Ozone is only another form of oxygen; it exists in very minute quantities, and is supposed to be generated by electrical conditions of the atmosphere, and by aromatic plants and flowers (Mentegazza). It is seldom found in the air of inhabited rooms (Wolffhügel), and is most abundant in open fields and places of great atmospheric moisture (Ebermeyer). Ozone has an exceedingly irritating effect on the respiratory passages, eyes and nose, and an attempt has been made to connect outbreaks of influenza with its presence in the air. Owing to its great oxidizing properties much influence has been attributed to it in checking epidemics and epizoötics, but evidence is wanting.

Carbonic Acid.—This is a constituent of the atmosphere, and as such is principally derived from the ground air. Its normal proportion is about ·04 per cent. Pettenkofer gives ·05 per cent. for the air of Munich. Analysis shows that the amount of CO_2 in the air varies considerably, not only from day to day, but from hour to hour; on succeeding days I found the following quantities: ·062, ·068, ·047, ·053, and ·032 per cent. Samples of air taken from the same place within a few minutes of each other yielded

·041, ·038, and ·032 per cent. The air close to the ground contains more CO_2 than that some feet above it.

In spite of the enormous amount of CO_2 passed daily into the atmosphere (computed by Dr. de Chaumont for London alone to be 822,000,000 cubic feet daily, and by Dr. Smith to be, for Manchester, 15,066 tons daily), yet, owing to the process of diffusion, the amount in the air of big towns is very little larger than in that of country places. Variations in the CO_2 of the air occur under certain circumstances. Mene found that it is lowest in winter, increases during the spring, falls again during summer, rises during the autumn, and obtains its maximum in October. On land it is greater by night than by day; the reverse holds at sea. It increases with snow, but diminishes, as might be expected, with rain. The greatest variation in quantity is attributed by Fodor to the ground air. An increase in the amount of CO_2 in the air of buildings is indicative of a reduction of oxygen *and an increase of organic matter.* The amount of CO_2 present is therefore used as an index of the purity of the air, as we shall have later to show.

Nitrogen is incapable of sustaining life, and its function in the air is to dilute the oxygen. During electrical conditions of the atmosphere, a portion may be converted into nitric acid, a substance often found in rain-water. There are no changes known to occur in it.

Watery Vapour.—The amount of this is constantly varying; its changes have no relation to the different proportions of gases which may be present—it is quite independent of them. The variations in moisture are due to the temperature; more vapour is contained in air when the temperature is high than when it is low.

Impurities in the Air.

It is not surprising to find that the impurities found in the air are numerous, and derived from many sources. The importance of these impurities is very great, when we consider that, in whatever form they exist, they obtain a direct entry into the animal's body by means of the respiratory passage. Absorption from the mucous membrane of the lungs is particularly rapid; the administration of medicines by the trachea, which has lately been strongly advocated, is based on this knowledge of bronchial absorption.

Certain provisions exist in nature to prevent an accumulation of the enormous amount of impurities poured into the air. The chief of these is the well-known law of diffusion, whereby rapid dilution of the particles occurs. The vegetable kingdom plays an important part, by assimilating as food certain impurities in the air, and replacing them, as in the case of oxygen, by material essential to life; the natural oxygen of the air assists in the purifying process by destroying organic compounds and breaking them up into simpler bodies. The elements perform their share in the process of disintegration and repair; the air is washed by means of rain, and impurities carried down by this means to the earth, where they are assimilated by plants, and thus destroyed. All these provisions of nature tend to keep the air in that condition of healthy balance which is so essential to animal life.

The lungs of a horse will contain from 1 to 1½ cubic feet of air, and at each inspiration about 250 cubic inches are drawn through the trachea; the surface of the lungs to which this amount of air is exposed is calculated to be equal to 289 square feet. Air, then, containing impurities, is exposed to an absorbent area within the body equal to five and a half times the surface of the skin.

Air is rendered impure by the products of respiration and the decomposition of excreta; by the influence of large manufacturing towns and thickly populated cities, the air becoming vitiated by the products of combustion and the gases of trades; and by disease poisons given off from the bodies of sick men and animals. For convenience of description, therefore, the impurities of air are divided into organic, inorganic, and gaseous.

Organic impurities, in small proportions, always exist in the air of places occupied by animals; and in order to distinguish between the amounts and their effects, they have been divided into neutral, putrid, and organized. Such a division is quite an arbitrary one, and is open to objection.

Organic impurities exist in the form of solid particles, accompanied in many cases by gases which are given off from them. These particles, such as bacteria, vibriones, spores of fungi, are only of microscopic dimensions; others, such as vegetable fibre, epithelial cells, etc., are much larger. The organic matter in the air can be collected; that from the human breath has been condensed and examined. Ehrenberg has discovered 200 forms of organism in air thus collected.

We know very little about these living particles of matter found in the air; they are largely met with in prisons, hospitals, houses, and stables, wherever the air is impure, and in a lesser degree they exist everywhere. We can filter them from the air, and can also destroy them by the action of chemical agents. On this process of filtration and disinfection of organic particles is founded the basis of antiseptic surgery.

Amongst these organized particles are also others, which form a distinct group. They are characterized as being the *materies morbi*, or disease-producing bacteria; such, for instance, are the poisons of pleuro-pneumonia, tuberculosis, sheep-pox, cattle-plague, influenza, and, probably, anthrax and glanders. That particles of disease-producing matter can be conveyed by the air is well known, and the following experiment made by Kuchenmeister is quite conclusive: A sheep was made to breathe, during one hour, air which was made to traverse a shirt worn by a small-pox patient for twelve hours; in five days the animal was affected with variola.*

Epithelial scales and pus-cells have been found in the air of hospitals, and in those devoted to the treatment of skin diseases actual disease-producing fungi have been found. The air of towns contains organic matter in a state of fine division; vegetable fibre derived from manure is frequent in the air of streets; pollen from flowers, feathers, epidermis, hairs, scales, and fungi, are commonly found.

Solid bodies in the air, both of organic and inorganic origin, have been observed for years. In examinations made by Dr. de Chaumont, epithelium, hair, and various fibres, sand, soot, and crystalline substances, sporangia of fungi, and monads were found. In the accident ward of St. Mary's Hospital he found pus-cells in the air near some beds where repeated cases of erysipelas had occurred. Dr. Veale found at Netley, under similar conditions, the air loaded with fungi. I have found in the air of stables, hairs, epithelial-cells, vegetable fibre, sand, spores of fungi, and in one case an acarus. Mr. Crookes and Dr. A. Smith both found large quantities of organic solid matter in the air surrounding animals affected with cattle-plague. In passing air from cow-houses through a solution of permanganate of potassium, Dr. Smith observed that the appearance produced in the water could not be caused by pure air, unless from fifty to one hundred times the amount was used. With regard

* 'Veterinary Sanitary Science and Police' (1st Edit.), G. Fleming, LL.D., F.R.C.V.S.

to the organic particles found in sheds where diseased animals were kept, he says: 'I came to the conclusion that the air of cow-houses and stables is to be recognised as containing more particles than the air of the street in which my laboratory is, and of the room in which I sit. There is found in reality a considerable amount of *débris*, with hairs or fine fibres.' Similar indications were found in a cow-house with healthy cows, so that Dr. Smith did not pretend to have discovered the poison of cattle-plague; but that when particles exist in the air surrounding diseased animals, it is only rational to believe that in the case of infectious diseases they may be the means of conveying the specific poison.

Various forms of bacteria have been detected in the air; putrefactive bacteria are always present; those of anthrax, tuberculosis, and glanders are probably present under certain conditions, particularly those of tuberculosis. Anthrax spores present in the air of rooms where wool-sorting is carried out are well known to produce the disease by inhalation. Slight air currents probably prevent floating bacteria from settling down; the condensed watery vapour which surrounds them tends to maintain their buoyancy; friction also retards their fall (Ziegler).* Wernich has shown that air currents may sweep off bacteria from moist fungus masses adhering to the surface of solid bodies.†

The distance which solid particles in the air will travel is very great. Ships, when several hundred miles from land, often have their sails and yards covered with sand. It is reasonable to suppose that if these particles can be conveyed such enormous distances, disease-producing matter can be just as readily carried about.

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* 'Pathological Anatomy.' † *Idem.*

The organic matter found in air vitiated by respiration and transpiration is made up of cast-off epithelium from the mouth, air-passages, and skin; organic vapours from the lungs and skin whose constitution is imperfectly known; fæces in fine division, and vapours derived from the decomposition of materials from the intestinal and urinary passages. This organic matter is accompanied by carbonic acid gas and watery vapour. Regarding the latter, the cutaneous and pulmonary transpiration from a horse, whilst in the stable, is equal to about 2 gallons of water in twenty-four hours; for the ox it is about $1\frac{1}{4}$ gallons. The vapour from the skin contains organic matter and carbonic acid.

It is this organic matter found in buildings which obtains such an important place in the hygiene of air. We have previously mentioned that it has been condensed and collected from the air; it may also be drawn through distilled water by means of an aspirator, and its presence detected on analysis. Angus Smith found that condensed from the air to be a thick oily liquid, smelling of perspiration, and capable of rapid decomposition. This air was taken from a crowded room. If organic matter derived from the skin and lungs of human beings possesses such objectionable properties, what must the organic matter from the habitations of animals possess, when we consider that not only are the skin and lungs acting, but that we have deposited in the place where they live the discharges from the bowels and kidneys?

When organic matter is produced, it rapidly adheres to the walls, woodwork, etc., and there, parting with its water, it becomes fixed, forming a greasy coating.

This is the reason why the peculiar penetrating odour of organic matter, in badly ventilated stables, is so difficult to remove, even with free perflation of air; it hangs to woodwork, walls, and ceiling, and is readily experienced on entering a building of this description, or the decks of transport ships.

This organic substance, owing to the moisture in the air, is constantly undergoing change, giving out carbonic acid, ammonia, and sulphuretted hydrogen—the blackening of the paint of such habitations is due to the latter gas. From observations made by Dr. de Chaumont and others, it has been shown that *the organic matter in the air of buildings is in proportion to the carbonic acid of respiration.* This is a most important point, for it affords us a ready index to the purity of the air by determining the amount of CO_2 present in it. It must be distinctly repeated, as we shall have later on again to note, that it is not the actual presence of a large amount of CO_2 in the air which is to be dreaded, but the certain indication which this affords of the large amount of organic matter which is present. This brings us to a consideration of the CO_2 present in the air as the result of respiration.

A horse in a state of quiescence gives off from 2 to 3 cubic feet of CO_2 every hour from the lungs, and a certain though undetermined proportion is also given off by the skin; but taking that from the lungs alone, it would amount to from 48 to 72 cubic feet in twenty-four hours; or, if converted into carbon, would give us a solid block weighing about two and a half pounds.

Muscular exertion greatly increases the amount of CO_2 expired, but if the work be carried to an exhausting degree the amount is lessened. A high temperature reduces the quantity expired; a low temperature increases it by about one-fifth. During abstinence the amount excreted is lessened. Disease has an important effect on the elimination of CO_2; in tetanus it is considerably increased, in hydrothorax and glanders it is reduced in amount.

Taking an animal in health, we find that 100 parts of expired air contain 19 instead of 21 parts of oxygen, and 1 or 2 per cent. instead of ·03 or ·04 per cent. of carbonic acid; in addition to these there is a variable amount of watery vapour containing organic matter.

It is evident that if the CO_2 in the air of buildings forms an index of the amount of organic matter present, our endeavours should be to keep that amount of CO_2 as low as possible, and as near that present in the external air as can be. The CO_2 in pure air is about ·04 per cent. The amount which experience has fixed over and above this, to allow of organic matter, is ·02 per cent.; therefore, the total of ·06 per cent. is regarded as the limit of organic impurity in buildings.

Hitherto we have had but little information given as to the amount of CO_2 in stables. I can only find a few published analyses—one by Leblanc, who found, in a stable at the Ecole Militaire, ·70 per cent.; two by Dr. de Chaumont, who found ·10 per cent. and ·059 per cent.; two by Märker, who found in a stable at Gottingen ·85 per cent. and 1·70 per cent.; and two by Dr. Angus Smith, who found ·083 and ·087 per cent.

Two of these show great impurity, particularly the Gottingen stable.

I selected a troop stable for ten horses, which was ventilated by the ridge, and I found the following amount of carbonic acid per 1,000 volumes of air:

Mean of 14 analyses	1·5700
„ 14 „	1·3200
„ 25 „	2·1000
Largest amount found	2·6585
Least „ „	·5716

The CO_2 in stables will differ in amounts in different parts of the same stable. And from a large number (over

200) of analyses of the air of stables I obtained some interesting results, of which the following is a summary :

1. In a stable where ridge ventilation or an outlet in the roof exists, the upper stratum of air is the purest; the stratum next the ground is very impure, though, owing to the presence of ammonia, this is not apparent. In collecting, therefore, stable air in future for analytical purposes, it should never be taken nearer than 6 feet from the ground. In stables where no outlet exists in the roof the upper stratum of air is the most impure.

2. The amount of carbonic acid in different parts of the same stable is not the same, of which the following is an example :

Air collected								
1 ft.	from	the ground	at bottom	of the stable	=	·6040	CO_2	per 1000
6 ft.	,,	,,	,,	,,	=	·9064	,,	,,
1 ft.	,,	,,	middle	,,	=	·6680	,,	,,
6 ft.	,,	,,	,,	,,	=	·8463	,,	,,
1 ft.	,,	,,	top	,,	=	·4897	,,	,,
6 ft.	,,	,,	,,	,,	=	1·2712	,,	,,

The original article giving all the experiments in detail may be consulted vide *Veterinary Journal*, vol. xxii., No. 128.

I have spoken of the carbonic acid as parts per cent. ; it is more simple to describe it as parts per 1,000, as it gives a whole number, or a larger decimal, which is more readily remembered. We may consider our volumes per 1,000 as cubic feet, so that in every 1,000 cubic feet of air of the Ecole Militaire, 7 cubic feet of CO_2 was found. Dr. de Chaumont found 1 cubic foot, and half a cubic foot ; Märker, $8\frac{1}{2}$ cubic feet and 17 cubic feet ; and Angus Smith, ·8 of a cubic foot. In addition to many independent analyses, I have made three experiments for determining the amount of carbonic acid in stables with doors and windows closed, observations being made every quarter of an hour for three hours in two cases, and for six hours in another. In every case the carbonic acid in the outside air, temperature, and moisture was determined, and the same done in the stable every fifteen minutes.

Taking the normal CO_2 in these cases at ·6 per 1,000, we have a rapid rise in the amount of carbonic acid, which is especially marked during the second and third quarters. This rise is kept up, though slower, until the second or third hours, when distinct fluctuations occur. The cause of these fluctuations appears to be that after a time the air gets so loaded with moisture, that proper diffusion of the gases is retarded, and thus more is obtained at some times than at others.

In Experiment I. the CO_2 varied from ·7 to 1·8 per 1,000. The maximum was reached in the middle of the second hour, and the impurity of this building was three times more than it should have been. In Experiment II. the CO_2 varied from ·7 to 1·6 per 1,000, or nearly three times larger than it should have been. In Experiment III. the observations were made regularly every fifteen minutes for six hours; the least amount of impurity was ·9 per 1,000, the greatest 2·6 per 1,000, or four times larger than normal. In this last experiment, the maximum was reached during the middle of the fourth hour.

I am afraid that the apparent smallness of the numbers representing the carbonic acid found in stables will have the effect of causing one to think but lightly of its presence. Drs. Angus Smith and F. de Chaumont have both pointed out that a very small amount of carbonic acid shows deterioration of the air sufficient for the senses to observe. Strange as it may appear, yet the sense of smell can distinguish in London air differences amounting to ·04 per 1,000; in fact, Dr. de Chaumont employs the sense of smell for detecting respiratory impurity in rooms, which is exceedingly accurate from ·6 up to 1·3 per 1,000 of CO_2. To bring, however, more home to one the small amount of CO_2 which may be present in the air, and yet be the indicative of extreme impurity, I may say that a difference of ·2 per 1,000 in a room is unpleasant to most of us, whilst the presence of 1 part per 1,000 of CO_2 in the air of a room renders the place extremely offensive and oppressive to the senses, or, as Angus Smith expresses it, 'odious and unwholesome.' Now, if this is the effect of 1 part of CO_2 per 1,000, one may imagine the condition of the stable in Experiment III., where I found 2·65 per 1,000 of this gas.

One more example to impress the fact that apparently minute changes in this acid are really indications of enormous increase. Let us take a stable of 10,000 cubic feet, such as would be occupied by six or seven horses; the total amount of carbonic acid in it should be 6 cubic feet (or ·06 per cent.). We now analyse the air of this stable, and find the carbonic acid is equal to ·265 per cent.; calculate it to show the amount in 10,000 feet, and we get 26·5 cubic feet, or in other words twenty and a half times more than it should be. This shows us how carefully we should note slight increases in the CO_2 of stables as indications of the utmost importance. In calculating the amount present in the air, we cannot be too minute; the calculations should always be made to the fourth place of decimals. On reference to page 44, it will be observed that we have three stables showing considerable impurity, 7 per 1,000 in the French stable, and 8½ and 17 per 1,000 respectively at Gottingen. It is quite impossible to imagine the condition of these airs to the senses; when I obtained 2·65 per 1,000 the air was abominable. Large quantities of CO_2 are found in the air of mines; the very worst specimen yielded 25 per 1,000 of this gas; but in this place lights would not burn, and the men could only work a few minutes at a time, and were often dragged out senseless; yet we find 17 per 1,000 in this Gottingen stable, and carbonic acid which has its origin in animal impurity, which is not entirely so in the case of mines.

Let us briefly recapitulate these important points. The CO_2 found in the air of stables is an indicator of the amount of organic matter which is present; numerous experiments have fixed the total amount of CO_2 which should be found at ·6 per 1,000 (viz., ·4 as normally present in the air, and ·2 permissible organic impurity); all above this indicates defective ventilation, and shows us that the animals are breathing impure air.

Ammonia is present in traces in the air of towns, but in air vitiated by respiration it may be found in large amounts. The ammonia itself is not injurious, but, as Dr. Smith expresses it, 'it has very bad relations, and keeps bad company'; in other words, it is the product of organic matter, and is regarded as another index of impurity. In determining ammonia chemists divided it into two forms, 'free' and 'albuminoid.' The free ammonia, as its name implies, represents the free, saline, or uncombined ammonia present in the air; the albuminoid ammonia, on the other hand, represents the amount of nitrogenous organic matter present. In pure air the amount of free ammonia is ·0025 grains in 100 cubic feet; and of albuminoid ·00168 grains in 100 cubic feet. I have made a few analyses of the air of stables for the presence of ammonia. We would naturally expect to find the free ammonia very large, and such is the case. I obtained ·042 grains of the salt in 100 cubic feet of air of a badly-ventilated stable, and in a litter shed the amount was ·014 grains. The albuminoid ammonia in stables badly ventilated is always high; ·039 grains, ·193 grains, and

·067 grains in 100 cubic feet of air were found. Over a dung-pit the amount was ·0785 grains of albuminoid ammonia.

Table Showing the Amount of Ammonia Present in Stable Air.

	Free Ammonia in 100 cubic feet.	Albuminoid Ammonia in 100 cubic feet.
Pure Air	·0025 grains ...	·00168 grains.
Badly-ventilated Stable ...	·042 " ...	— "
Litter Shed	·014 " ...	— "
Air over a Dung-pit ...	— " ...	·0785 "
Badly-ventilated Stable ...	·0418 " ...	·039 "
" " " ...	— " ...	·067 "
" " " ...	— " ...	·1935 "

These quantities, like the carbonic acid, may appear very small, but in reality are indications of enormous impurity.

Sewer Air has a variable composition, depending upon the amount of decomposition and the extent of dilution with air. The sewer gases are hydrogen sulphide, ammonium sulphide, nitrogen, carbon dioxide, carburetted hydrogen, and fœtid organic matter (Parkes). The organic matter is peculiar, and possesses such powers of penetration that it is stated it will pass easily through walls; its vapour is carbo-ammoniacal, and the putrid substance a compound of ammonia. The air of sewers, by means of proper ventilation, may be kept in a fairly pure state. In London sewers ·532 per cent. of CO_2, much ammonia, and traces only of hydrogen sulphide were found by Dr. Letheby. It is the organic matter in sewers, and not so much the gases, that does the harm. This organic matter has been collected and estimated by Angus Smith, who found that 8,000 cubic feet of the air of a house into which sewer-gas had found its way, destroyed more than twenty times the amount of permanganate of potash as pure air of similar amount; he also found that 62 feet of air from a cesspool destroyed as much potassium permanganate as 176,000 cubic feet of pure air.

The largest amount of material contributed by stables to sewers is in a liquid form, consisting of urine with suspended matter from the fæces. Compounds of ammonia are the chief gases in this mixture, derived from the decomposition of urea.

From the air of sewers bacteria of different forms have been obtained.

Emanations from Manure Pits are commonly believed, even by well-informed persons, to be *healthy.* The idea is a very absurd one, and probably arises from the fact that outbreaks of disease are not traceable to this cause, as others more potent, and nearer to the animal, are acting at the same time. Manure, when placed in the pit, undergoes decomposition; large quantities of ammoniacal gases, organic vapours, and carbonic acid are formed, but owing to the nature of the mass these substances can only escape in a partial degree, and are rapidly diluted with air as they pass out, so that the odour of the substance, though marked, is faint. But let the surface be removed, then the noxious, penetrating, poisonous products of animal and vegetable decomposition come out with full intensity.

I have made several experiments on the air of manure pits. I chose one where the manure had been standing three months: (pure air that day gave ·3496 of CO_2 per 1,000 vols.). On removing a foot or so of the mass I found the carbonic acid was 3·1762 per 1,000, or more than nine times that in pure air. On removing the upper crust I obtained 1·1282 per 1,000, or less than half that first found. On taking the air from the top of the pit, without touching the mass, I found ·8750, or nearly quarter less than the original amount. I next determined how far from the pit the excess of carbonic acid could be detected: I found that at thirteen yards to leeward it could not be found; at seven yards it was marked.

TABLE SHOWING THE CARBONIC ACID IN THE AIR OF A MANURE PIT.

	Carbonic Acid.
Pure Air	·3496 per 1,000 volumes.
Air from the oldest part of the pit, the mass being turned up to collect it	3·1762 " " "
Air from the top of the pit, the upper surface just removed	1·1282 " " "
Air from the top of the pit, the surface being undisturbed	·8750 " " "
Air from some fresh manure recently deposited	·8517 " " "
Air taken seven yards to leeward of the pit	·4096 " " "
Air taken thirteen yards to leeward of the pit	·3474 " " "

We may, therefore, say that no dung-pit should be nearer to a stable than thirteen yards. I next examined air collected in litter sheds, such as they use in the service to place the bedding in during the day. I found, as a rule, only a slight increase in carbonic acid, though in one case it was very large. The small amount of CO_2 in these sheds is accounted for by the care which is observed in separating all manure and soiled litter from the bedding which is to be retained.

Gaseous Impurities are conveyed to the air by the products of coal combustion, manufactories, particularly chemical works; brick-fields, copper smelting; and the result of organic decomposition, such as arises from slaughter-houses, bone and tallow works, etc. These gases are composed of carbon, sulphur, nitrogen, chlorine, etc.

Coal-gas is a compound containing olefiant gas, hydrocarbons, hydrogen, marsh-gas, carbonic oxide, hydrogen sulphide, nitrogen, carbonic acid, sulphur dioxide, carbon disulphide. The odour of coal-gas is so penetrating that one part in ten thousand is readily recognised by smell. Pettenkofer has recently investigated the subject of coal-gas poisoning. The burning of gas alters the composition of the atmosphere the same as the process of respiration; it gives off carbonic acid, watery vapour, and consumes oxygen. A single gas flame raises the temperature of a room as much as eight men; contributes as much carbonic acid as three; and nearly as much aqueous vapour as five; while it consumes as much oxygen as six men. One cubic foot of gas will raise the temperature of 31,290 cubic feet of air 1° Fahr. It is necessary that the amount of air vitiation which the combustion of gas will bring about should be remembered. Most of our stables are lighted by this means, and arrangements should be made in badly-ventilated buildings, by means of an outlet above the flame, to reduce the contamination as much as possible.

Sulphuric acid works give out sulphuric acid, nitrous and sulphurous acid gas, and arsenic; copper works send out large quantities of sulphurous acid and arsenic; alkali works give forth hydrochloric acid. From ammonia works sulphuretted hydrogen is evolved. The effect of these acid gases on vegetation is considerable, as we will refer to later on.

The Air from Marshes contains an excess of CO_2, a diminished proportion of oxygen, and compounds of hydrogen, nitrogen, and watery vapour. The organic matter contains bacteria.

Inorganic substances in the air produce no ill-effects on animals of which I am aware. The long list of diseases in man produced by their agency is entirely the result of civilization. I allude to those affections produced by the inhalation of poisonous vapours, as in match-makers, tin-plate workers, copper-smiths, painters, etc., etc.; or of solid particles, as in miners, potters, knife-grinders, file-cutters, etc.

Diseases produced by Impure Air.

It is only since the end of the last century that the necessity of animals being supplied with pure air has been recognised. James Clark, a veterinary surgeon, of Edinburgh, in a work published in 1788, drew forcible attention to the foul condition of the air of stables. Following close on this we had the outcry of Coleman; it was the position of influence which he occupied in the scientific world which enabled his views on ventilation to be brought prominently before the public. Fresh air in those days was considered not only unnecessary, but actually pernicious, and every attempt was made to rigidly exclude it from buildings; every aperture, as Stewart tells us, being closed, the key-hole and threshold of the door not being forgotten. Is it any wonder that, in an atmosphere of this sort, disease reigned supreme?

There is probably no cause, or aggregate of causes, which has contributed so much to the production of disease as foul air. The introduction of a proper system of ventilation has been the means of practically eradicating diseases which carried off animals by hundreds, and has saved both the country and private owners thousands of pounds. The credit of this must be entirely given to Coleman. Apart from what has been handed down to us by tradition, we have the fact actually placed on record by Sir Astley Cooper,* in which it is stated that thousands a year were

* 'Life of Sir Astley Cooper.'

saved to Government in consequence of Mr. Coleman's annual visits to the military stables throughout Britain. Farcy, which, previously to his interference, had committed annually most extensive ravages, became nearly erased from the Government returns of disease. We are told that 'a stable in which many horses had died in rapid succession, although it had undergone the usual discipline of cleaning and whitewashing, was reported to Mr. Coleman as having some undiscoverable evil, probably arising from its situation. Mr. Coleman accordingly examined it, and having ascertained that its defects arose from a mal-construction, by which all proper ventilation was prevented, recommended Government immediately to make certain alterations, by means of which this would be remedied. This recommendation at first met with considerable opposition on account of the expense involved in the proposed improvements. His plan, however, was afterwards adopted, and it is a curious fact, that in the first year the expenses of Government were repaid by the saving, in consequence of the entire absence of disease among the horses.'

The mortality amongst the horses of the French cavalry was at one time frightful; previous to 1836 they lost 180 to 197 per 1,000 per annum; the air space being increased reduced the losses in the next ten years to 68 per 1,000.

The following table * shows the admission for glanders and lung disease amongst the horses of the French cavalry, from 1847-1866, a period of nineteen years:

	1847-52. Ratio per 1,000.	1853-56. Ratio per 1,000.	1857-61. Ratio per 1,000.	1862-66. Ratio per 1,000.
Glanders ...	23·32	21·44	10·97	7·24
Inflammation of lungs and pleura	104·7	110·6	45·8	3·59

* Copied from a most interesting and valuable paper on 'The Vital Statistics of Cavalry Horses,' by Dr. Balfour, F.R.S., *Journal of the Statistical Society*, June, 1880.

This table shows that in nineteen years a reduction of 16·08 per 1,000 had occurred in cases of glanders, and no less than 101·11 in cases of pneumonia and pleurisy. These wonderful results were obtained through the labours of a Commission of Veterinary Military Hygiene, which pointed out the necessity of the ventilation of stables, increased cubic capacity, and attention to sanitation, feeding, and general care. The practical outcome of these results were, that a saving of £90,000 per annum was effected in the purchase of horses alone. Exception may be taken to my introducing cases of pneumonia and pleurisy into this table, but it should be remembered that the production of these diseases from chills and exposure to inclement weather is generally considered by the best authorities to have been carried too far, and that the impure air breathed is a much more probable cause. This view has especially gained ground since pneumonia, at any rate of the human subject, has been proved to be an infectious disease. The table lends great strength to this theory; there is no reason to believe that the winters from 1857 to 1866 were milder than those between 1847 and 1856. The only explanation of the great difference in the mortality, is the larger amount of pure air supplied, and the better ventilation of the stables.

Take the case of thoroughbred brood mares, turned out all day, summer and winter, no clothing on, exposed to biting winds, and often rain. They do not suffer from the exposure; in fact, they possess considerable immunity from diseases of the respiratory passages.

Reynal has shown that in the old crowded stables of the Alfort Veterinary School, cases of pneumonia, as well as severe wounds, quickly assumed a putrid character, and nearly always terminated fatally; but when the buildings were enlarged, well ventilated, and fewer animals admitted, this mortality ceased.* The dreadful sufferings of animals crowded together in transport and cattle ships are well known. Professor Coleman, in his evidence before a Committee of the House of Commons, stated, that in the Expedition to Quiberon, the horses had not long been on board the transports, when it became necessary to shut down the hatchways on account of bad weather; the consequence of this was that some of them were suffocated, and all the rest were disembarked either glandered or farcied. He further stated, that in the year 1796, when there was a great encampment at Dover, the Government could not get sufficient stabling for the horses, and overcrowding in close and confined places was the result. The most healthy horses became glandered. Some animals were sent to Hythe and placed in an open shed, and not one of those became affected. Percivall's experience during the Peninsular War was identical with regard to overcrowding. The production of tuberculosis amongst cattle confined in ill-ventilated sheds is well known. In the Italian War of 1859, M. Moulin, the Chief Veterinary Surgeon, kept 10,000 horses many months in barracks open to the external air in place of closed stables. Scarcely any horses were sick, and only one case of glanders occurred.† The case of the monkeys in the Zoological Gardens is well known. A room most luxuriantly fitted up was erected for their occupation. The ventilation was, however, so defective, that of sixty healthy animals placed in this house, fifty were dead in a month from phthisis, and the remainder were dying. On being properly ventilated, the place became perfectly healthy.

About thirty years ago a severe epizooty of influenza appeared in Boston. At the instigation of Professor Bow-

* 'Sanitary Science and Police' (1st edition). G. Fleming, LL.D., F.R.C.V.S.

† 'Practical Hygiene.' E. Parkes, M.D., F.R.S.

ditch, every stable in the city was inspected, and classified as 'excellent,' 'imperfect,' or 'wholly unfit,' in respect to warmth, dryness, light, ventilation, and cleanliness. It was found in the first-class fewer horses were attacked, and the disease was milder; while in the third-class every horse was attacked, and more severe and fatal cases occurred. In respect to the numbers attacked, and the general characteristics of the disease, the three classes stand to one another, as 1 : 3 : 5.*

During dense fogs in December, 1873, great mortality occurred to the cattle at Islington Show, due entirely to the exceedingly impure air of a London fog.

More examples might be quoted; it is almost unnecessary to adduce the present low mortality amongst army horses, as the facts are well known. Their healthy state is entirely due to the amount of pure air allowed them, for in no other circumstance of life do they differ from their predecessors of sixty years ago.

All we have said may be formulated in the precise language of Parkes: 'Disease and health are in the direct proportion of foul and pure air.'

We have thus endeavoured to prove by established facts the value of pure air, and the mortality produced by impure. It only remains now to deal with the different substances found in impure air, which contribute to the production of disease.

The Contagia.—By this is meant those particles of morbific matter constantly present in the air, according to some views, or occasionally present, according to others, which represent the poisons of specific diseases.

It is generally accepted that these poisons are particulate. With regard to some affections, these particles have actually been seen and isolated; such, for instance, as the poisons of

* 'Hygiene and Public Health.' A. Buck, M.D.

anthrax, tuberculosis, and vaccina. With other diseases, although the evidence of particulate poison is strong, yet the fact of their invariable presence is not so well established; such is the case with glanders, pleuro-pneumonia, eczema-epizootica, cattle-plague, and influenza. These particulate bodies are known generally as bacteria, bacilli, micrococci; or briefly, micro-organisms. That they are the actual disease-producers, and not the products of disease, has been proved in the case of anthrax, tuberculosis, and vaccina, by filtering the liquid products of these diseases through a filter sufficiently fine to retain the solid particles, when inoculations made with the filtrate have proved innocuous.

It must be regarded as undoubted that the air is a means of conveying these micro-organisms from one animal to another (see Kuchenmeister's experiment in producing variola in a sheep, page 40). That it possesses this power in a more marked degree with some than with others is well known; for instance, the poison of cattle-plague spreads with wonderful rapidity, and a vast tract of country is soon infected by it. The poisons of anthrax and glanders are confined within certain limits, the latter more than the former; both of these diseases may devastate one stable, and leave another, quite close, untouched. We have no idea of the rules which govern the atmospheric diffusion of specific poisons. It is believed that the contagia of eczema-epizootica may be conveyed from 50 to 300 feet; whilst influenza and cattle-plague may be carried considerable distances. Once the contagia has left the body and escapes into the air, destruction is prevented by an albuminous coating, or by epithelial or pus cells, which may cover and protect it; in this condition it is carried about ready to infect, if deposited on suitable soil.

The length of time which the poisons of specific diseases retain their power to infect after they undergo the process of drying is not well ascertained, but it is probable they do so for some considerable time. Anthrax poison will keep for years; cattle-plague the same; vaccina will probably only retain its vitality for a short time; glanders is very persistent. Extreme heat and cold have not much effect on these poisons. Anthrax contagium has to be exposed to boiling-point for two hours to kill the rods, or to steam at 221° Fahr. to destroy the spores. Freezing does not destroy the virus. On the other hand, a temperature of 112° Fahr. destroys the variola poison, and freezing has the same effect. A humid state of the atmosphere favours the infectiousness of some viruses, notably those of anthrax and cattle-plague. Air rendered impure by the process of respiration and transpiration is, from the fact of its being the most general, the most important impurity which concerns us. Until the importance of human and veterinary hygiene is more generally understood and appreciated, so long will families be crowded in small and ill-ventilated rooms, and horses and cattle condemned to low and stuffy stables, which never receive the light or breath of heaven.

We have before seen the enormous amount of impurity conveyed into the air by horses and cattle in health, and have pointed out that, owing to the fact that animals have to live, sleep, eat, drink, defæcate, and urinate, all in one place and under one roof, the organic emanations are particularly foul.

To make matters worse, we have a strong and popular prejudice against fresh air—a prejudice not perhaps so marked as in the days when every crevice, including the keyhole, was carefully stuffed; but still sufficiently strong to form a most formidable barrier to the progress of veterinary hygiene amongst the civil population. On entering stables of this description, a penetrating odour, unmistakably of organic matter, is met with; a hot, damp, muggy feeling which is insupportable, accompanied by pungent ammoniacal vapours which irritate the conjunctiva; all contributing to form the 'poisoned atmosphere of the stable,' which Professor Coleman believed to be the cause of glanders. It will be remembered that Coleman held the view that glanders could be produced in a previously healthy horse by exposing him to an atmosphere rendered impure by effluvia from his urine, fæces, and perspiration.

It was these views which laid the foundation of veterinary hygiene, which freed our army from zymotic diseases, which saved the country enormous sums of money, which increased the efficiency of our forces; it was the adoption of these views which rendered the French cavalry effective, and reduced their mortality. But in spite of what we can show as a result of a better knowledge of the laws of hygiene, in the civil world glanders-farcy is very common, influenza and strangles very fatal, pneumonia a scourge, blood diseases only too frequent.

It must be conceded that, in the present state of our laws, it is impossible to exercise the same supervision over private property as it is over public; but if only the loss of life amongst animals in this country, due directly or indirectly to confinement in an impure atmosphere, were obtainable, the results would be sufficiently appalling to call for immediate legislation.

Men should not, either from ignorance or indifference, be allowed to shut their animals up in places not big enough for a human being to live in, or make them breathe impure air, either through their personal prejudice or carelessness. It is no argument that, because it is his own property, a man is at liberty to do what he likes with it! He is not! Why should a horse-owner be allowed to run the risk of producing disease, not only amongst his own horses, but amongst those of others he may come in contact with? A man is fined for leading a glandered horse along the public road, and if legislation can be provided for this, it could be provided to insist on the proper ventilation of stables and cow-houses, and owners made by law to provide their animals with that due ration of air which science dictates they require; these duties should be performed by a veterinary sanitary police. No person should be allowed to breed disease amongst his own animals, or risk the property of others and the lives of human beings, any more than he is allowed to have a smoky chimney which proves a nuisance to his neighbour.

The effects on animals kept in an impure atmosphere are—they never look well; they are hide-bound, require more food for the amount of work expected from them; they work indifferently, owing to enervation; their legs swell; colds, coughs, pneumonia, ophthalmia, diabetes, and glanders-farcy are common; if an epizooty occurs, it is much more fatal amongst these than amongst other horses placed under better hygienic conditions. Animals living in stables badly ventilated would not last so long as they do but for the fact that they spend many hours daily in the open air at their work, and it is this and nothing else that spares them.

Organic matter derived from the bodies of animals in overcrowded and ill-ventilated places may, as the result of its decomposition, produce disease, and these particles will be carried about by the air. Grognier has described a stable-fever of animals in France, analogous to hospital and prison fever in man;* and in the Alfort School, as before stated, wounds quickly became putrid, and caused death, owing to the overcrowding and bad ventilation. Con-

* 'Sanitary Science and Police' (1st edition). G. Fleming.

stitutional ophthalmia and other diseases of the eye have been attributed to the same cause.

In 1792, during the siege of Mayence, dysentery of a very aggravated character broke out amongst the horses and cattle closely confined in the casemates.*

The effects of gaseous inorganic substances in the air possess a very important influence on animal and vegetable life.

An excess of CO_2 produces serious changes in the blood, reducing the circulation and causing great dyspnœa. In slow poisoning the animal becomes sleepy, lethargic; the heart's action fails, and anæsthesia is produced. The exact amount of carbonic acid which will destroy life is not quite known, so much depends on its source. Breathing an atmosphere containing an excess of oxygen and carbonic acid (produced artificially), the results are different; Reynal and Reiset found that under these conditions 17·23 per cent. of CO_2 might be present, and the animals suffer no injury. In these cases the excess of oxygen protected them.

Carbonic oxide induces a reduced arterial tension and paralysis of the heart. It is rapidly fatal to animals if it exists in a larger proportion than 1 per cent.

Ammoniacal gases are largely formed in stables as the result of the decomposition of urea. Where free ventilation is denied the ammonia remains very persistent, and is generally believed to have a destructive influence on the eyes.

Sulphuretted hydrogen results from the decomposition of animal and vegetable matter. The odour of this gas is so penetrating that one cubic inch of it will, according to A. Smith, scent some hundreds of cubic feet of air. Four volumes per 1,000 of this gas will kill a horse; it induces diarrhœa, purging, and extreme prostration. This gas blackens the paint of those buildings where it may exist in any appreciable quantity.

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* 'Sanitary Science and Police' (1st edition). G. Fleming.

Sulphur dioxide is given off from copper-smelting works. The fumes have the remarkable effect of producing ossific deposits on the knees and hocks, falling off of the hair, and general emaciation of both horses and cattle; the affection is termed 'copper-smoke' disease. This so-called copper smoke consists of about 68 per cent. arsenious acid, 28 per cent. sulphuric acid, and small quantities of iron, copper, and nickel. Although the disease is produced by inhalation of this vapour, yet it may also be assisted by the quantity of these salts deposited on the ground, and taken into the stomach with the herbage.

The effects on vegetation of acid gases derived from manufactories, is to shrivel up and discolour the leaves and stems of trees and farm crops. Mr. Rothwell says that old grass meadows and pasture-lands receive much damage in the winter from this cause, and further adds, that on fields much exposed to the vapours, handfuls of dead grass can be pulled up in the spring, smelling strongly of the vapour.* Dr. Smith has not verified this last condition, but he notes the damage done to the flowering heads of wheat by the action of acid gases; the crops may be, to all appearance, full and ripe, when scarcely a trace of grain is found. In a report published by the French and Belgian Governments on the subject of the damage done to plants by acid gases, much interesting information is to be obtained. It is shown that the amount of damage done is in relation to the hygrometric, barometric, and thermometric conditions of the air and atmospheric currents. It is not sufficient that the acid vapours pass over the plants, but they must actually touch them; the effect of this is the production of a stain on the leaf, and ultimate perforation and destruction of it. A curious case is recorded of three vigorous vines growing against some stables, which showed a staining and

* 'Air and Rain.' Dr. A. Smith.

shrivelling of some of their leaves; the damage was undoubtedly due to acid, but the cause was far from apparent. It was ultimately found that below the damaged leaves there was an opening from which the air of the stables escaped, and which from want of cleanliness contained a deal of ammoniacal vapour, and it was this and the sulphuretted hydrogen which had stained and destroyed the leaves.

Regarding emanations from drains, we have very little evidence to show their ill effects on animals. Still, there is one most interesting case recorded when this condition produced a serious outbreak of disease.

At Cabul, in 1880, twenty-eight cases of diarrhœa occurred amongst the horses of the 9th Lancers, nine of which proved fatal. The disease was principally confined to two troops, which were then moved out of the lines. V.-Major Woods, then veterinary surgeon of the regiment, who records the outbreak, states that, after removing the affected troops, he had the flooring of the sheds dug up, and he found running through them a ditch three or four feet deep, filled with manure and refuse, and covered by only nine inches of earth. The effluvia from this, and from two or three pits several feet in depth, which were also found, was very bad. The whole place was cleaned out, fresh earth put down, and the epizooty ceased.* There is a practice which prevails amongst regiments of native cavalry in India, of burying vessels underground in the stalls for the reception of urine, and these are not emptied or removed for years; another common practice is burying the manure in or near the lines. The emanation from these places is pestiferous. V.-Major Woods tells us, in his account of the above epizooty, that the 3rd Bengal Cavalry,

* For a detailed account of this interesting outbreak, see *Veterinary Journal*, vol. xv., No. 88.

which were lying next to the 9th Lancers, had six cases of diarrhœa, of which three were fatal. The ground on which this regiment was encamped had previously been occupied by the 5th Punjaub Cavalry; the place had become thoroughly soiled, and in many parts consisted of nothing else but excrement, to the depth of a few inches.

CHAPTER III.

VENTILATION.

THE objects of ventilation are the supply of pure air to the lungs, the removal from the stable of the products of respiration and cutaneous exhalations, and the effluvia arising from the fluid and solid excreta deposited in it. Not only is the removal of these substances required, but the air entering the stable must be derived from a pure source; it would not be ventilation if the entering air was derived from a contaminated atmosphere.

Our subject will be divided into certain portions for the convenience of description:

1. The quantity of fresh air required per head.
2. The mode in which this quantity may be supplied.
3. The methods of examining whether ventilation is sufficient or not.

The Quantity of Air Required.

A horse takes into his lungs about 100 cubic feet of air per hour, though the amount is subject to great variation. Now, if he is standing in the open, this is the quantity of air he requires; but it is not a guide to his requirements when he is in the stable, and for the reason we have before stated, that one of the objects of ventilation is the supply of pure air for the proper dilution of the matter given off during respiration, and from the excreta.

How, then, are we to ascertain this important point if the quantity of air the blood requires is no guide to the quantity of air the stable requires to keep it sweet? It is ascertained by the CO_2, and, at the risk of repetition, I must again state that the CO_2 present in the air of inhabited places bears a distinct and definite proportion to the organic matter present in the air of such places; if we find on examination that the carbonic acid is small, then we know that the organic matter is small; if it is high, then we know that the organic matter is correspondingly high. The carbonic acid found in the air, arising from respiration, should not exceed a certain definite quantity—we will presently refer to this amount—but what I wish to make quite clear is, that if it does exceed a certain amount it indicates impurity, and it also indicates that a proper amount of air has not been entering the place to dilute the organic matter; therefore, we use the CO_2 not only as an index of the organic matter present in the air of stables, but also use it *as a means of ascertaining the amount of air a horse requires in the stable.*

We cannot have the air of a stable *absolutely* as pure as the outside air; there must of necessity be a certain amount of impurity in it; our object is to keep that impurity down to the lowest possible amount. The organic matter is at its lowest possible quantity when, on entering a stable, there is no sensible difference between the freshness of the air inside and that outside.

This fact was discovered by Dr. de Chaumont as the result of a very large number of experiments on the air of barrack-rooms, and he found that the sense of smell carefully employed *immediately on entering the building from the outside air*, gave a fair idea of the amount of impurity in the room.

Dr. de Chaumont found that the maximum amount of *respiratory* impurity which could exist without impairing the freshness of the air was ·2 of CO_2 per 1,000 of air; anything above this produced a most decided smell, and this observer classified his results as follows: When on first entering the room, if there is *no sensible difference* in smell between the air outside and the air of the room, the amount of CO_2 is equal to ·2 per 1,000 volumes; if the air of the room smells *rather close*, the quantity of CO_2 is equal to ·4 per 1,000; if the air is *close*, the organic matter is still larger, and the CO_2 equals ·67 per 1,000; but if the air smells *very close, disagreeable, and offensive*, the CO_2 present is equal to ·9 parts per 1,000. It was found impossible to determine by the simple sense of smell any larger amount of organic matter than is represented by ·9 parts of CO_2 per 1,000, for the senses were blunted. My own analyses of stable air agree with those of Dr. de Chaumont on the air of barrack-rooms, and we can with confidence select the number adopted by him, viz., ·2 of CO_2 per 1,000 volumes of air, as representing the *maximum amount of organic matter* permissible in a well-ventilated stable.

We can now calculate by Dr. de Chaumont's formula the amount of fresh air required by a horse in cubic feet per hour. The formula is $\frac{e}{p} = d$, where

e = the amount of CO_2 stated in cubic feet exhaled per hour, viz., 3;*

p = the limit of admissible respiratory impurity per cubic foot of air, viz., ·0002;

* This number is much smaller than the one which appeared in the first edition of this book, and is partly based on my observations, 'The Chemistry of Respiration in the Horse during Rest and Work,' *The Journal of Physiology*, vol. xi., No. 1, 1890. The original number was based on early Continental inquiries, and was doubtless too high.

d = the required delivery of fresh air in cubic feet per hour.

$$\frac{3}{\cdot 0002} = 15{,}000 \text{ cubic feet of air per hour.}$$

During work the amount of CO_2 given off is greatly increased, practically we may regard it as doubled; it is fortunate for the horse that his conditions of work (under ordinary circumstances) admit of him obtaining an unlimited supply of pure air; still, on returning to the stable, the extra amount of CO_2 given off would for some little time be going on, and we may, therefore, safely conclude that for animals doing hard work between 15,000 and 16,000 cubic feet of air per hour are required. For horses working in mines at least 16,000 cubic feet of air per head per hour should be supplied.

It should not be forgotten that the combustion of candles and gas, and the presence of men working in the stable, all add to the impurity of the air.

The quantity of air required by sick animals cannot, for obvious reasons, be too large. The amount in excess of the 15,000 cubic feet named above for horses in health will vary with the disease. In tetanus, for example, the patient gives out per hour three and four times as much CO_2 as in a normal state. All chest and surgical affections require a large amount of air, and many of the latter cases, such as large suppurating or sloughing wounds, canker of the foot, gangrene of lungs, pyæmia, etc., require it in such large amounts that these cases should practically live in the open.

Cubic Space.

A very common error is made in considering that cubic space will supplant ventilation, and consequently much stress has been laid on the importance of large cubic capacity.

Large cubic capacity is a most desirable condition to be obtained in stables, but not for the reason which is generally supposed, viz., that ventilation is less necessary. An example will best explain our meaning:

Let us suppose two stables, one of 600 cubic feet, the other 1,500 feet; now, irrespective of size, these two stables have each to supply exactly the same amount of air to their occupants: let us take the amount to be supplied at 15,000 cubic feet per hour. In order that the horse may obtain this amount of air per hour, the stable of 600 cubic feet capacity would require to have its air changed a little more than twenty-five times per hour; whereas the stable of 1,500 cubic feet would only require its air changing ten times per hour. This, then, is the object of cubic space; it is not to supplant ventilation, but it is to avoid as far as possible any large number of changes in the air during the hour, and thus prevent the rapid cooling of the atmosphere, and constant chill and draught. Cubic space is not to render ventilation less necessary, for a space of 1,500 cubic feet will without ventilation become just as foul as a space of 600 cubic feet under similar conditions, only that it will take about double the time in one compared with that of the other to render it equally impure; once, however, the impurities of the airs are the same, then both the 600 cubic feet and 1,500 cubic feet stables (quite irrespective of the differences in their cubical capacity) must supply exactly the same amounts of air. In other words, the value of cubic space soon vanishes unless regular ventilation is established. I have introduced a table, calculated from Professor de Chaumont's formula, which will enable this to be understood.

TABLE SHOWING THE CONTAMINATION OF THE AIR BY RESPIRATION IN DIFFERENT CUBIC SPACES, AND THE AMOUNT OF FRESH AIR REQUIRED TO DILUTE TO THE GIVEN STANDARD, VIZ., ·2 PER 1,000.

Breathing space for one horse in cubic feet.	Ratio of CO_2 per 1000 at the end of first hour if there has been no change of air.	Amount of air necessary during the first hour.	Amount necessary every hour after the first.
600	5·03	14400	15,000 cubic feet
700	4·38	14300	,, ,,
800	3·75	14200	,, ,,
900	3·33	14100	,, ,,
1000	3·00	14000	,, ,,
1100	2·72	13900	,, ,,
1200	2·50	13800	,, ,,
1300	2·30	13700	,, ,,
1400	2·13	13600	,, ,,
1500	2·00	13500	,, ,,
1600	1·87	13400	,, ,,
1700	1·76	13300	,, ,,
1800	1·66	13200	,, ,,
1900	1·57	13100	,, ,,
2000	1·50	13000	,, ,,
3000	1·00	12000	,, ,,

The objection against small cubic space, as stated above, is that the air requires changing a large number of times in the hour to supply the amount necessary. It therefore has the drawback that such a stable would be draughty if properly ventilated; and also, if the conditions which bring about natural ventilation become suspended or interfered with, the air contents of a small stable become *more rapidly* impure than those of a large one.

The cubic space best suited for animals is, therefore, readily arrived at; the whole thing hinges on the question of how many times the air space can be changed in an hour without producing a draught or causing the stables to become too cold. In barrack-rooms it was found that under the ordinary conditions of our climate a change of air six times per hour was out of the question; five times could not be borne, and three times under the conditions of barrack-warming was all that could be attempted. With regard to horses, it is well known that they are not so susceptible of draught and cold as men are, and certainly a change of six times in the hour can be and is borne by them with impunity; still, if it were decided that three times should be the limit in the number of changes of air in the hour, it would argue a capacity of 5,000 cubic feet per horse, an utterly impossible amount to give when the expense of stable construction is considered, but still the theoretical amount where expense is no objection, and only a small number of changes of air per hour are desirable. If the changes were to be five times per hour, the cubic space should be 3,000 feet per head. The cubic space for all future army stables has been fixed at 1,605 feet per head, and for infirmary stables 1,900 cubic feet per head.

In order to provide the horse with 15,000 cubic feet of air per hour, the number of changes for the stable of 1,605 cubic feet would be about nine and a quarter times per hour; and for the 1,900 cubic feet stable, nearly eight times per hour.

Will a horse stand the air of his stable being changed nine times per hour in winter without suffering as a result? The question is rather a difficult one to answer, but I think there can be no doubt that if properly fed, the natural coat not interfered with, or if removed a blanket given to take its place, that horses will stand it with impunity. It practically means living in the open (for the whole air of the stable would be changed once every seven minutes), with none of the disadvantages of cold wet ground, snow or rain, or a sharp biting wind to contend against. It is not to be expected that a horse living in such a stable will carry a fine glossy coat, but animals living under this condition will be better able to stand the exposure to all weathers which those that do service in the army are at all times liable to be called upon to face. The same remark will equally apply to large bodies of horses in civil life, such as are employed by omnibus and tramway companies, large carriers, contractors, and railway companies.

The effects of hot stabling are to make the coat fine and glossy, to cause the animal to put on fat, and to render him more susceptible to cold (Stewart); the effects of cold stabling are to cause the coat to become long and rough; there is no tendency to the accumulation of fat, for much is required to maintain the body temperature, and the susceptibility to cold is reduced to a minimum. Animals living in cold stables require more corn, for the reason that the body is robbed of an amount of heat which the ordinary ration will not fully supply.

Altogether, the question of cold stabling and pure air is a difficult one to settle where expense is objected to and personal prejudice has to be overcome; and there is no doubt that although we now know with fair exactitude the amount of fresh air which horses require, the full amount of this will never be supplied to them, owing to the risk which owners believe they incur by leaving their stable-windows open.

It is considered that of the total cubic space for men the largest part should be made up in length and breadth, and not in height; and 12 feet has been fixed as the limit in height of rooms; more than this is useless for the purpose of ventilation. A man may be suffocated in a well in spite of very large cubical contents.

With regard to stables, much will depend upon whether they have other buildings over them or not; if they have, then it is undoubted that the height should not exceed 14 feet, and that the remainder of the cubical contents should be made up in length and breadth; on the other hand, if no buildings exist over the stables, and the part can be ventilated by a ridge, then a height of 12 feet to the spring of the roof may be employed with advantage.

Superficial space should be large, both for the comfort of the horse, his safety, and the safety of the man who attends on him. Horses are packed, as a rule, much too closely in army and many civilian stables. For man, $\frac{1}{12}$ of the cubic capacity is desired as the minimum superficial area. In stables, the superficial area for each horse not only includes the ground comprising his stall, but his share of the passage in the stable; this will often bring his total superficial area up to $\frac{1}{12}$ of the cubic capacity; unfortunately much of this superficial area is where it is of the least benefit to the horse, viz. behind him; if he had it actually in the ground of his stall, it would be of great advantage. The superficial area for a stall should be about 70 feet, and the total area made up to 100 feet by the share of the passage.

The superficial area of army stables has been fixed as follows: for the stall alone, 52 feet; for the stall and share of passage, 91 feet; for infirmary stalls and share of passage, 200 feet; and for infirmary boxes, 204 feet.

The Principles of Ventilation.

The process of ventilation may be defined as that by which the foul or vitiated air of a building becomes removed, and its place taken by pure air. The principles which bring this about are not difficult to understand, as they are based on the action of well-known physical laws, but the arrangement of a building to admit of these natural laws acting is not always a simple matter. In bringing about ventilation in the habitations of animals, we labour under a great disadvantage compared with the human hygienist, in not being able to utilize fireplaces or chimneys as a means either of extracting foul air or introducing warmed; our ventilation must almost invariably be produced by purely natural means.

Ventilation is divided into natural and artificial. The former principally concerns us; the latter is rarely used, though it is to be hoped it will soon be more generally adopted.

Natural ventilation is produced by three forces: 1st, that of diffusion; 2nd, the action of winds; 3rd, the unequal weight of masses of air of different temperatures (Parkes). The process of diffusion is governed by a certain fixed law; every gas diffuses in inverse proportion to the square root of its specific gravity. In other words, the less the specific gravity the greater the power of diffusion. Diffusion is the means by which the uniform composition of the atmosphere is maintained; in buildings it is not sufficiently rapid by itself as a means of ventilation; still, it is constantly going on, and is an important factor; the process may occur through brick and stone walls.

Pettenkofer has practically demonstrated that air will pass through a brick wall a foot in thickness; and if subjected to compression it will pass through with sufficient force to blow out a lighted candle on the opposite side. This hygienist is also of opinion that one of the evils of a newly built and damp house is that diffusion cannot occur through its walls. An experiment made by Roscoe showed that CO_2 evolved into a room was reduced to one half in ninety minutes by the process of diffusion.

Winds are produced as the result of differences in atmospheric pressure. Wind as a ventilating medium is one of the most perfect we can have; for example, blowing at the rate of 3 miles per hour (which is a little more than perceptible) through a ventilator 1 square foot in size, there will pass every minute 264 cubic feet of air, or 15,840 cubic feet per hour.

This wonderful perflating power of the wind is, therefore, our chief means of ventilation; all we have to do is to build our stables in such a manner that it may be allowed to act, and to arrange by means of ventilators that draughts are prevented, and that a thorough mixing of the incoming air with that already in the stable takes place. To favour perflation our stables must have opposite doors and windows, and the buildings should not be more than 25 or 30 feet wide; any greater width than this interferes greatly with free perflation. We see the evil of arranging stables after the plan of most of our old military ones, where the opposite doors and windows were sometimes as much as 65 feet apart, and where two small windows and a door at each end had to suffice for the ventilation of a stable containing twenty-four horses. It is quite evident that only those horses situated close to the windows received any fresh air.

A current entering through a ventilator will cause the air in the stable to set in towards it in a direction more or less at right angles; and if the velocity of the incoming current is great, it may pass out again at the opposite opening before it has properly mixed with the air in the stable. The proper distribution of air currents on entering is therefore very essential, not only with the object of preventing a direct draught, but also by changing the direction of the incoming current to cause a more complete mixing of the airs.

I have studied, by means of a special contrivance, the course which currents of air take on entering a stable under different arrangements of ventilation. The results obtained are of great practical importance.

With windows fully open to windward, opposite ones closed, and with ridge ventilation, it was observed that the

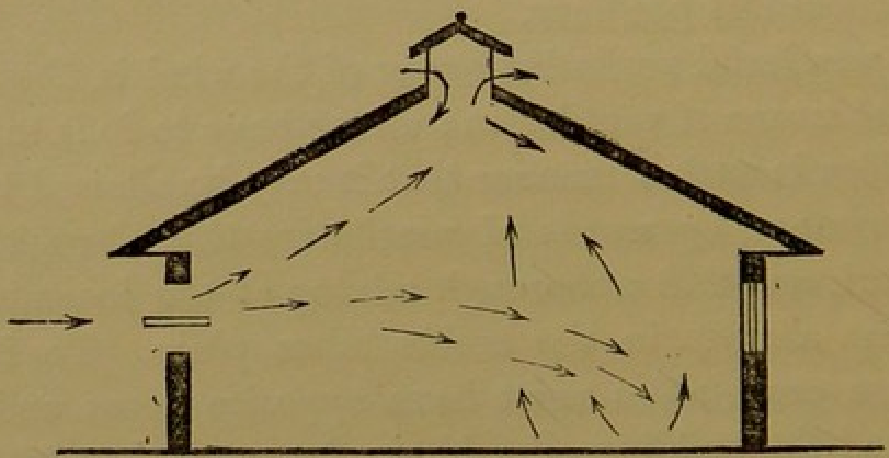


Fig. 1.—Direction taken by Air Currents with the Windward Windows open.

current of air rushed in, carrying all before it; that shortly after entering it spread out fan-shaped and fell to the ground; if the current is powerful it may be measured 18 or more feet from the point of entry; but it is usually found that its velocity rapidly and suddenly decreases about 6 or 8 feet from the inlet, owing to its meeting with a large column of air in the stable which causes it to become broken up, spread, and fall; it strikes the ground on the opposite side of the stable, and rises again, much of it escaping by the leeward side of the ridge, or sent out the road by which it entered, owing to a sudden but momentary reversing of the wind. The windward side of the ridge-opening is also an inlet. It is necessary to observe that no currents could be detected in that part of the stable under the open window; the force with which

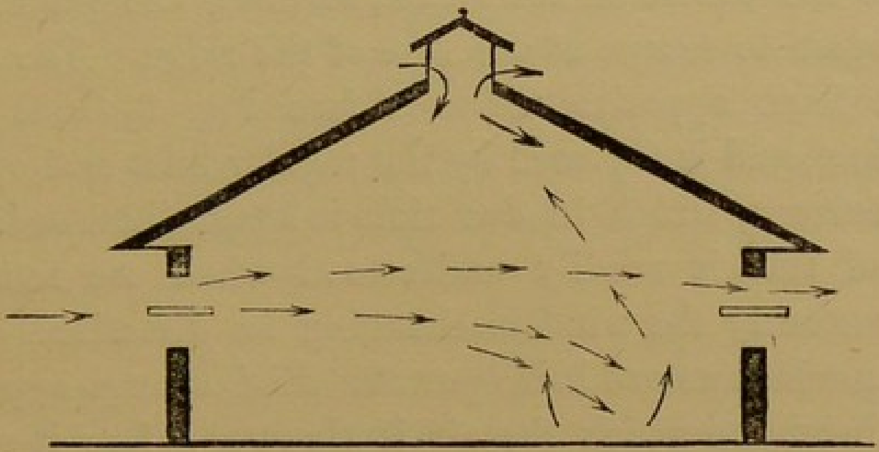


Fig. 2.—Direction taken by Air Currents with Windward and Leeward Windows open.

the air is driven in carries it over this part for 6 or 8 feet. Fig. 1 illustrates diagrammatically ventilation by means of windows open to windward.

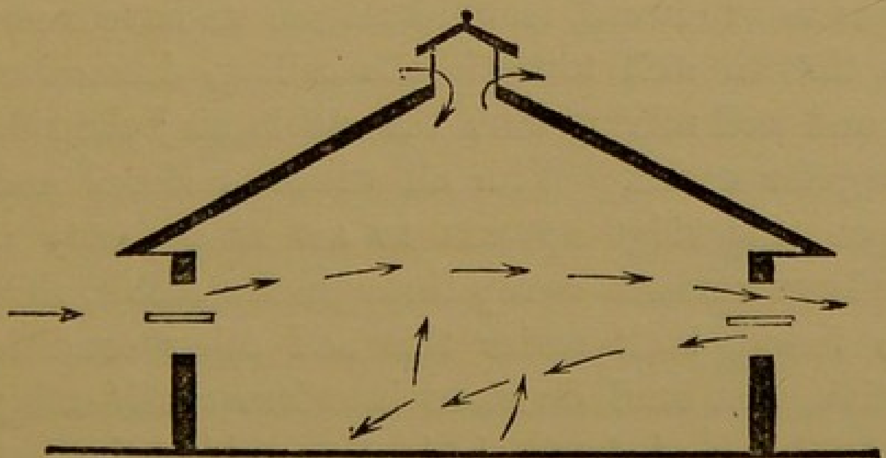


Fig. 3.—Double Current from opposite Windows.

When opposite windows are open, the air rushes in on the windward side, behaving much as described above, the air striking the ground and rising again; some of it escapes directly, without mixing with the stable air, by means of the window to leeward. This condition may go on regularly for some time (see Fig. 2), when suddenly a backward current through the outlet window occurs, the two currents entering from opposite windows spreading out, meeting towards the centre of the stable, striking the ground, and rising again to escape at one side of the ridge. The double current from opposite windows (see Fig. 3) lasts but a short time, and is replaced by the regular inlet and opposite outlet current, which in due time is again disturbed. The cause of this is readily understood when we remember how constantly the wind is changing its direction. When opposite windows are half open the chief change appears to be the height to which the air is thrown before it reaches the ground (see Fig. 4); the leeward window is the principal outlet, but not before the incoming current has time to mix with the air in the stable; on the contrary, if the windward window remains half open, and the leeward one fully open, the tendency is for the incoming air to rush out of the stable without mixing properly. With windows half open to windward, leeward closed, we have a powerful current thrown well towards the ceiling, descending fan-shaped and well mixing with the stable air; the ridge is a fairly regular outlet. With all windows closed and door only open, the ridge appears to act as a pretty regular outlet; large currents sweep through the stable, though it will be found, both under this and other conditions of ventilation, that stall divisions interfere considerably with the free mixing of fresh air in the stable; the incoming current strikes the stall division and goes over it. With doors and windows shut, the ridge is both inlet and outlet, the inlet being the windward side (see Fig. 5).

The practical outcome of my observations on the direction taken by currents of air show clearly the form of stable which can best be ventilated. This is undoubtedly one not more than 30 feet wide, but of any length which necessity may occasion, with windows above the horses' heads sloping inwards, which can be arranged at any angle suitable to the velocity of the wind, with the object of direct-

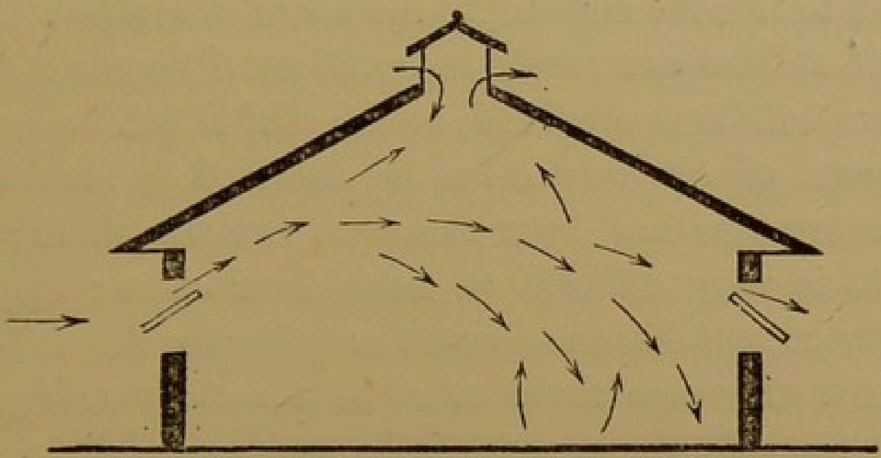


Fig. 4.—Direction taken by Air Currents when opposite Windows are half open.

ing the current upwards and so breaking its force before it descends. The ridge, though extremely valuable, is not a regular outlet, and I think that perhaps large upcast tubes

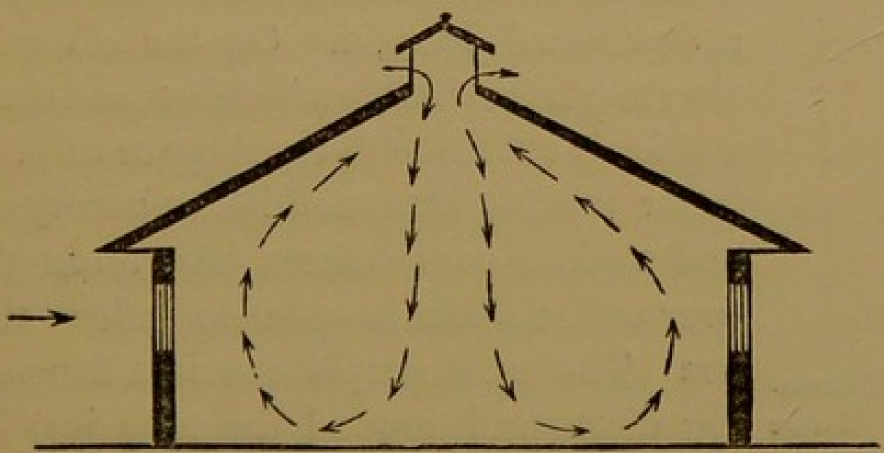


Fig. 5.—Direction taken by Air Currents when all Doors and Window are closed.

would be found more satisfactory. These tubes are described later on. Those animals standing under the windows on the inlet side suffer no draught whatever. Ground-ventilators placed between the standings where bails are used, may be useful in drying the ground, but are quite unnecessary as ventilating media if the windows are kept open. On the other hand, where stall divisions or boxes are used, ground-ventilators play an important and useful part in assisting to remove and dilute the air of the place. Ventilation of stables can rarely be satisfactorily managed when there are buildings overhead, or the roof is flat.

Currents of air may often be detected in stables even when every care has been taken to exclude them; sometimes it is very difficult to trace their cause; they may generally be found in the corners or going up the side of the walls, and of course there must be a corresponding down current towards the centre of the stable. Their presence may be readily detected by a piece of knitting-wool suspended from any convenient part of the roof, or from the movement of the cobwebs where these are allowed to exist.

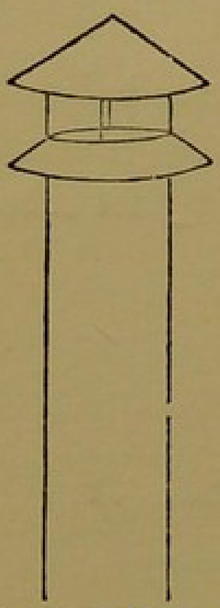


Fig. 6.—Extraction Tube (Parkes).

Powerful currents passing over stables provided with ridge or tube ventilation may cause a downward draught. On the other hand, they may have the opposite effect, and draw the stable air out through the ridge or tube. This latter process is termed its aspiratory effect, and various contrivances have been placed over outlet shafts in order to induce this to act. The most simple one is a flange sloping downwards around the tube just below the cap; the effect of the flange is to throw the current of air upwards as it strikes, which passes thus directly across the mouth of the tube, and so aspirates or draws out the air contained within it. Fig. 6 shows one of these cowls. It is a series of these tubes, or some working on this principle, which I would propose to fix in the ridge of the stable instead of the ordinary louvre, in order to establish a regular up-draught.

The objection to the wind as a ventilating medium is that the air may become stagnant; this is rarely the case in England, where the mean velocity is, according to Parkes, from 6 to 12 miles per hour. In the tropics, on the contrary, a stagnant condition of the atmosphere is common, and particularly so at the very time of the year when the least movement of the air is attended by the most benefit. The process of diffusion is now the only one left us to remove the vitiated air of the stable; and to admit of this being fully and rapidly carried out, all tropical stables should be left well open on both sides, and but few obstructions in the shape of pillars, etc., should be permitted.

The wind is the power which is used in the ventilation of transport ships, it being introduced into the lower decks by means of windsails. Owing, however, to the defective distribution of the air by this method the results are very unsatisfactory. The few animals near the windsail are exposed to a great draught, and those some distance from it receive but little air. In other words, the introduction of the air is satisfactory, but its distribution is bad. The ventilation of ships is considered later on.

Columns of Air of unequal Temperature.—Though this is the basis of artificial ventilation, yet to an extent it comes under the head of natural. In obedience to a physical law, hot air becomes lighter and ascends; cold air, being of a greater specific gravity, descends. By the application of heat, air may be made to assume any degree of lightness.

A familiar example of the expansion of air by heat is the flaccid bladder with its mouth tied; if heated in this condition the air within expands, and if the heating be carried far the walls of the bladder burst.

The heated air which plays a part in natural ventilation is that which is given off from the lungs of animals, the result being that the whole bulk of air in the stable becomes raised in temperature above the external air; thus we have a fairly continuous current established between the outside and inside of the stable. It should be remembered, however, that as this air ascends it becomes cooled, and particularly is this the case where the stable is high and ridge-ventilation exists; thus there is a tendency for it to fall again, unless we have something more powerful in the shape of ventilating windows to overcome this attempt at obstruction and force it out. In other words, we can never trust to this process alone to keep the air in a pure condition. If long tubes are used as extraction shafts, the air in them becomes rapidly cooled and falls instead of ascending, unless there is a column of air entering below to press it upwards. Even when this pressure from below is exercised, we may yet have obstruction to the exit of foul air where the tube is long and exposed to the cold; in cases of this description a double current is established in the tube, one of warm air up one side of it, and cold air descending on the other. The practical deductions are obvious: extraction tubes cannot be too short; if used, as in the case of flat roofs, passing through rooms above, they should be kept warm by being placed close to the fireplaces; or if passing through a loft, should be protected from the cold air by placing trusses of hay or straw around them.

In summarising the three forces acting in natural ventilation, we place the wind as our chief one; diffusion is of course very important, but excepting in a still atmosphere the wind replaces it; unequal bulks of different temperatures only act irregularly, as they entirely depend upon the difference between the temperature of the outside and inside air. It may be made the most perfect system of artificial ventilation if expense is no objection.

Artificial Ventilation.

If we can artificially warm the air of our stables, the difference in weight of unequal bulks of different temperatures will be of wonderful assistance to us in keeping up a constant movement of air; it moreover leaves no excuse for ventilation not being established, for if we can warm the air entering, and keep the stable at a temperature of 60° Fahr., the greatest opponent of fresh air would no longer have any valid reason left him for closing an aperture.

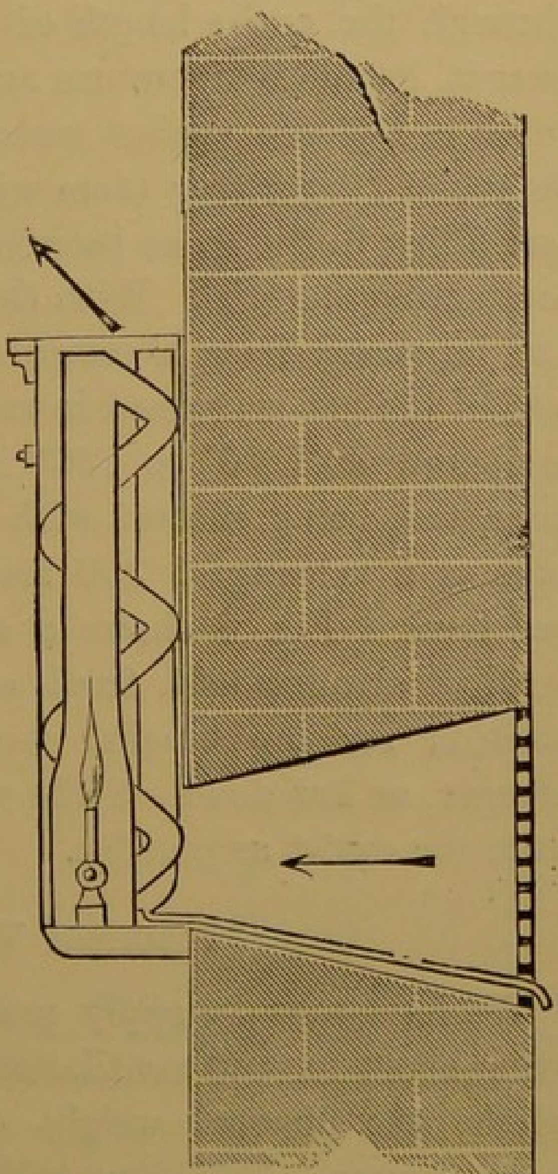


Fig. 7.

When artificial heating is adopted, we can carry on ventilation without the direct aid of the wind, for the air of the stable, being warmer than the outside air, expands and escapes, and its place is at once taken by colder air from without, which, by passing over the heating arrangement, has its temperature raised, and so the process goes on continuously and regularly.

Messrs. Boyle, the ventilating engineers of Holborn Viaduct, appear to have solved the problem of artificially heating (and thus ventilating) stables. The inventors say: 'The arrangement consists of a copper or iron pipe placed in an inlet tube, preferably of the form of a bracket. This pipe is made of zigzag shape so as to cross and recross the tube from top to bottom, causing the incoming air to repeatedly impinge upon it in its passage through the tube. At the bottom of the tube an air-tight chamber, so far as the interior of the tube is concerned, is fixed, in which a "Bunsen" burner is placed, the flame of which plays up into one end of the pipe which is connected with the top of the chamber. The heat travels through the entire length of the pipe, and the air, passing over it, has its temperature raised (see Fig. 7). Where the tubes are placed against woodwork, all chance of fire may be avoided by fitting them with a double casing or jacket, and filling in the space between with asbestos or other non-conducting material. With this arrangement, the air supply can be raised from a temperature of 30° to 130°, and the cost of the gas consumed in raising the incoming air from a temperature of 40° to 100° is less than one farthing per hour, this being effected with the air passing through the tube at a velocity of 300 feet per minute, or 18,000 feet per hour.' Fig. 8 shows a section of a stable with the heating arrangement fixed against the wall. The best position for the bracket would, I think, be under the manger, or low down on the wall between the stalls, as far from the outlet as possible.

Practical Ventilation.

We have now to apply practically the principles which bring about natural ventilation, viz., diffusion, the action of winds, the unequal weight of bodies of air of different temperatures. Diffusion will occur, as we have shown, through a brick wall; all we have to do to allow of it acting for the purpose of ventilation is to have a communication between the air inside and that outside the stable: this is of course brought about by doors, windows, etc.

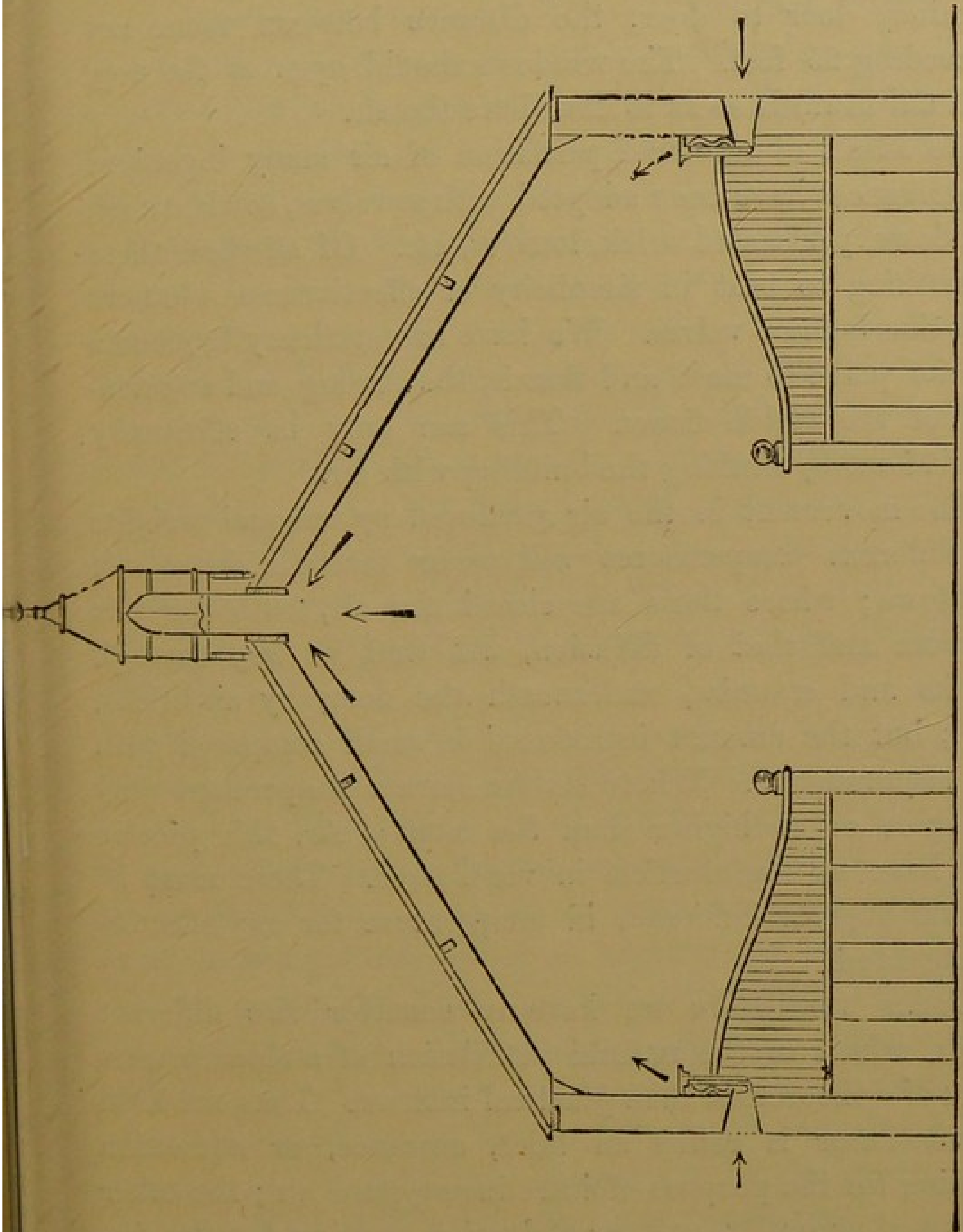


Fig. 8.—Section of a stable heated artificially by means of Boyle's gas-bracket; the latter would be best close to the ground. On the ridge may be seen the exhaust "air-pump" of the same firm.

In order that winds may act to advantage in flushing out the stable, we must have opposite doors and windows. This is a *sine quâ non.* Window should be opposite to window, door to door, the distance between them not exceeding 25 feet. The windows should open at the top, and fall inwards so as to distribute the air.

To admit of this free perflation of air many ingenious contrivances have been adopted, such as valves, cowls, tubes, windows, perforated brick, louvres, etc. Of all these there is nothing to beat in simplicity or effectiveness windows and Sheringham valves. We have in veterinary hygiene a special point to meet, and that is, the drying and sweetening of the stable floors. This can only be effectually carried out by flushing the building with air.

The movement in the air produced by unequal weights of different temperatures will occur through doors and windows; where these are closed the air, both for this purpose and that of diffusion, will find its way through cracks and crannies, underneath the door, by air-bricks, etc.; but the amount introduced is small compared with the requirements. Where stables have a temperature only a degree or so higher than the outside air, this process will have no useful effect in ventilation. There must be several degrees difference in temperature for any effect to be observed.

Under ventilators we have to consider two different kinds, which in the natural ventilation of stables possess more of a theoretical than practical interest. Thus one kind of ventilator is called an inlet, entrance, or adduction opening for the purpose of introducing pure air; the other is termed an outlet, exit, or abduction opening for the discharge of impure air. Let us clearly understand this, and thus avoid a very common error; *any opening* may be an inlet or outlet; an inlet one minute, an outlet the next; all we attempt to do is to arrange the position of openings so that they may serve to direct the currents, and assist the natural laws in rendering one an incoming, and the other an outgoing current. We cannot, when depending on natural ventilation, point out any particular opening as a regular inlet, or one as a regular outlet. There is nothing regular in it; they are in their behaviour, it may be said with absolute accuracy, as variable as the wind.

What we desire to do with regard to openings is to have inlets in the wall, and outlets in the roof. Theoretically the idea is an excellent one; practically it is most erratic and irregular in its working, and cannot be depended upon.

It is necessary to somewhat qualify this statement with regard to certain tubes now in the market, which appear to act as outlets only. But the statement is positively accurate when speaking of ordinary ridge or louvre ventilation. These arrangements, devised as outlets, are as often inlets, and this is a point of importance which should be remembered.

Inlets are of various kinds—tubes, shafts, windows, perforated brick, holes in the wall, doors, etc. The two former have been made of great length, placed at all angles to each other, arranged never to be again opened, and protected indifferently. All these are important points to avoid in using tubes either as inlets or outlets, for in the first two cases the losses by friction have not been taken into consideration. Air passing through a tube at a certain rate will, before it has proceeded far, have this rate diminished, owing to the friction of the air against the side of the tube; the longer a tube the greater the friction. The wider a tube the less the friction.

Angles or bends in a tube are more important causes of loss. A current passing along a tube at 10 feet per second will, on coming to a right angle, have its velocity reduced to 5 feet per second; and if there be another right angle in the tube the velocity will be only $2\frac{1}{2}$ feet per second. Thus a right angle diminishes the velocity by half, and yet we have stables ventilated by tubes with inlet shafts bent at two or more right angles. Fig. 9 explains why right-angled tubes diminish velocity; the current strikes the bend (marked with a star in the figure), and then flows on again; the impact has destroyed half of its velocity. Fig. 10 is a curved bend, which is the only one admissible.

Dust and dirt accumulate in these tubes, so provision must be made for their periodical cleaning; the external opening of the inlet should be covered with wire, and the shaft should be made to open by a hinge-flap at any

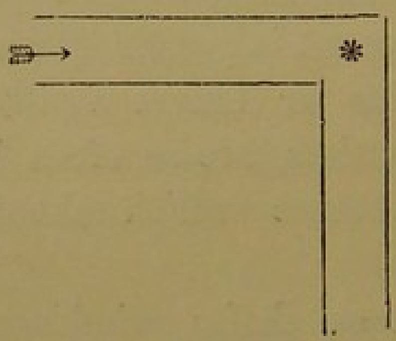


Fig. 9.

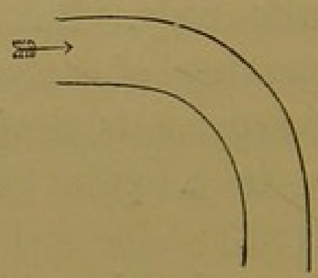


Fig. 10.

part of its course, so that it may be cleaned out. The shape of the shaft is important; a circular one gives the largest area in the least circumference, and Dr. de Chaumont's tables of friction due to form of sectional area show that the nearer the shape approaches to a circle the less the loss from friction. If two shafts be taken, one a square and the other a circle, both of the same area (1 square foot), the velocity through the square opening will be $\frac{7}{8}$ of that through the circular opening (Parkes).

As an inlet a shaft must be absolutely condemned for military or all big stables, for the reason that it can never be made sufficiently large to supply the enormous amount of air required by the occupants. We see at the present day shafts as inlets for horses which would not supply the amount of air needed by the same number of men. In private stables, on the contrary, a shaft may be a useful inlet for a few horses, and the points to be observed in its construction are that it be circular, of sufficient sectional area, that there are no right angles in its course—all angles should be rounded (see Fig. 10)—that its entrance be protected, that it can be easily cleaned out at any part, and so situated that the air it conveys is obtained from a pure source.

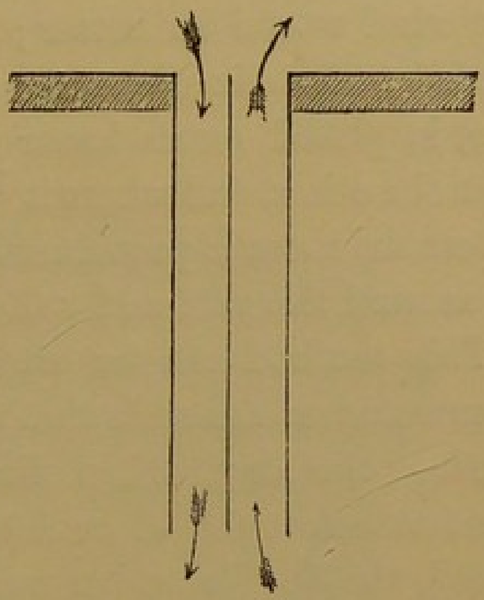


Fig. 11.—Divided Tube (Parkes).

A tube with a central division has been made to act as an inlet and outlet (see Fig. 11). There is an upward current on one side and a downward on the other; it is arranged to be placed in the ceiling and open on to the roof. A shaft having four partitions was designed by Muir. The external opening was protected by a louvre. These tubes act fairly well under favourable circumstances, but they are far too uncertain for general adoption. Some of the London stable-constructors advocate their use, and the tube is placed over the rear of each stall; but there is not only a danger of a down-draught on the horse's back, but the air entering the stable is badly distributed. Another form of divided tube, performing a double office as inlet and outlet, is McKinnell's circular tube (Fig. 12). This consists of two circular tubes, one placed within the other; the area of each is equal, but, as pointed out by Dr. de Chaumont, it would be better to have the area of the outer tube larger, as the friction to be overcome is double that of the inner tube. The latter is the outlet, as the air in it is kept warmer by the outer tube; it is raised much higher than the inlet, and covered by a hood. Parkes says, that instead of a hood, a cowl turning away from the wind would be better; the inlet tube, viz., the outer one, is placed much lower than the other, and where it enters the room is protected by a flange which distributes the air around the roof and walls, and prevents a down-draught.

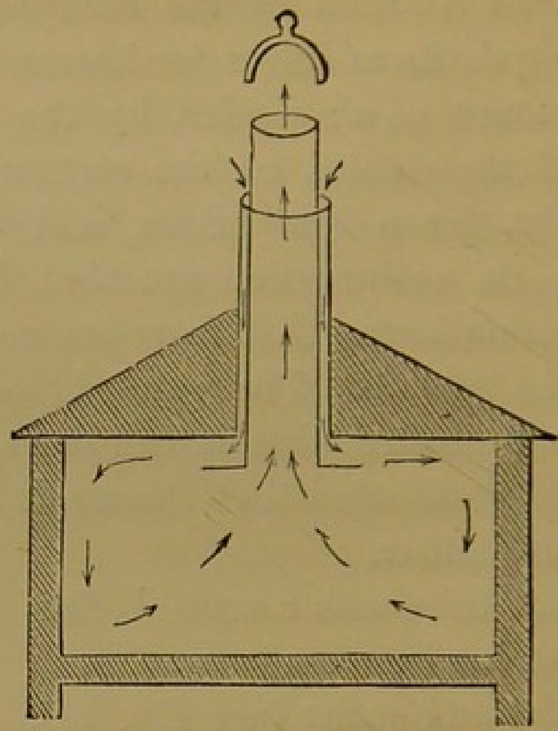


Fig. 12.—McKinnell's Tube (Parkes).

This method can be made a very useful one where the circumstances are such that no simpler plan can be adopted. During the day, when the stable-doors are open, both these tubes would be outlets; but at night, when they are closed, the double action would be established. Again, we must repeat, that the section area of both tubes must be sufficient to meet the requirements of the occupants of the stable.

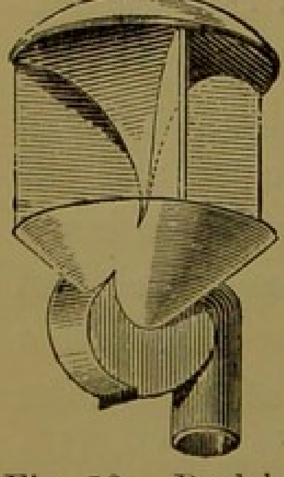


Fig. 13.—Boyle's Inlet Cowl.

Another form of inlet tube is a fixed inverted cone-shaped cowl (see Fig. 14). It will be observed that it is just the opposite shape to the fixed upcast tube (Fig. 6, p. 80). Messrs. R. Boyle have a cowl which acts as a regular inlet (see Fig. 13).

Perforated bricks can be made a useful inlet. In military stables they are carried completely around the building under the eaves; but for a private stable this would not be necessary. These bricks are of two sizes, 9×3 inches, giving an inlet of $11\frac{1}{2}$ square inches; and 10×6 inches, the perforations giving an inlet of 24 square inches. The perforations in the bricks might be so arranged as to throw the air upwards. Air-bricks with conical holes—viz., when the hole on the inside is much larger than that on the outside—have the effect of considerably breaking powerful currents, distributing them in a fan-like shape, and so preventing a draught; these bricks are known as Ellison's.

Fig. 14.—Inlet Cowl (Parkes).

Sheringham valves are excellent inlets. The proper

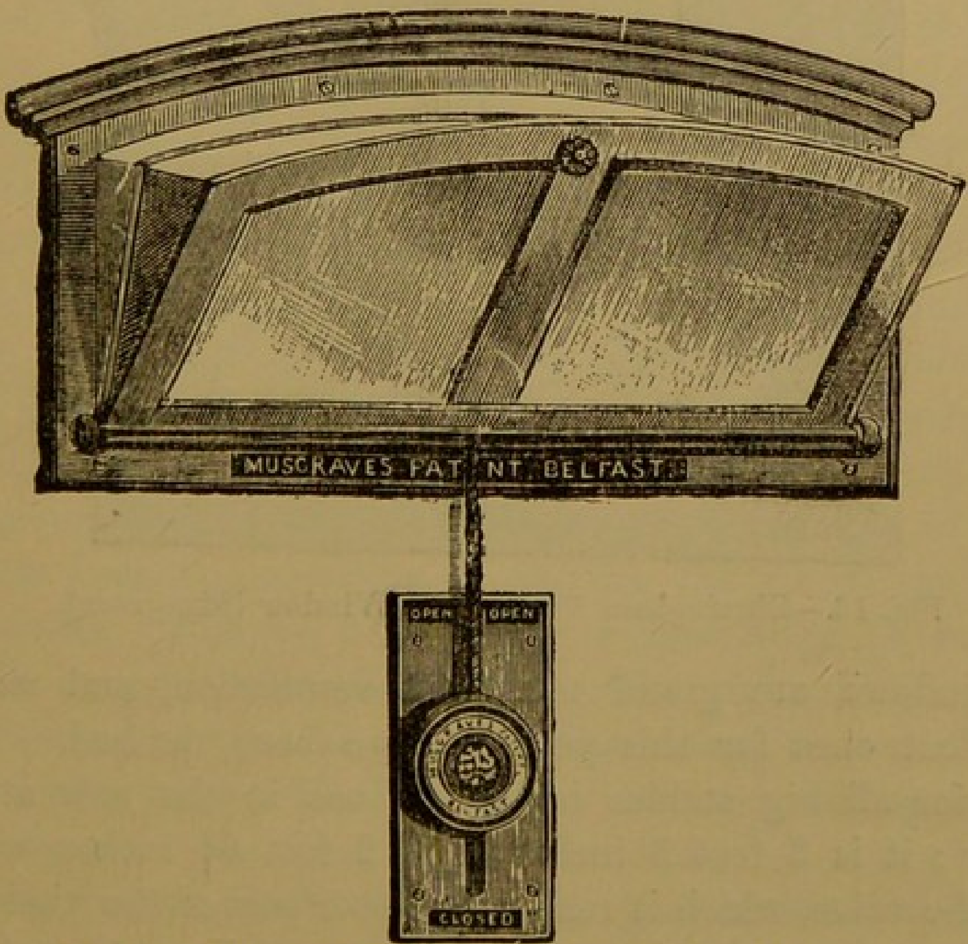


Fig. 15.—Sheringham Ventilating Window (Musgrave).

Sheringham valve is protected outside by an air-brick; but for stable purposes nothing can be better than an ordinary ventilating window constructed on the same principle of opening inwards, and thus throwing the air up to the ceiling: it should be so constructed that the valve may be made larger or smaller at pleasure (Fig. 15). This valved window is placed a little above the horse's head, and as a window it is a useful addition to the lighting of the stable. Its size, as of that of the other openings described, must depend upon what inlets exist, and this subject will be dealt with presently.

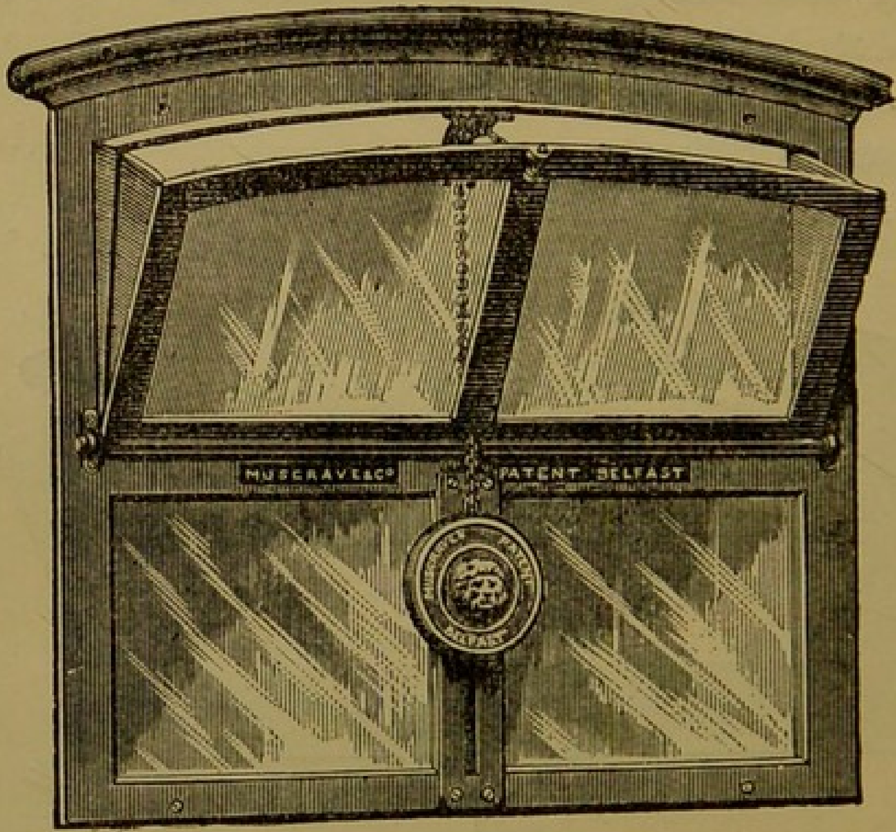


Fig. 16.—Sheringham Ventilating Window (Musgrave).

Windows are grand means of ventilation, and many excellent ones for this purpose have been devised. The best for all big stables is that in use in the new army stable; it is 3 feet 3 inches high, 2 feet 6¾ inches wide, and the valve, which is really the upper part of the window, is arranged to swing inwards. It is open fully at 19 inches, and thus affords a ventilating area of a little over 4 square feet. This window can be regulated to any size, and as a ventilating medium cannot be surpassed. The following windows are very suitable for private stables :

Fig. 16 is a good one for the wall behind the horse ; it affords ample light if made 3 feet wide by 3 feet 6 inches high. The lower half is immovable; the upper half is a Sheringham valve. This window should be opposite to one placed over the horse's head, of which Fig. 15 is very suitable for the purpose. Both these valves open by means of a contrivance with which the horse cannot interfere. When much light is wanted, as in cities, larger valved windows may be used; the opening should, however, always be made on the Sheringham principle, to avoid a down-draught.

Ground inlets may be air-bricks, obliquely-shaped holes, or openings provided with an arrangement to regulate the current through them. Tubes were used as inlets in some of the old-pattern army stables—they are nearly useless. In stables with bails, I regard ground-ventilators as unnecessary if proper window ventilation is provided, but where there are stall divisions they are useful. Ventilating stall divisions have been made, the air being admitted close to the ground, and carried up through a hollow in the division; they are intended for the introduction of fresh air to the horses. I consider the chief function of ground-ventilators as being the drying and ventilating of the floor, and assisting in keeping the air of the stall in motion. Fig. 17, p. 94, shows a ventilating pillar, the air is brought from the outside. The right-angled junction should be avoided, and the diameter of the tube made sufficiently large. If these pillars be used, arrangements must be made for cleaning the tubes out.

Inlet ventilation should be made wider on the side which opens into the stable, so as to produce a fan-like direction of the air, and thus facilitate distribution and prevent draught.

Doors as inlets are important; they of course only act during the day, but their effect is very great.

Outlets or abduction openings have been placed by general consent at the upper part of the building, it being said that the ascent of heated air is rapid, and that it will escape at the highest point of the stable if means are provided for this purpose. From what we have previously stated, it can be seen that outlets may be equally effective when placed in a side wall. The expansion and rapid escape of

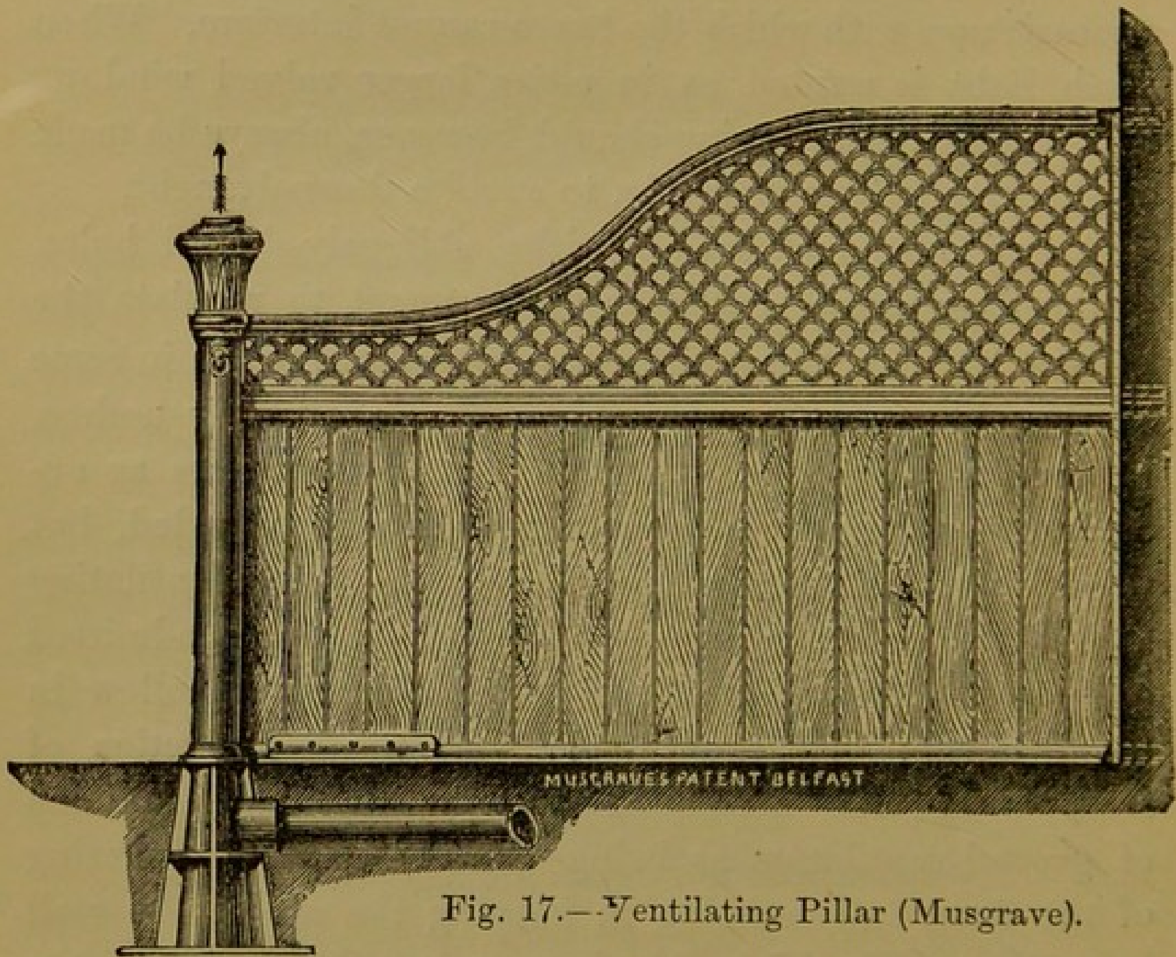


Fig. 17.—Ventilating Pillar (Musgrave).

heated air has been much overrated in veterinary hygiene; and I say so for this reason, that such rapid cooling of expired air occurs when no artificial heating of the building is practicable, that it readily falls again unless we are prepared to flush it out of the stable.

If there is no proper outlet, then the action of the inlets is interfered with, so it is most important that means be provided to allow of the escape of foul and heated air.

Ridge-ventilation in army stables is carried from one end of the building to the other; the opening is protected by a louvre with the boards sloping upward, and thus an attempt is made to prevent a down-draught. Much stress has been laid upon the proper angle the louvre should form to exclude rain. It appears to me, that the main point to attend to is the proper width of the board—a narrow board even placed at a suitable angle will not keep out drifting rain. In point of fact, a ridge opening is an inlet on the windward side, and an outlet on the leeward; it is for this reason that I should suggest extraction tubes, so as to establish a regular outgoing current. In the meantime, however, the ridge is the best arrangement we have for roof ventilation: in army stables it affords 4 square feet for each horse. A point to notice with regard to ridge-ventilation is the size or width of the opening in the roof compared with that formed by the louvre. I have often observed an opening in the roof of 18 inches, and a ridge only four inches high. The height of the louvred opening should be the same as the width. Where wind blows down the ridge, an attempt may be made to prevent the draught on the horses by means of a false roof placed below it, which will have the effect of turning and breaking the current. I have seen this plan very successfully adopted, canvas being nailed to a frame just below the ridge.

Louvred openings could easily be made to shut and open at pleasure; but this is not advisable, for the reason that the direction of the wind is constantly changing, and it leaves too great a temptation in the way of people to close the outlet.

Extraction Tubes and Shafts.—Two of these we have previously described under inlets. They should be smooth, circular, as short as possible, and protected in their course from cold. This class of outlet is indicated in most stables with rooms over them, or where ridge-ventilation is not provided; where they commence inside the stable, they should be provided with an arrangement to break any down-draught; they should all be of one height, or the discharge will be unequal, and be provided with either a louvred covering, a fixed extraction cowl, or with a cowl turning away from the wind. The great objections to shafts are, that they are liable in their course to become cooled, and thus retard the discharge in the tube, or if very cold stop it altogether; also, unless they are sufficiently numerous, the foul air is not carried off quick enough. These objections apply principally to the ordinary tubes in use; there are some of special manufacture, to be described presently, where these drawbacks are overcome.

Cowls for covering extraction tubes are of various patterns; they are made with a vane to open on the opposite side to which the wind is blowing; the mechanism is liable to get out of order, and for many reasons a fixed cowl is considered best; the one on page 80 (Fig. 6) acts in this way: the air impinging on the flange is thrown upwards, and then shoots across the opening of the ventilator, and in its passage causes an up-current in the tube; a reverse arrangement (Fig. 14, p. 91) produces a down-current. If extraction tubes can be heated, the discharge through them is rendered much more regular; therefore, when gas is used in stables where these tubes exist, it should be arranged to burn beneath them, so as to facilitate extraction, and carry off at the same time the products of gas combustion. Tubes passing through lofts above should, as before noticed, be protected by trusses of hay, in order to maintain the temperature in them as much as possible; if this is not done, extraction will be irregular. Should these tubes pass through dwelling-rooms, the heat of the rooms will ensure a regular up-current.

The outlet for all stables should, in my opinion, be a tube fixed in the ridge (see Fig. 8, p. 85), the top of which is so arranged that the aspiratory action of the wind is taken advantage of, and there is a constant up-current. Boyle's so-called 'air-pump' (Fig. 19) is thus arranged. The principle of its working is simple; the wind passes through certain openings in the cowl, so arranged as to increase its velocity, causing it to pass the open mouth of the tube it covers, and thus produce a constant up-current.

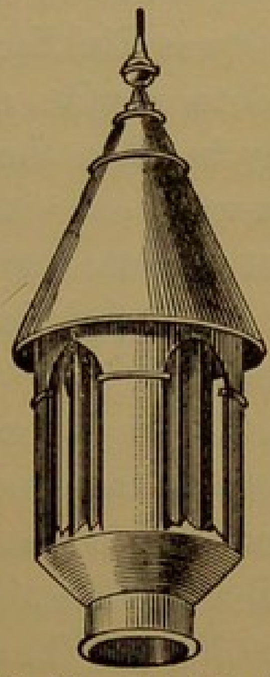


Fig. 19.—Boyle's Air-Pump Extractor.

'In the plan of the ventilator (Fig. 20), A indicates the opening into which the wind passes and impinges upon the deeply-curved bell-mouth arrangement B, in which a large body of air is collected and forced into the narrow annular space C, at which point, owing to the compression of the air, which cannot otherwise escape or free itself, it attains a greatly accelerated velocity, and, in passing over the slip D, creates a powerful induced current, exhausting the air with considerable rapidity from the central chamber E. The foul air immediately rushes up the shaft to supply the place of the air extracted, and is in its turn drawn off, thus creating a continuous and powerful upward current in the shaft connected with the place being ventilated. F, diaphram to deflect the air over slip D. G, curved

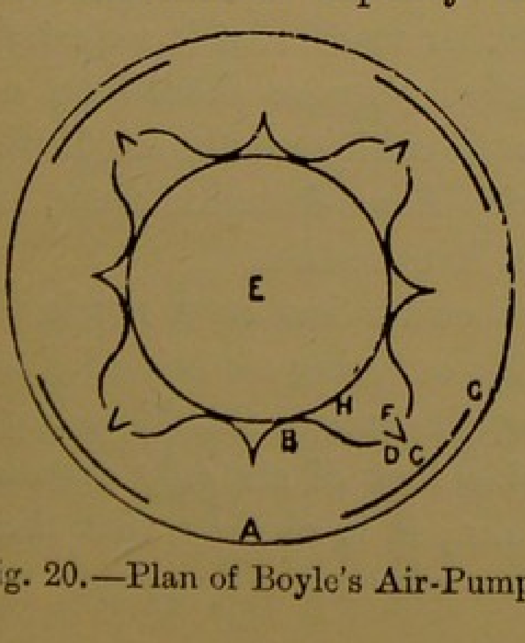


Fig. 20.—Plan of Boyle's Air-Pump.

baffle-plate or guard to protect the slip opposite, concentrate the current, and prevent it from expanding and being deflected backwards without passing over the slip D. H, space dividing the exit slip from the central chamber, and to receive and run off any water that might find its way in when the ventilator is used on board ship with seas sweeping over it. J, deep lip or rim to prevent any water that might enter the space H from passing into the central chamber and down the shaft. The shaft attached to the ventilator may be made any diameter required, but it should be borne in mind that the extracting power of a properly constructed roof-ventilator lies exclusively in the head, and is solely determined by the size of the same.'

Buchan has also what he terms an induced-current fixed ventilator. 'The wind, or horizontal air current, in rushing between the outside perpendicular plates and past the body of the ventilator, draws out with it the air contained within the ventilator, and so causes an up-current in the pipe upon which the ventilator is fixed. The inside diameter of the upcast shaft or pipe may be *rather less or more than half* the diameter of the body of the ventilator, thus a 20-inch ventilator may have its upcast pipe any size from 9 inches to 12 inches diameter. The larger the body of the ventilator in proportion to the ventilating pipe, the greater up-current is expected.'

All tubes intended for outlet purpose should be surmounted by a fixed upcast cowl which works on Boyle's or Buchan's principle, otherwise down-draughts occur, and the action of the tube or outlet is uncertain.

The relative size of inlets and outlets has been much discussed; it has been said that the outgoing air being lighter, and thus occupying more space, the outlets should be larger than the inlets; but as a cubic foot of air only expands 1-17th of its bulk for 30° Fahr., it is obvious that there need be no difference in the sizes of the two openings.

For all practical purposes we may disregard any other force than that of the wind in calculating the size of inlets for natural ventilation. It is evident that the size must depend upon the velocity of the incoming current; but for each horse it need never be more than 3 to 4 square feet, which can be reduced in size at pleasure. This is the total inlet ventilating area, and it is made up of windows, ground openings, and air-bricks, which should be in something like the following proportion: A Sheringham valve, or swing window, capable of giving an area of 2½ to 3 square feet; air-bricks around the eaves to give ½ square foot, and a ground-ventilator capable of giving ½ square foot of area. It is quite evident that the system of ventilation to be adopted must depend upon the arrangement of the stable; still the above should be a useful guide. In a private stable there will be no difficulty in arranging all the inlets and outlets, so that they may be decreased or enlarged at pleasure; but when the ventilation of a large stable has to be effected, all but the window ventilation should be placed beyond control.

The following table will be useful in determining the size of inlets per head, depending upon the velocity of the wind:

Description of Wind.	Mean Velocity in miles per hour.	Size of Inlet to admit 15,000 cubic feet of air per hour.
Calm	3	1 square foot.
Light Air ...	8	·4 " "
Light Breeze ...	13	·2 " "
Moderate Breeze	23	·12 " "
Fresh Breeze ...	28	

The table shows the velocity of various ordinary conditions of the wind. From the mean velocity I have calculated the size an inlet should be to supply 15,000 cubic feet of air to one horse for an hour; we have now only further to know the size of the ventilators or windows, their number, and the number of animals in the stable, and the width to which these windows or ventilators should be open, for each of the velocities, is then only a simple calculation.

The rule for ascertaining this will be as follows. Multiply the number of horses to be supplied with air by the figures in the second column, opposite to the velocity with which the wind is considered to be blowing; divide this by the number of windows or ventilators on the inlet or windward side of the stable, and the result is the size in square feet which each window or inlet should be open. If the measurements of the window or inlet are known, a little calculation will show how far the ventilator should be opened to correspond with the number of square feet obtained as above.

Example.—How wide open should be the windows or ventilators of a stable under the following conditions?

1. The velocity of the wind is 13 miles per hour.
2. The number of horses in the stable, 12.
3. The number of windows on the inlet side, 6.
4. The width of each window, 2 feet 6 inches.

In the table opposite to 13 miles is ·2; therefore,

·2
12 = number of horses.
Number of windows = 6 | 2·4
·4 = number of square feet for each window × 144 = 57·6 linear inches.

The width of each window is 2 feet 6 inches = 30 inches. Therefore 57·6 ÷ 30 = 1·9. Or, in other words, each window or ventilator must be opened 2 inches to admit, at a velocity of 13 miles per hour, 15,000 cubic feet of air per head.

This calculation, then, shows the size to which the *inlet* windows should be opened; but it is obvious, from what has been previously stated, that the outlet windows should be opened the same width, not only that they may act as outlets for an equal bulk of air which is admitted by the inlets, but for the reason that the wind may shift round, and they must then act as inlets.

In calculating the width which ventilators should be open when both sides of the stable are occupied by horses, it is necessary to remember that the inlet windows must be calculated for supplying two rows of horses, viz., those under the windows, and those on the opposite side of the stable.

No difficulty should be felt in estimating approximately the velocity of the wind from the table given above. The average velocity of the wind in England is from six to twelve miles per hour.

The leading principles to guide us, therefore, in the natural ventilation of stables are:

1. Effective ventilation can only be produced where the distance the air has to travel from one side of the stable to the other is not greater than 30 feet; better still if this distance be reduced to 25 feet. In order that this should be brought about it is essential that not more than two horses be placed between opposite windows; therefore, the transverse arrangement of horses in stables should be discontinued. Fig. 21 shows the best plan of arrangement to facilitate ventilation, Fig. 22 the worst.

2. The size of ventilators depends on the velocity of the wind; each horse must receive at least 15,000 cubic feet of air per hour; and this can be obtained by allowing it a swing window, or Sheringham valve, capable of

enlargement to $2\frac{1}{2}$ or 3 square feet, a course of air-brick under the eaves of the building equal to $\frac{1}{2}$ square foot, and a ground-ventilator of $\frac{1}{2}$ square foot in area. The outlet is

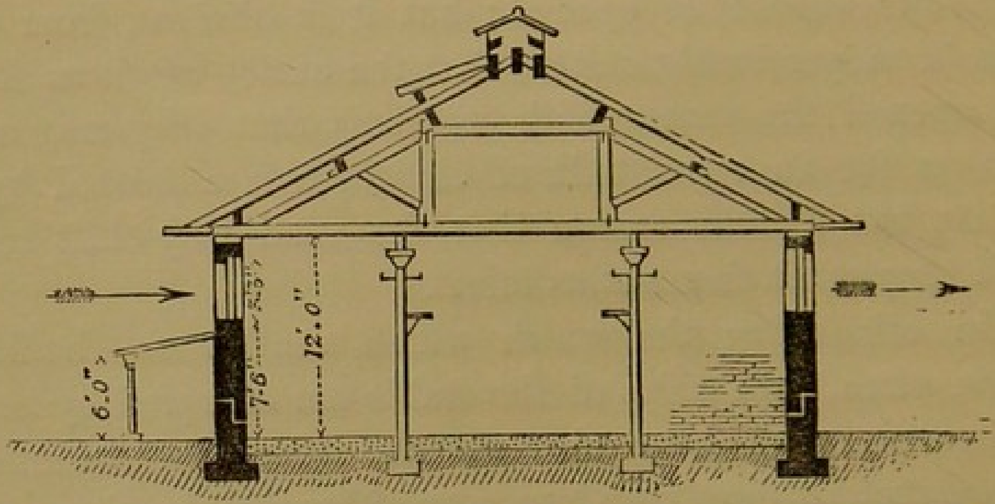


Fig. 21.—Transverse Section of Model Troop Stable. Two horses are placed between opposite windows, heads to outer walls. The arrows indicate the direction of the wind.

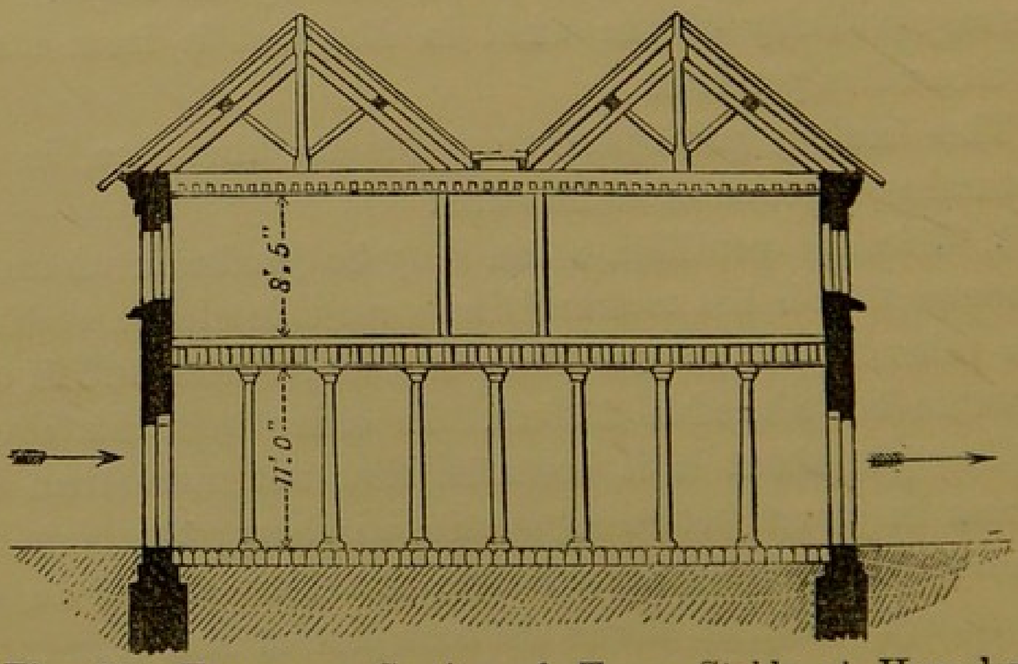


Fig. 22.—Transverse Section of Troop Stable at Hounslow Barracks. Eight horses are placed between opposite windows, with their heads to dividing walls. The arrows indicate the direction of the wind.

obtained by a ridge-ventilator carried from end to end, louvred openings in the roof, upcast tubes, or ridge tubes covered by a fixed extraction cowl; the ridge-outlet not being less than 2 square feet per head, and in private stables capable of reduction in size as circumstances may require. Men's rooms should not be over the stable, for it precludes ridge-ventilation; and, worse still in the old-pattern stable, necessitates the transverse arrangement of the stalls.

Examination of Air and the Sufficiency of Ventilation.

The object of this section is to explain the methods of calculating cubic space, of ascertaining the amount of air supplied to each animal, and the chemical composition of such air.

The measurement of cubic space is simple, the length, breadth, and height of the building being multiplied into each other, the result being the cubic contents; where roofs are angular, and where deductions have to be made for stable-pillars, etc., we adopt certain well-known mathematical means of estimating them.

To obtain the **area of a rectangle** or oblong, the most common form of stable, multiply two sides which are perpendicular to each other.

The **area of a triangle** is obtained by multiplying the height by half the base, or the base by half the height.

The **area of a circle** is obtained by multiplying twice the diameter by ·7854.

The **cubic contents of a solid rectangle** are obtained by multiplying together the breadth, length, and height.

The **cubic contents of a cylinder** are obtained by multiplying the area by the height.

In estimating the cubic contents of a stable with an angular roof, divide it into two parts—the body and roof. Ascertain the contents of the body by the rule for the solid contents of a rectangle or parallelogram, and obtain the roof by multiplying the area of its triangle by the length; then add the two together for the total cubic capacity. The deductions which have to be made on account of stable fittings are unimportant; if the stable pillars are large, their contents must be ascertained by the rule for the cubic contents of a cylinder, and deducted from the total amount. The only important deduction to be made is that for the animal itself; a horse will occupy from 18 to 20 cubic feet.

In measuring buildings it considerably simplifies the calculations if the measurements are made in feet and decimal parts of a foot, and not in feet and inches. For the decimal parts of a foot, see Appendix.

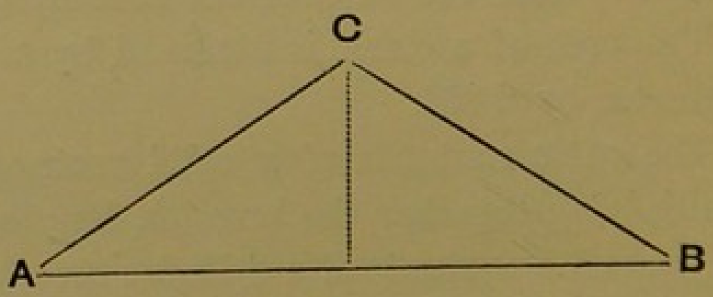
Example.—A stable for ten horses, let us suppose, possesses the following measurements—

Breadth	15 feet.
Length	60 ,,
Height to spring of roof ...	15 ,,
Height of angular roof	5 ,,

Supporting pillars, 8; diameter, 6 inches; height, 15 feet.

$15 \times 60 \times 15 = 13{,}500$ cubic feet for body of building alone.

To obtain the contents of the triangular roof, ascertain the height from the base to the vertical angle. In the figure which represents the roof under consideration, A B is the base, which we know from the breadth of the



building to be 15 feet, and C is the vertical angle; the distance from C to the base, shown by the dotted line, is the height of the angle, given as 5 feet. The rule, then, to obtain the area of this angle is to multiply the base by half the height, or the height by half the base; taking the former, the sum stands, $15 \times 2\frac{1}{2} = 37\frac{1}{2}$ square feet of area, multiplied by 60 (the length of the building) = 2,250 cubic feet for the roof alone. Add this to the amount already found for the body of the building, which gives 15,750 cubic feet for the gross contents of the stable.

From this make the deductions, viz., ten horses occupying 18 cubic feet each = 180 cubic feet; eight pillars, 6 inches diameter, 15 feet high—each pillar therefore occupies 11·78 cubic feet of space $\times 8 = 94\frac{1}{4}$ cubic feet. Deducting $180 + 94\frac{1}{4}$ cubic feet from the gross amount found, leaves us within a fraction 15,476 cubic feet of space for the ten horses; or 1547·6 cubic feet per head.

Our next step in examining the sufficiency of ventilation is to obtain the size of all the doors and windows, and any other means of ventilation which may exist, such as Sheringham valves, tubes, ridge opening, etc. Observe whether there are opposite doors and windows; the place on which they open; whether the air is likely to be well mixed in its passage across the stable; regard all the openings on one side of the building as inlets, and calculate whether under ordinary conditions of wind-velocity they will admit sufficient air for the whole of the occupants. The doors had better be omitted from this calculation. To determine the proper distribution and mixing of the air, and also as a guide to the inlets and outlets, generate some smoke by burning a little damped straw, and observe the points noted; do the same with doors and windows closed, and observe the inlets and outlets under these conditions.

The velocity of the incoming air may be accurately measured by means of an anemometer, an instrument with sails which revolve by the wind, and the number of cubic feet of air which passes in a given time being recorded on a dial. In default of this instrument the Beaufort scale of wind given on p. 99 should be used.

The examination of the air of the stable by the senses should not be omitted. We have previously drawn attention to this; it furnishes us, up to a certain point, with the amount of CO_2 which is present in the air, the CO_2, as before explained, being the index of the organic purity of the atmosphere.

It is absolutely necessary that in applying this test the observer should enter the place after he has been some little time in the open air, and he should record at once the sensation conveyed on entering the stable, as the senses become rapidly blunted.

	The amount of CO_2 per 1,000 vols. of air due to respiratory impurity is
When the air smells fresh, or not differing sensibly from the outside air	= ·2000
When the air smells rather close	= ·4132
When close	= ·6708
When very close	= ·9054

We can thus in a rough way judge of the purity of the atmosphere; we could by chemical means obtain exactly the amount of CO_2 which exists.* If we have clearly and satisfactorily determined the purity or otherwise of the air to the senses, we may by means of a formula (Dr. de Chaumont's) judge of the amount of air with which each horse has been supplied.

To find from the condition of the air of the stable the average amount of fresh air which has been supplied to each horse:

$\frac{e}{p_1} = d$, where $e =$ the amount of CO_2 exhaled per hour, viz., 3 cubic feet.

$p_1 =$ the observed ratio of vitiation per 1,000 volumes.

* By observing the difference between the outside air and that of the stable, a fair estimate may be formed of the purity of the atmosphere, (that is, assuming the stable is not being heated artificially). I have observed in the middle of winter a difference of 5° Fahr. to be associated with considerable impurity, and a difference of 1° Fahr. with great purity of atmosphere. The reason is obvious, the heating of the stable air arises from the hot expired air from the lungs.

Let us suppose on entering the stable the air smells close; from the table we know that the amount of organic CO_2 present is about ·6708 per 1,000 volumes. Therefore:

$$\frac{3}{\cdot6708} = 4\cdot46.$$

As the observed ratio is expressed per 1,000 volumes, our answer must represent *the number of thousands* of volumes, or, in the example given above, each horse was supplied with 4,460 cubic feet of air per hour instead of 15,000 cubic feet.

My analyses of stable air show how rapidly by free perflation organic impurities may be removed. In half an hour the CO_2 of respiration may be reduced from ·6 to ·1 per 1,000.

The following table gives the result of a large number of experiments. The air was collected for examination 6 feet above the ground, and was taken in three different parts of the same stable:

		Bottom End.	Middle.	Top End.	
Experiment I.	*a*	·9064 ...	·8463 ...	1·2712 ...	Co_2 per 1,000 vols.
	b	·6322 ...	·4252 ...	·4862 ...	"
Experiment II.	*a*	·8771 ...	·9793 ...	1·0197 ...	"
	b	·5069 ...	·5898 ...	·5691 ...	"
Experiment III.	*a*	·8706 ...	·6603 ...	·9558 ...	"
	b	·6707 ...	·6012 ...	·7827 ...	"

Opposite to the letter *a* are the amounts found before ventilation, and opposite *b* the amount after all windows and doors were opened.

Opposite the letter *b*, it will be observed that sometimes one-half, sometimes two-thirds, of the carbonic acid had been removed by half an hour's free ventilation. Moreover, the amounts found correspond very closely with those laid down as being the admissible limit of total CO_2 in pure stable air, viz., ·6 per 1,000.

The carbonic acid in the air is ascertained by Pettenkofer's process of pumping air into a large glass bottle, introducing a known quantity of lime or baryta water, which possesses the power of absorbing CO_2, and then finding out from the lime or baryta how much carbonic acid it has absorbed. If the capacity of the bottle is known, it is a simple matter to calculate the amount in 1,000 cubic feet of air.

In my examination of stable air, I found that the ammonia present (the result of the decomposition of urea) interfered considerably with the accuracy of the results, owing to its action on the lime or baryta water. To avoid the fallacy arising from this, the air must be collected for analysis 6 feet from the stable floor, and at least three samples from the same stable should be taken.

The further chemical tests to which stable air may be subjected are susceptible of extreme accuracy, but entail the use of special apparatus and reagents, and are thus placed beyond the use of the ordinary hygienist. By these methods of investigation the amount of ammonia, either in the form of free ammonia derived from the decomposition of urea, or as ammonia (albuminoid) derived from the decomposition of organic matter, may be readily estimated.

The amount of oxidizable organic matter in the air can also be ascertained by means of a standard solution of permanganate of potassium.

The same test may be roughly applied by exposing a very weak solution of the permanganate in a saucer or shallow vessel to the stable air, and observing how long it will be before it changes colour. A similar vessel containing permanganate of the same strength and quantity should be exposed to the outside air as a means of comparison. The length of time it will take before the permanganate solution changes colour must entirely depend upon the state of the air. The test as described is a very imperfect one.

The method by which air is collected for the ammonia and oxygen analysis, is by drawing it, by means of an aspirator, through a series of bottles containing distilled water.

The presence of ammonia and sulphuretted hydrogen in the air may be determined by means of test papers. Ordinary blotting-paper soaked in a solution of logwood turns purple in the presence of ammonia, and H_2S will turn paper soaked in a solution of lead acetate of a brown or dark colour.

The amount of watery vapour present in the air is ascertained by means of the wet and dry bulb thermometers, or by the hygrometer. The temperature outside and inside the stable should be recorded, not only as a means of knowing the difference between the two temperatures, but also with the view of judging whether the ventilation is assisted by it or not.

The microscopical examination of the air is more easily accomplished than the chemical. A simple method is to expose for some hours in the stable a slide moistened with glycerine, to which the floating particles in the air adhere. There are other more elaborate methods, such as drawing by means of an aspirator a known quantity of air through a tube terminating in a drop or two of glycerine; or drawing a known quantity of air into a glass tube containing nutrient gelatine; the solid particles adhere, the colonies grow and may readily be counted, and thus the number of living organisms in a known bulk of air can be estimated. A simple plan, to obtain in the form of water the invisible vapour of the atmosphere, and with it the solid particles, is to place some ice in a vessel; the moisture condenses on its surface and runs down, and may so be collected and examined.

Ship Ventilation.

The necessity of ventilating ships for animals is now fully appreciated; but, owing to the style of ship-architecture, it is often an exceedingly difficult matter to arrange any method. It is evident that a ship which is lofty between decks is best suited to the requirements of animal transport. All the decks of a ship are not equally foul, or difficult to ventilate. Experience shows that the main deck is the one in which the most sickness occurs, and which, from its close proximity to the water-line, is difficult to arrange for drainage.

The introduction of fresh air to the lower decks is usually accomplished by means of windsails. The method is a rough and ready one, but not without its objections. To be efficient the windsails must be kept constantly trimmed to the wind, or their action is considerably impaired; the body of air introduced is large, and subjects those animals standing close to it to a continual draught, whilst the distribution is so bad that only those near it receive the fresh air. The outlets consist of tubes terminating in a trumpet-mouthed shaft on the deck, kept turned from the wind. Arrangements are made by which these can be cleaned out and the foul air extracted by means of a steam jet. Some of the inlets are also of this nature, the trumpet-mouth being turned to the wind. The ventilation of the ship rests entirely with those persons detailed for the purpose of keeping the outlets and inlets properly trimmed.

There is no longer any necessity for trusting to these very uncertain and unsatisfactory methods of ship-ventilation. Automatic ventilators are now to be had by which both an inlet and outlet current can be readily obtained. The action of these ventilators lies in the head, the principle of which has been before explained. Figs. 23, 24 show Mr. Boyle's inlet and outlet shafts for ships. The advantages claimed for these tubes are that they act continuously; the wind blowing over the outlet causes a draught up the tube, and extracts the air from below, its place being taken by fresh air introduced by the inlet. These tubes act whether

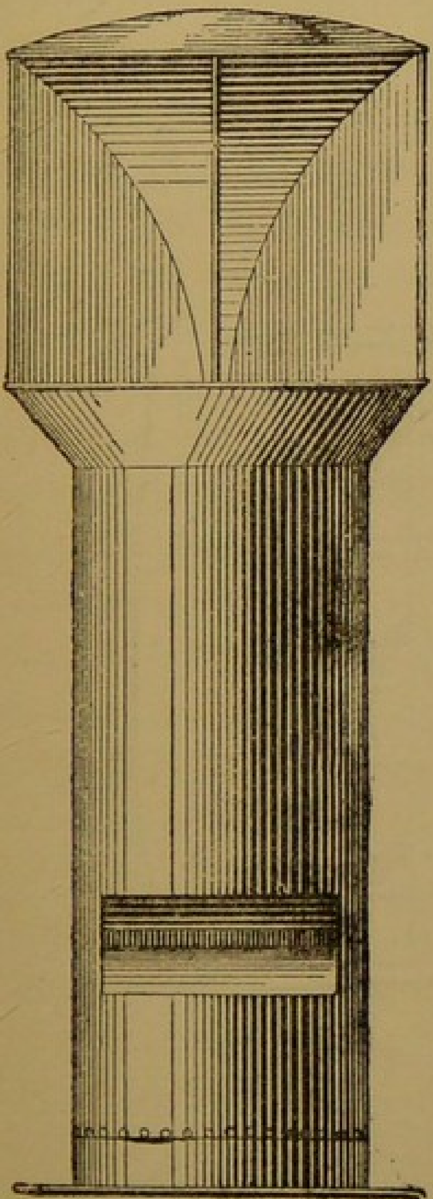


Fig. 23.—Inlet Ship Ventilator (Boyle).

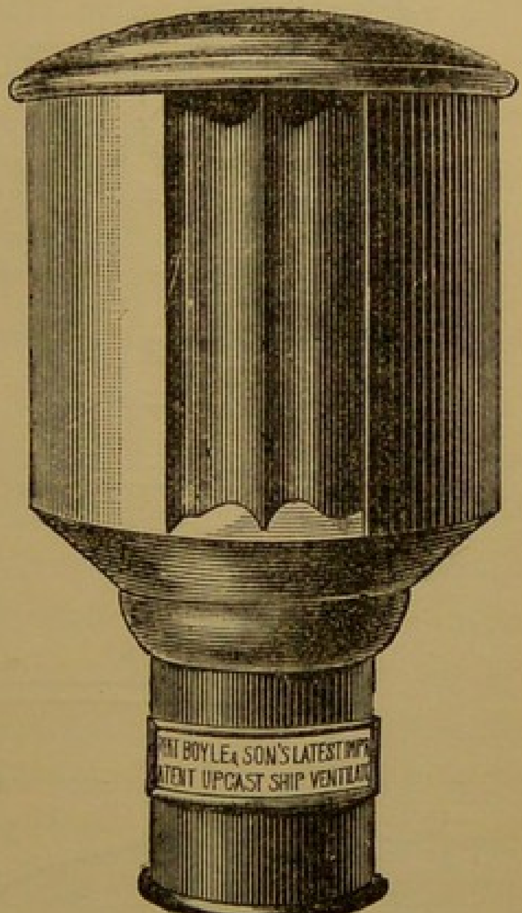


Fig. 24.—Outlet Ship Ventilator (Boyle).

the ship is at sea or lying in harbour; the outlet is quite free from down-draught. They are water-tight, can act during bad weather with seas washing over them; and are so arranged that water cannot get down them; moreover, they never require trimming.

I propose to introduce Mr. Boyle's system into the ventilation of ships for animal transport. Fig. 25 shows my idea of how these tubes should be arranged. There must be distinct inlet tubes for each deck, introduced near the

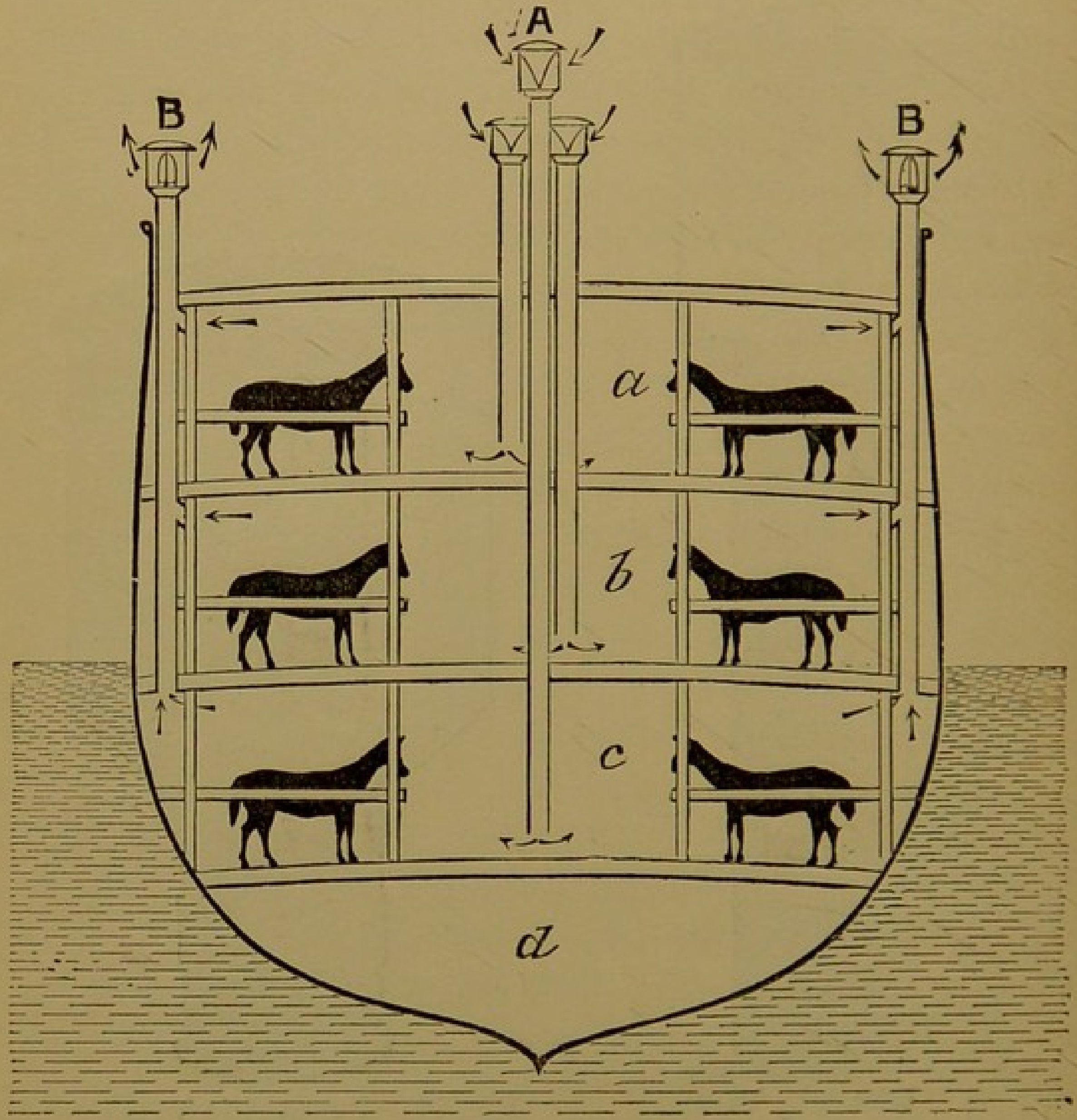


Fig. 25.—Section of Ship for Animal Transport. A, Inlet Ventilators to each Deck. B, Outlet Ventilators from each Deck. *a*, Upper Deck; *b*, Main Deck; *c*, Lower Deck; *d*, Bilge (Boyle).

middle of the vessel, which should terminate about a foot from the deck, so that the current is broken and distributed on either side; the outlets are on the opposite side of the stalls and above; they are worked by the automatic extraction head, and so arranged that a current of air is drawn through the stalls continuously from the inlet. The outlet tube passes through the decks above, and acts as outlet for these also. I think the outlet tubes for each deck should be separate; but the inventors say that the one outlet will extract from all decks.

As to the number of tubes, inlet and outlet, which should be introduced for every 100 animals, my opinion is *to have as many as the architect will grant;* we cannot keep the decks below too pure, or too cool, and will never reduce the temperature to a hurtful degree. The fact is that invariably the error is made on the wrong side; the objection against a number of tubes not only being that connected with the numerous holes which these represent in the decks, but also the number of tubes on deck which may interfere with the working of the ship. I calculate that the least ventilating inlet or outlet area which we should allow per head is 14·4 square inches, or 1 square foot to every ten horses.

The velocity with which the wind blows must influence the rate of extraction; the greater the velocity, the greater the extraction. The above calculation is based on the supposition that the mean velocity of the wind at sea is twenty-five miles per hour; the amount of air which will be extracted per head is 13,200 cubic feet, an amount much less than the requirements, but probably the largest quantity that can be afforded on board ship. It is evident that there are occasions when the velocity of the wind at sea will fall much below that stated; inlets of 14·4 square inches per head would then fail to keep the atmosphere even tolerably pure, though it would prevent the animals below from being suffocated. The inlets need not be so numerous as the outlets, for the reason that there are other sources of inlet than tubes, such as hatchways, scuttles, etc. For the lower deck distinct and ample inlets are imperative.

CHAPTER IV.

FOOD.

THE food and feeding of animals is a subject of social economy, and one of the most important with which in relation to animals it has to deal. Feeding, in relation to agriculture, is a subject of paramount importance to the owner and rearer of stock; to have the best results at the lowest possible cost, the feeding of animals must be based on a scientific foundation. The results of practical experience have taught the British farmer and grazier facts connected with feeding, the why and wherefore of which he seldom understands, but which science has no difficulty in explaining; and there can be no doubt that if to all interested in the feeding of animals a little scientific instruction on this most important subject were given, much disease and a large annual loss would be saved. It has been repeatedly pointed out that the problem of stock-management resolves itself into the question of 'how to feed.' It is not sufficient to know that certain substances possess great nutriment, and that others are practically useless, but it must be known what foods are most suited to the varying conditions of the organism, in what form these should be administered, and to ascertain how the best feeding can be obtained in the most economical manner.

In considering the feeding of horses used both in the military and civil world, the object aimed at is to obtain the maximum amount of energy at a low cost. With cattle the question is not one of the production of energy, but the accumulation of flesh and the production of milk for the purposes of human food.

Dieting as dealt with by the human hygienist, is much simplified by the fact that he has only one system of digestive organs to deal with; but with the veterinary hygienist the matter is different, for he has at least two, and if we consider the feeding of swine, three totally different arrangements of digestive canal to legislate for. What is right and proper for one is totally unsuited for the other; the feeding of cattle differs much from the feeding of horses, and the feeding of swine is different from either.

The arrangement of the digestive apparatus of animals has an important bearing on their system of feeding. The small and single stomach of the horse, his capacious bowels, and the absence of a gall bladder, are in marked distinction to the enormous stomachs of the ox, his small intestines, and the presence of a gall bladder. Such anatomical differences in animals both belonging to the class of herbivora, point to some vast difference in their process of alimentation.

The following table, compiled from Colin,* will show how different are the proportions in every 100 parts of the gastro-intestinal organs of various domesticated animals:

	Stomach.	Small Intestines.	Cæcum.	Colon and Rectum.
Horse ...	8·5	30·2	15·9	45·4
Ox ...	70·8	18·5	2·8	7·9
Sheep ...	66·9	20·4	2·3	10·4
Pig ...	29·2	33·5	5·6	31·7

The ratio between the length of the body and that of the intestines is as follows: Horse, 1 : 12; ox, 1 : 20; sheep,

* 'Physiologie Comparée des Animaux.'

1 : 27; pig, 1 : 14. Putting aside the differences in the horse and ox in the arrangement of the teeth, salivary and biliary secretion, rumination, etc., we have sufficient data in the above to show how entirely opposite the digestive arrangement is in the two animals, and it gives us some insight into the process of their nutrition.

All substances taken in by the digestive tract, destined for the purpose of nutrition of the fluids and organs of the body, and the production of animal heat, are called foods. A food must consist of organic and inorganic principles, and these may be derived in part or whole from the animal or vegetable kingdom; in veterinary hygiene it is the vegetable with which we have to deal. The plant is the organism which converts carbonic acid, water and ammonia, into flesh and heat-forming material; the animal system is the medium by which these structures are converted into higher tissues, heat and energy. All substances used as food can be traced back directly or indirectly to the vegetable kingdom.

The animal body is composed of certain elements, compounds of these elements, acids, salts, alcohols, ethers, anhydrides, ammonias and their derivatives, and colouring matters. The elements, only a few of which exist in a free state, are oxygen, hydrogen, carbon, nitrogen, sulphur, phosphorus, chlorine, fluorine, silicon, potassium, sodium, calcium, magnesium, iron, and manganese. Oxygen exists in the body in a free state, and serves the purpose of burning up other bodies, and so breaks up into simple products complicated compounds; it is also found in the body-fluids either in solution or combination. Nitrogen is absorbed in a free state, and is excreted either in a free condition or associated with compounds of ammonia.

The chemical constituents of the body may be thus classified:

1. Albuminous substances, characterized by the presence of carbon, hydrogen, oxygen, and nitrogen.

2. Carbo-hydrates and hydro-carbons, characterized by the absence of nitrogen and the presence of carbon, hydrogen and oxygen.

3. Saline matters and water

Chemistry and Classification of Foods.

A food consists of a nitrogenous portion (likewise termed albuminate, proteid, or flesh-former); a hydro-carbonaceous portion (fat and heat formers); and a carbo-hydrate portion (starch and sugar bodies). The hydro-carbons and carbo-hydrates are also called non-nitrogenous bodies. In addition to these, we have acids and salts entering into the formation of a food. These are the so-called immediate or proximate principles.

The following exhibits a tabular classification of foods:

Organic	Nitrogenous.	
	Non-nitrogenous.	Hydro-carbons.
		Carbo-hydrates.
Inorganic	Salts.	

Nitrogenous Bodies.—These principles are represented by albumen, fibrin, gluten, casein, legumen; generically they may be spoken of as proteids or albuminoids, and their characteristic chemical feature, in spite of the fact that some belong to the animal and others to the vegetable kingdom, is the unity of their composition. Thus, they all contain carbon, hydrogen, oxygen, nitrogen, and the proportions in which these exist may be judged from the analysis of the so-called protein. This contains carbon, 55·160; hydrogen, 7·055; nitrogen, 15·966; and oxygen, 21·819. The nitrogenous bodies belonging to the animal kingdom are albumen, fibrin, gelatine, and casein; they are found in the blood, flesh, tissue, etc. Those of the vegetable kingdom are gluten and legumen; these substances are also called vegetable albumen, fibrin, and casein. The following analysis by Dumas will show how closely the nitrogenous principles of plants are allied to those of animals:

	Fibrin.		Albumen.		Casein.	
	Animal.	Vegetable	Animal.	Vegetable.	Animal.	Vegetable
Carbon ..	52·8	53·2	53·5	53·7	53·5	53·5
Hydrogen ..	7·0	7·0	7·1	7·1	7·0	7·1
Oxygen ...	23·7	23·3	23·6	23·5	23·7	23·4
Nitrogen ...	16·5	16·5	15·8	15·7	15·8	16·0
	100·0	100·0	100·0	100·0	100·0	100·0

Albumen in its vegetable condition may readily be obtained by washing flour in a cloth. The clear fluid which runs through contains much of the albumen; the sticky mass which remains behind is the vegetable fibrin or gluten; it is a mixture of vegetable fibrin, casein, and albumen. Animal fibrin is found in the blood, muscles, chyle, and lymph; it is readily digested, and thus forms a contrast to its vegetable counterpart. Casein is found in milk and butter; in the vegetable form it exists largely in beans and peas under the name of legumen, in oats as avenin, and in wheat as gliadin and mucidin.

This nitrogenous, albuminous, or plastic group, forms one of the most important in connection with food; according to Liebig's theory their sole function was the construction and repair of the muscular tissue, and their destruction in this tissue by oxidation led to the development of heat and force. From numerous experiments which have been made, this theory has proved to be incorrect; that the nitrogenous substances do repair the waste there is no doubt, but that they only act as excitors of force is now known to be wrong. An animal cannot live on a purely nitrogenous diet,* and it would appear that though the nitrogenous substances give rise to but little energy themselves, yet they determine the absorption of oxygen, and without the presence of oxygen no energy could be manifest. This appears to be the explanation why nitrogenous substances are so instinctively sought after as food. We have another point in connection with this important group; experiment has proved that the nitrogenous bodies can become converted into non-nitrogenous (fats, and possibly glucose, or a substance allied to this); in the fattening of animals all the fat in the body could not have been derived from the fatty matters which entered it, and it is the albumen which has contributed to its formation. A nitrogenous food breaks up in the system into two parts—a nitrogenous and a non-nitrogenous portion; 33 per cent. of the food is convertible into albuminoids, and 64·8 per cent. into carbo-hydrates.

The whole of the nitrogen taken into the system is not used up, some portion of it is stored in the tissue; this is the explanation why animals can subsist for some little time on a diet containing no nitrogen; but after a while, when this store is expended, exhaustion supervenes, for the reason that repair is not taking place. When nitrogenous matters are undergoing oxidation their full amount of energy is not obtained, for a portion leaves the system as urea; one-seventh of the potential energy of albuminous food is thus lost to the body.

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* Dogs and rats have, however, been kept in health on an entirely nitrogenous diet.

The functions of the nitrogenous principles may thus be summarized :

1. They repair the tissues.
2. They determine energy by the absorption of oxygen.
3. They contribute to the formation of fat.

The nitrogenous substances have very different powers of nutrition; gelatine, for instance, is only one quarter as nutritive as albumen; the gluten of barley and wheat differ considerably in their nutritive functions, and the valuable stimulating properties of the avenin of oats is not equalled by any other food. The digestion of albuminoids is first obtained by their transformation into peptones; as albuminoids they cannot diffuse; in the form of peptones they diffuse readily, and digestion is rapid. The effete nitrogenous matter is excreted from the system in the form of urea, hippuric acid, creatine, etc.

Those compounds of nitrogen existing in plants, termed amides, do not contribute to flesh-formation; they are excreted as urea, and by combustion assist in heat and force production. Amides are peculiar bodies known as asparagine, glutamine, etc.; they are derived from ammonium-salts, and exist in different proportions in various food material; in hay about 20 per cent. of the nitrogen exists as amides, whilst in mangels 75 per cent. of the nitrogen is in this form. Very little is known at present about these bodies; we know, however, that they do not possess the value of albumen, and, moreover, that as the growing plant increases in maturity a portion of the amides becomes converted into albuminoids.

The **Hydro-carbonaceous** group is represented by the fats; they are composed of carbon, hydrogen, and oxygen, the latter being less than sufficient to convert all the hydrogen into water. The substances contained under this head are the various animal and vegetable fats, olein, stearin, and palmatine, the latter being the chief component of vegetable fats. Fats are insoluble in water, converted into an emulsion by albumen, bile, or pancreatic juice, and so rendered capable of absorption. Fats only exist in a small proportion in the food of herbivora. Oats and maize contain more fat than the other cereal grains. The fat in hay and straw is more of the nature of wax, and cannot have the same value as true fat.

The function of the hydro-carbons is a respiratory or heat-producing agent (hence the fats are often called respiratory food); this they are enabled to perform owing to the arrangement of the oxygen with the hydrogen in their composition. Owing to the oxidation of fat, energy and animal heat are produced; the fats also assist in the digestion of albuminous substances, and the conversion of these into tissue structure; they assist in the formation of bile, and the action of the pancreatic fluid is in a measure due to their presence; fat is a direct nutrient to the nervous system, and assists in the removal of worn-out substances from the body. Taken in excess it is deposited in the tissues, sometimes in large amounts, and in these places performs a physical office in maintaining the form, diminishing friction, and, being a bad conductor of heat, maintains the animal temperature.

There is much doubt as to whether the fats and the carbo-hydrates are interchangeable; bees fed on sugar alone will form wax, but this is probably derived from the stored-up albumen; the question is still a very doubtful one. The fat in the body is derived from the fat which enters it, but principally from the albuminous portions of food. The calorific and motive powers of fat are very great, being two and a half times larger than that developed bv an equal amount of sugar and starch.

The **Carbo-hydrate** or starchy group is made up of carbon, hydrogen, and oxygen, the latter being in the exact proportion to form water with the hydrogen. This class contains a large number of substances such as starch, dextrin, cellulose, glucose, and sugar; they may be viewed as formed of carbon plus water. and for this reason they are called hydrates of carbon.

Cellulose.—All plants contain cellulose, it being the basis of their structure. In stems and leaves it is found in great abundance, and it forms a large proportion of the husk of seed. In some forms of cellulose the substance is impregnated with a tough material, lignin. The cellulose found in young and succulent plants is readily digested by the herbivora; in tough substances, as stems, it appears to be digested with difficulty. Cellulose forms an important part of the diet of herbivora, and is very nutritious; lignin, on the other hand, is not digested by them.

Starch, in its many forms, exists in the cells of plants; it is found in small grains, which are microscopically different in each group of plants. Muta arranges five classes of starch. The potato group, oval or ovate cells, with hilum and concentric rings well marked. The leguminous group, consisting of round or oval cells, concentric rings all but invisible, with a well-marked cracked or stellate shaped hilum. The wheat group consists of round or oval cells, the hilum and concentric rings being invisible. The sago group have their granules truncated at one end. The rice group have polygonal-shaped granules. The starch of oats belongs to this class; it consists of masses of polygonal-shaped cells. Starch is insoluble in cold water, is coloured blue by iodine; and by the action of hot water, heat, acids, or alkalies, is converted first into dextrin, and then into glucose. Inuline is a body which closely resembles starch; it is found in the artichoke, chicory, and other Compositæ.

Dextrin is considered to be found in small quantities in the sap of all plants; acids and ferments produce it from starch and cellulose. Limpricht obtained nearly a pound of dextrin from 200 lb. of the flesh of a young horse.*

Lignin is the tough substance which impregnates and incrusts the cell-wall (Schulze) of vegetable tissues, and cellulose containing it is, in the herbivora, very difficult of digestion; the substance itself is indigestible, and its function in food is to give the necessary bulk to the digestive organs, and by its toughness induce mastication, a process so necessary for the proper solution of the various principles of food.

Sugars are of several kinds: there is saccharose or cane-sugar, which is also found in the stems and roots of grasses, unripe maize, parsnips, turnips, carrots, and in numerous fruits; levulose, or fruit-sugar; glucose, or grape-sugar, which can also be obtained from starch, and cellulose. Glucosides are substances of a bitter taste, but containing glucose; such are tannin, salicin, and substances from the apple-tree, horse-chestnut, etc. Other sugars are lactose, from milk; mannite, from the bark of the ash; quercite, from the acorn; mycose, from ergot of rye. The most important point to observe in relation to the sugars is their mutability; they all have the power of becoming converted into each other. The plant can convert starch into dextrin, glucose, and cellulose; the animal can convert cellulose, starch, and dextrin into glucose. All these sugars are very soluble in the digestive juices, and are readily absorbed. The function in the system of this large group of bodies, starch, cellulose, and saccharine matters (after they become converted into glucose by the action of the saliva, pancreatic, and intestinal juices), is the produc-

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* 'Ann. Ch. Ph.'

tion of energy and animal heat by oxidation; their energy is not so great as fats, being in fact two and a half times less. They give rise to the formation of lactic, butyric, formic, and acetic acids, found in the body fluids and tissues; they contribute largely to the formation of fat in the system, and are excreted in the form of carbonic acid and water.

Other bodies entering into the formation of plants require some notice, such as the gums, the vegetable acids, essential oils, resins, etc.

Gums are found in a large number of bodies in the vegetable kingdom; in the form of mucilage it is met with in the seeds of wheat, rye, barley, oats, maize, and millet; gums are converted into sugar by boiling with acids. Grouven's experiments show that gum is digested by the herbivora, which is contrary to the recognised view. **Resins** and **Essential Oils** serve no purpose as food, but act as stimulants to some organs, and are excreted from the system by the skin, kidneys, or bowels. The **Vegetable Acids** are a numerous group; they are oxalic, tartaric, malic, and citric, and occur in combination with salts of lime, potash, and soda; these acids excite the appetite, and are eliminated from the system principally by the urinary organs.

The **Saline Matters** of food are concerned in the process of digestion, absorption, secretion, assimilation, and disintegration. They convey the nutriment into the system, and carry the disintegrated matter out of it. Phosphates are found in cerebral, muscular, and bony structure, and in many of the body fluids. The foods richest in phosphoric acid are oil-cake and bran; hay and straw are poorest in this constituent. Lime is necessary for the bony framework, a deprivation of it producing disease of this structure. Lime is found largely in clover, hay, bean-straw, and turnips, and in small quantities in the cereal grains and potatoes. Maize is very poor in lime, and would be an unfit food for growing animals, unless supplemented by lime in a soluble form. Potash and soda are found in nearly all plants in the form of carbonate. The potash salts would appear to be particularly required by the muscles, the soda by the blood. Potash exists largely in roots, hay, bean-straw, bran, and oil-cake; but in the cereals it is found only in small quantities. Iron is required by the blood and muscular structure; chlorine is required for the gastric juice. Other substances, such as lactates, citrates, acetates, and tartrates, seem specially to be required to preserve the normal character of the fluids of the body. One of the most important and the largest distributed salt of the body is chloride of sodium; it enters into the composition of all the body fluids, and a horse of ordinary weight is calculated to contain in his system no less than about 8½ lb. of this substance.

Water is required for the various body fluids and secretions; it is removed from the system by the skin, kidneys, and air-passages. The water contained in food serves its purpose in nutrition; some foods contain more of it than others—thus we find that the greater the amount of water, the less the nutritive value in a given weight. Food containing much water is consequently unsuited for animals doing fast work; but this objection cannot exist in the case of cattle, where in fact the presence of water in the food is of much use: for instance, milch cows give a large amount of milk, and animals fattening make flesh rapidly when receiving food, such as roots, containing much water. There is a limit, however, to the advantageous point of water in the food. Warrington has pointed out that the nutritive value of roots, or other food rich in water, is diminished by the fact that part of the heat they produce in the system, is occupied in raising the water they supply to the temperature of the animal's body. Roots, or green fodder, should not form a sole diet, but should be mixed with dry material in order to reduce the quantity of water consumed.

Nutritive Relation and Digestibility.*

We have shown that a food to be complete must contain albuminoid, fatty, carbo-hydrate matters, and salts. In addition to the functions which these principles perform in the nutrition of the system, they mutually assist each other in the process of digestion; thus the fats favour the absorption of the albuminoids, the carbo-hydrates, and the cellulose; the starch aids the absorption of the fats and sugars. We find consequently that foods which contain these substances in such proportions as to render digestion easy, are of great nutritive value.

It is evident that all foods are not equally well balanced in their proximate principles; and as the subject is an important one to know, we have a method of obtaining this knowledge for each food by ascertaining its nutritive relation.

Nutritive Relation is the proportion in which the proximate principles of food are arranged towards each other. Nutritive relation is of three kinds, that which shows the proportion in which the nitrogenous elements exist in relation to the fats and carbo-hydrates, minus the cellulose; that which shows the proportion of the fats to the nitrogenous principles; and lastly, the proportion of the nitro-

* The subject of this section has principally been worked out in France and Germany, and it is chiefly to these countries that we are indebted for our knowledge of these important facts.

genous to the whole of the non-nitrogenous elements. The first we call the nitrogenous ratio, the second the fatty ratio, and the third the complete nutritive ratio.

To obtain the nutritive relation of any food it is necessary to know its chemical composition ; but as this varies within certain limits, depending upon the growth of the food and its cultivation, etc., it is best, where possible, to take the mean of several analyses in order to obtain approximately correct results.

The **Nitrogenous Ratio** of a food is obtained by selecting the nitrogenous quantity which chemical examination shows to exist in it, and using this number as the numerator of a fraction the denominator of which is to be formed by the quantities which represent the fats and sugars, *less the cellulose and mineral matter.* For example, required the nitrogenous ratio of oats presenting the following composition :

Water	13·7
Nitrogenous matter	12·0
Fatty matter	6·0
Sugars	56·6
Cellulose	9·0
Salts	2·7
	100·0

The formula will stand thus :

$\frac{\text{Nitrogenous matter}}{\text{Fatty matter}+\text{Sugars}}$. The answer is obtained by dividing the nitrogenous quantity on the upper line of the formula, into the non-nitrogenous quantity below it—thus :

$\frac{12{\cdot}0}{6{\cdot}0+56{\cdot}6}=\frac{12{\cdot}0}{62{\cdot}6}=\frac{1}{5{\cdot}2}$. The number $\frac{1}{5{\cdot}2}$ represents that for every one part of nitrogenous matter, there are 5·2 parts of non-nitrogenous. The nitrogenous relation of oats is consequently 1 : 5·2.

The nitrogenous ratio which a food should be, varies with the age and class of animal. In young animals it should be higher than for adults. Experiment has proved that the best nitrogenous ratio for the young animal is 1 : 2; at middle age it should be 1 : 3; and for the adult 1 : 5. Speaking of the horse, we say that the ratio for early life corresponds to that found in mare's milk, and at adult age the number closely corresponds to that found in good hay.

To obtain the **Fatty Ratio** of a substance or food, we select the quantity representing the fats, and use it as the numerator of a fraction the denominator of which is the nitrogenous portion. For example, required the fatty ratio of oats presenting the composition given above: $\frac{6{\cdot}0}{12{\cdot}0} = \frac{1}{2}$. Therefore, for every two parts nitrogenous we have one part fatty matter, which we express as 1 : 2. The most favourable fatty ratio in food should not be greater than 1 : 2·2 or less than 1 : 3.

To obtain the **Complete Nutritive Ratio** of a food, the nitrogenous substances are used as a numerator, and the *whole of the non-nitrogenous* as the denominator of a fraction; as it is evident that the object of this relation, amongst other things, is to ascertain the proportion of indigestible matter to the nitrogenous in a food, we will take as our example a complete diet containing nitrogenous matter, 1,377 parts; fatty matter, 429; starch and sugars, 6,268; cellulose, 5,289. Therefore $\frac{1377}{429 + 6268 + 5289} = \frac{1377}{11986} = \frac{1}{8{\cdot}7}$. The complete nutritive ratio of this food is therefore 1 : 8·7. When the cellulose is in excess in a diet the complete nutritive ratio falls to 1 : 10, 1 : 12, or 1 : 15; such a diet would not matter much for the ox, whose power of digesting cellulose is great, and whose digestive organs are very capacious; but for fast-working horses the relation of 1 : 10 or 1 : 12 would indicate that too large a proportion of indigestible matter exists in the diet for the animal to obtain from it the nutriment it requires. Experience shows that for hard-worked horses the complete nutritive relation should be about 1 : 7 or 1 : 6; for horses doing ordinary work a relation of 1 : 8 or 1 : 8·5 is judicious. There should not be more than 32—34 parts of cellulose and lignin in every 100 of water-free matter.

The composition of a food which will present a favourable nutritive relation would be as follows in every 100 parts of water-free substance.

Nitrogenous matters	10·6	The Nitrogenous Ratio is ...	1 : 5·2
Fatty matters ...	3·7	„ Fatty Ratio	1 : 2·5
Starch, Sugar, etc.	51·8	„ Complete Nutr. Ratio	1 : 8·4
Cellulose and Lignin	33·9	Amount of Cellulose and Lignin under	34%
	100·0		

This may be accepted as a typical food for an adult horse in ordinary work; the typical food for the young is usually regarded as the composition of the mother's milk.

A knowledge of the nutritive value of foods is important if we are to feed well and economically. Every substance used as food must contain the proximate elements; if these are large and properly balanced, the food is said to be of a high nutritive value; but if the proximate principles are small, and not arranged in the proportion in which science and experience dictate they should exist, then the food is one of low nutritive value. An aliment may be rich in nitrogen, and yet its component parts so improperly balanced that it cannot singly be used for feeding purposes; it must therefore be mixed with another food which supplies the deficiency, and so become converted into a ration of favourable nutritive relation. Thus peas and beans, highly nitrogenous, are unsuited for feeding purposes used alone, for the reason that they are deficient in carbonaceous material; to supply the necessary carbon a very large amount of them would have to be given, which would increase the nitrogen to an extent which could not possibly be utilized. The deficiency of carbon must here be met by a food which will contain it in sufficient quantity to render the aliment of a useful nutritive value. Two foods may contain exactly the same amount of elements, and so theoretically be of the same value, but the difference in their digestibility may be such as to render one doubly as nutritious as the other.

This is an important point we have to bear in mind in calculating the nutritive ratios of food.

Digestibility.—The knowledge of the nutritive value of a food, as just dealt with, is not complete without knowing its digestibility.

Digestibility of a food is its power of undergoing absorption into the system for the purposes of nutrition. The conditions on which digestion depends are principally the nutritive ratios existing in the food, and the age and health of the animal. It is evident that the nature of the food must also exercise a considerable influence; for example, food containing much lignin would be very indigestible, whereas that containing much water of vegetation and young cells would be readily absorbed. The digestibility of a food applies to each of its proximate principles; there is a distinct digestion of nitrogenous, fatty, and carbo-hydrate matters in each food presented to an animal. It is without the province of hygiene to deal with the subject of digestion, but we may here note that in the horse the principal digestion occurs in the large intestines; it is here that he, in company with other herbivora, has the power of assimilating cellulose, a substance which carnivora and omnivora excrete unacted upon, and it is in these intestines that the ingesta may be divided into two parts: first that capable of absorption, and second that which will remain unacted upon and must be excreted; the first is digestible, the second indigestible matter. It is evident that every food contains a certain proportion of substances which are indigestible; but more than this, *every food given to animals has a portion of its digestible matter unacted upon, and which is excreted from the system without undergoing absorption.* It would appear that they only have the power to extract a certain amount of each principle from their food, and this amount differs for each proximate principle, for each food, and for each class of animal. This subject, which is of paramount importance, has occupied the attention of German agriculturists and chemists, and they have determined for each food the amount of its proximate principles which is capable of absorption, all other conditions being favourable.

If a food becomes completely absorbed, its digestibility would be considered as unity, and the number which expresses it would be called its co-efficient. As, however, in ordinary foods complete digestion cannot occur, the co-efficient of digestibility is expressed either as a fraction or a decimal.

When we say that the mean co-efficient of digestibility of nitrogenous matters in the horse is ·69, of fats ·59, and of carbo-hydrates ·68, we mean that out of every 100 parts of each of these substances presented to him, he can only digest and absorb $\frac{69}{100}$ of the first, $\frac{59}{100}$ of the second, $\frac{68}{100}$ of the third.

The following table, which is a German one, shows the mean co-efficients of digestibility of the proximate principles of food in various animals. It must be observed that these are only the means of a mixed diet. The actual amount of each food digested will be shown in another table:

TABLE SHOWING THE MEAN CO-EFFICIENT OF DIGESTIBILITY OF THE PROXIMATE PRINCIPLES IN EVERY 100 PARTS OF A MIXED DIET.

	Horse.	Ox.	Cow.	Sheep.
Albuminates...	69	65	57	57
Fatty matters	59	64	65	61
Carbo-hydrates	68	66	70	73
Cellulose and Fibre ...	33	60	61	58

Experiments have shown that the same amount of proximate principles is not digested by all classes of animals. A horse does not digest grass and hay so well as a sheep; of these foods he digests much less of the carbo-hydrates, fats, and cellulose, though his digestion of the albuminoids is equal to that of the sheep. It was also found that he digested about half the amount of straw-chaff that a sheep was capable of assimilating.

The following tables, showing the mean digestibility of foods in different animals, are taken from Dr. Wolff's works, presented to the English reader through Mr. Warrington's 'Chemistry of the Farm':

DIGESTIBILITY IN HORSES OF THE PROXIMATE PRINCIPLES OF FOOD.

Food.	Proportion Digested for 100 Supplied.				
	Total Organic Matter.	Albuminoids.	Fat.	Soluble Carbo-hydrates.	Cellulose.
Grass	62	69	13	66	57
Meadow Hay (very good) ...	52	64	23	57	42
Meadow Hay (ordinary) ...	46	58	19	52	37
Lucern Hay ...	58	74	3	70	39
Oats	72	87	78	76	25
Beans	87	86	8	93	69
Maize	91	77	63	94	100

DIGESTIBILITY IN CATTLE AND SHEEP.

Linseed Cake ...	80	84	90	78	?
Beans	90	88	93	93	?
Oats	71	79	84	76	24
Barley	81	77	100	87	?
Maize	88	79	85	91	—
Bran	67	75	50	70	37
Meadow Hay ...	59	56	47	62	57
Clover " ...	59	55	56	69	44
Lucern " ...	59	76	38	67	40
Oat Straw ...	51	38	30	43	61
Wheat " ...	46	20	36	39	56
Bean " ...	50	51	55	60	36

DIGESTIBILITY IN PIGS.

Food.	Proportion Digested for 100 Supplied.				
	Total Organic Matter.	Albuminoids.	Fat.	Soluble Carbo-hydrates.	Cellulose.
Sour Milk ...	97	96	95	99	—
Meat Flour ..	92	97	87	—	—
Pea Meal ...	91	88	58	97	—
Bean „ ...	84	79	71	91	—
Barley „ ...	84	79	70	90	—
Maize „ ...	91	84	76	94	—
Rye Bran ...	67	66	58	75	—
Potatoes	94	81	—	98	—

A comparison of these tables will show how different is the digestibility of the proximate principles of food in different animals.

The digestibility of a food depends upon its age, mode of growth, and preparation. The young plant is always more digestible than the mature one; the digestibility of hay appears to decrease by long keeping, and is also influenced by the care with which it is harvested. The digestibility of a food is not increased by any reduction or increase in the amount given, and labour does not influence the digestion one way or another. It is influenced, however, by a mixing of foods; the addition of one food will materially alter the proportions digested of another. Wolff states that the addition of starch or sugar to a diet of hay or straw, if it exceeds 10 per cent. of the dry fodder, decreases its digestibility, particularly of the albuminoids. The addition of small quantities of oil appears to slightly increase their digestibility; but the addition of a large amount decreases the appetite. Potatoes, from the amount of starch they contain, exercise a very depressing effect on the digestion of hay; roots, from their containing sugar, have a less depressing effect. We are thus shown the necessity for foods being properly balanced in their proximate principles, to prevent the depressing effect of a large amount of carbo-hydrates on the digestion of albuminoids.

In some experiments of my own, I found that the addition of 2 lb. of oats to 12 lb. of hay increased the amount of the latter digested by more than nine per cent. The addition of corn to a ration of hay is therefore economical, as the nutritive value of the hay is raised.

In calculating a diet to ascertain its suitability for an animal, we must first obtain from the tables given the proportion of principles digested, and then ascertain the nitrogenous, fatty, and complete nutritive ratios.

We will give an example of this method of calculation. A horse receives as a daily ration 12 lb. of hay of medium quality, and 10 lb. of oats; we require to know the ratios of this diet before and after digestion, and the proportion of proximate principles digested.

Hay: analysis per cent.		12 lb. hay contain.	Digestive co-efficient.	Amount digested.
		lb.		lb.
Water	14·3	1·70	—	—
Albuminoids ...	8·2	·98	58	·568
Fat	2·0	·24	19	·045
Carbo-hydrates ...	41·3	4·95	52	2·574
Cellulose ...	30·0	3·60	37	1·33
Nitrogenous Ratio,	1 : 5·3			Nitrogenous Ratio, 1 : 4·6
Fatty ,,	1 : 4·1			Fatty ,, 1 : 12
Complete ,,	1 : 9			Complete ,, 1 : 7

Oats: analysis per cent.		10 lb. oats contain.	Digestive co-efficient.	Amount digested.
		lb.		lb.
Water	14·7	1·47	—	—
Albuminoids ...	12·0	1·20	87	1·04
Fat	6·0	·60	78	·468
Carbo-hydrates...	56·6	5·66	76	4·30
Cellulose ...	9·0	·90	25	·22
Nitrogenous Ratio,	1 : 5·2			Nitrogenous Ratio, 1:4·5
Fatty ,,	1 : 2			Fatty ,, 1:2·2
Complete ,,	1 : 6			Complete ,, 1:4·7

This table shows us how badly the fat in hay is digested, the fatty ratio falling from 1 : 4·1 in the natural forage to 1 : 12 in the digested form. With the exception of the fat the nutritive value of the food is raised by the process of digestion, owing to the exclusion of the cellulose.

We are clearly shown the important fact that only a certain amount of the digestible matter is obtained from food:

	The total diet contained.		The horse only obtained from it.
Albuminoids ...	2·18 lb.	...	1·6 lb.
Fats	·84 ,,	...	·5 ,,
Carbo-hydrates	10·61 ,,	...	6·9 ,,
Cellulose ...	4·50 ,,	...	1·5 ,,
	18·13 lb.		10·5 lb.

A Nutritive Equivalent is a useful method of comparing the feeding values of food; it is established by selecting a typical food and comparing all others with it. Thus we call one typical food 100; every aliment which contains as much nitrogen as the typical food is equal to it, and called 100. But if a food contains twice the amount of nitrogen, then its nutritive equivalent would be 50, for half the amount would be equal to the typical food; but if it only contains half the amount of nitrogen as the standard of comparison, then its equivalent is 200, for it will take twice as much to equal that found in the typical food. By general consent hay has been adopted as the standard of comparison, and very elaborate tables have been drawn up by Boussingault of the nutritive equivalents of many foods compared with hay.

NUTRITIVE EQUIVALENTS OF VARIOUS FOODS COMPARED WITH 100 PARTS OF HAY.

Hay	100	Barley ...	48
Lucern Hay	90	Maize ...	45
Trefoil „ ...	95	Bran	60-150
Lucern Green	420	Linseed ...	30
Trefoil „ ...	420	Linseed Cake	25
Oat Straw ...	280	Peas	40
Barley Straw	350	Beans ...	40
Oats	60	Carrots ...	290
Wheat ...	45		

The reading of the table is simple; 280 parts of oat straw, or 45 parts of maize, or 25 parts of linseed cake, are equal, chemically, to 100 parts of hay. Useful as such a table is in arranging diets, yet it must be remembered that digestibility governs the whole question; so that, having ascertained our equivalent, we must then turn to the table on digestion, and see whether the per cent. digested is greater or less than hay: a food which may according to its equivalent be doubly as nutritious as another, may only be of half the value owing to its indigestibility.

Alternative or Substitutional Dieting is adopted where the best results are wanted at the very lowest cost, and also when from the nature of the work an animal may be performing, the original diet is unsuitable. By substitutionary dieting we understand the mixing, changing, or substitution of one food for another in a ration, by replacing it by an aliment of equal nutritive value but at a cheaper market-price; or else replacing a food which is badly balanced in its nutritive relation by one which contains the elements in the necessary proportion. (Consult Hunting; *vide* Preface.)

The **Heat and Work producing Power of Food** is a point we must now consider. The importance of a knowledge of this subject is great, as the theoretical heat-producing and mechanical value of food is in direct proportion to its feeding value. Indeed, it has been stated that the only means of comparing the nutritive value of foods is to compare their heat-producing powers.

The amount of heat which can be evolved by food undergoing oxidation was ascertained in a very ingenious manner by Frankland. The food to be examined was dried, then mixed with a powerful oxidizing substance, such as chlorate of potash, and the whole placed in a sort of oven, known as a calorimeter, which is surrounded by water. The substance was then burned, and the amount of heat developed raised the temperature of the surrounding water; 1 gramme (15·432 grains) of the water, raised 1° Centigrade (1·8° Fahr.), is called a *heat unit.* By this method of investigation it was found that

15·432 grains of Albumen	evolved,	when oxidized,	4,263	heat	units.
,, ,, ,, Fat	,,	,, ,,	9,069	,,	,,
,, ,, ,, Starch	,,	,, ,,	3,912	,,	,,
,, ,, ,, Grape sugar	,,	,, ,,	3,277	,,	,,

In plain language, 1 lb. of albumen oxidized will raise the temperature of 4,263 lb. of water 1·8° Fahr.; or 1 lb. fat will raise the temperature of 9,069 lb. (nearly four tons) of water 1·8° Fahr.

In the animal body the carbon of the albumen is never fully oxidized, as so much of it passes off in the urea as carbon monoxide. In the above table the deduction on this account has been made.

If we ascertain the amount of heat evolved, it is a very simple process to convert it into its equivalent of mechanical energy.

Joule, of Manchester, demonstrated that the heat required to raise the temperature of 1 lb. of water 1° Fahr. was equivalent to the power required to raise a weight of 1 lb. 772 feet high. The foot pound is, therefore, the unit of work, and 772 foot pounds is the mechanical equivalent of 1° Fahr.

We know the number of heat units each substance is capable of producing, and from this is calculated its potential energy or mechanical value.

1 oz.	Albumen	oxidized	in the	system	yields	173	ft. tons	potential energy.
,,	Fat	,,	,,	,,	,,	378	,,	,, ,,
,,	Starch	,,	,,	,,	,,	138	,,	,, ,,
,,	Grape-sugar	,,	,,	,,	,,	124	,,	,, ,,
,,	Carbon converted into CO_2				,,	310·625	,,	,, ,,

With the aid of these tables we can calculate the potential energy any food can develop; but as a rapid means of comparing the heat-forming powers of food we may adopt a simpler plan, and that is, to multiply the actual amount of food digested, by certain numbers which represent the comparative heat-forming value of fat, albumen, and starch; these co-efficients are: fat, 100; albumen, 47·4; starch, 43·1.

An example will explain the process. What is the comparative heat-forming value of the following foods?

1st Food.

		lb.		
Albuminoids	...	·568	× 47·4 =	27
Fats ...	...	·045	× 100 =	4·5
Carbo-hydrates	...	2·574	} × 43·1 =	168·2
Cellulose ...	...	1·330	}	
				199·7

2nd Food.

		lb.		
Albuminoids	...	1·04	× 47·4 =	49·3
Fats ...	...	·468	× 100 =	46·8
Carbo-hydrates	...	4·30	} × 43·1 =	194·8
Cellulose ...	...	·22		
				290·9

The second food is nearly one and a half times more heat-producing, hence work-producing, than the first food. The first food is the digested principles of 12 lb. of hay, the second of 10 lb. of oats.

If we wish to know the actual number of foot tons such a diet is capable of producing, we use Frankland's table already given, and having ascertained the number, deduct $\frac{4}{5}$, for the whole of the potential energy of food is not converted into work—not more than $\frac{1}{5}$, perhaps even less. In a steam engine only $\frac{1}{10}$ of the actual power of the fuel is produced in work.

Taking, again, our diets of 12 lb. of hay and 10 lb. of oats, we find the following to be their potential and actual energy :

12 lb. of Hay.		lb.	Foot tons of potential energy.	
Albuminoids...	...	·568	= 1572	Deducting $\frac{4}{5}$ from the total potential energy leaves 2093 foot tons for external work.
Fats	...	·045	= 272	
Carbo-hydrates	...	2·574	= 8620	
Cellulose ...	...	1·330		
			10464	

10 lb. of Oats.		lb.	Foot tons of potential energy.	
Albuminoids...	...	1·04	= 2879	Deducting $\frac{4}{5}$ from the total potential energy leaves 3138 foot tons for external work.
Fats	...	·468	= 2830	
Carbo-hydrates	...	4·30	= 9980	
Cellulose ...	...	·22		
			15689	

Our diet of 12 lb. of hay and 10 lb. of oats will, therefore, develop a total potential energy of 26,153 foot tons, and that of the oats is capable of producing 3,138 foot tons of external work, or, to put it in a practical form, is capable of allowing a horse weighing 800 lb. and carrying a weight of 200 lb. to perform a journey of 10 miles in 57 minutes.

Analytical Valuation of the Losses of the Body.

We have previously dealt with the substances required by the organism to maintain life; we have now to consider the important subject of the amount of these which is required daily by the body. It is evident that the daily loss represents the requirements, and this loss is affected by the weight of the animal, the temperature, and the work done.

Weight of Animal.—The smaller the animal the larger are his requirements. The requirements of a pigeon are comparatively larger than those of a dog, a dog more than a man, and so on. It is a well-known fact that the processes of vital activity are greater in small than in large animals, owing to the comparatively larger surface they expose.

Boussingault's experiments lead to the same conclusion; he found that if 7 oz. of nitrogenous material sufficed for a horse or cow weighing from 1,100 to 1,300 lb., 8 oz. would be required for an animal weighing 880 lb. Thus, for equal weights, there is a greater expenditure among small than among large animals, and M. Crevat has stated that the ration required by animals of different weights is proportional to the squares of the cube root of their weight. Therefore, of two animals, one weighing 125 lb. and one 8 lb., the requirements for the first would be 25 and for the second 4; in other words, the requirements of the big animal, instead of being more than fifteen times greater than those of the small, are little more than six times; or, to put it clearer, our 8 lb. animal would require more than 60 parts of food for 125 lb. of body-weight, whereas the 125 lb. animal only requires 25 parts.

Temperature has a marked effect on the requirements of the system. More food is necessary when the temperature is low, for much is expended in maintaining the body-heat which would otherwise be devoted to other functions.

Work of course increases the necessity for food, producing what we have termed the variable diet. The production of milk, which represents a loss to the system. has also to be taken into consideration.

Experimental investigations have shown that the minimum amount of food necessary is lowest when the elements are mingled together in a definite manner. The mixture to contain proteids, fats, or carbo-hydrates, water and salts in certain proportions; the salts being in the smallest, the water in the largest proportion (Hermann).

The loss in the animal economy is of two kinds—(1) that dependent on the internal work of the body, such as the action of the heart, movement of the bowels, respiration, etc.; and (2) the loss from muscular and other movements. We have, therefore, two diets to maintain, the first to allow of a perfectly balanced condition of the body, restoring the loss occasioned by the internal work, so that the body-weight shall remain unchanged; and the second to restore the waste of muscular and increased respiratory activity resulting from external work. The first may be called the *essential* or *subsistence diet;* the second the *variable diet.* Our knowledge of the important subject which we are now about to deal with is derived almost entirely from experiments made by French and German physiologists and chemists.

Determination of the Essential and Variable Diets.

A horse weighing 1,000 lb., doing no work, and placed under conditions which will ensure as far as possible that no external movement of the body occurs, requires in twenty-four hours, according to Boussingault, 5·42 lb. carbon, 9 oz. hydrogen, 4·06 lb. oxygen, and 1·34 oz. nitrogen.

These elements are supplied in 8·36 oz. nitrogenous matter and 9¾ lb. non-nitrogenous, reckoned as starch. The potential energy of this is:

Nitrogenous ...	8·36 oz.	= 1446	foot tons.
Non-nitrogenous ...	9¾ lb.	= 21528	"
		22974	"

From some careful experiments of my own, I ascertained that horses might be kept in perfect health, and practically without loss of body-weight, on 12 lb. hay per diem; of which, on an average, 5·69 lb. were returned with the fæces. Deducting from the weight of the hay 1½ lb. for moisture, there would remain 4·81 lb. digested and assimilated by the system. Assuming the 4·81 lb. of assimilated food possessed the same digestive co-efficients as are given in the 12 lb. hay on page 135, these animals received and required—

	lb.	
Albuminoids	·656	The potential energy being equal to 11041 foot tons.
Fat	·100	
Carbo-hydrates ...	2·574	
Cellulose	1·330	
Salts	·150	
	4·810	

There is a wide difference, with regard to the non-nitrogenous matter, between my experiments and those of Boussingault given above, which I cannot reconcile, and the matter must be further investigated. We agree pretty closely in the amount of nitrogen given off; he found 1·34 oz., I found 1·68 oz. It is certain, however, and this is the most practical point, that a horse requires 12 lb. hay daily for the internal work of his body (for his vital processes), and that on this amount he can be kept in health without loss of body-weight, doing, of course, no work.

An ox weighing 1,000 lb. requires daily, to prevent loss of body-weight, 8 oz. nitrogenous matter, and 7·5 lb. non-nitrogenous calculated as starch (Wolff).

Sheep (shorn) for 1,000 lb. of live-weight require 14 oz. nitrogenous matter, and 10·8 lb. non-nitrogenous (Wolff).

These are the quantities of food required to support life; if work is to be performed, milk, wool, or flesh to be produced, we have then to increase the diet to meet these conditions; this forms the variable diet. The production of work must first engage our attention.

In calculating the diet of working-horses, we labour under great difficulties in obtaining correct data as to the actual work they perform, the pace, the nature of the ground, and, in draught, the force of traction employed. We will have later to consider these points in a separate chapter, but we must here note that they possess a considerable influence on the amount of food required. Where labour is slow and prolonged, there is less force exercised than when it is laborious but short. The resistance which the animal's body meets with increases as the square of the velocity with which it is working, and the force it has to exercise to overcome this resistance increases not as the square, but as the cube of the velocity.

During labour the amount of carbonic acid given off by the lungs is greatly increased in amount, and the faster the pace the more carbonic acid is expired. The system has, therefore, to make good in food the direct loss in carbon, and the increased need which exists for oxygen and nitrogen.

If the food required by the system increased in a corresponding proportion with the work, the calculations of the amount required would be much simplified. Dr. de Chaumont has shown that with man one-fifth of the potential energy obtainable from food may be converted into productive work, but only to a limited amount of labour, calculated at 300 foot tons per diem; over and above 300 foot tons per day, the value of the food, instead of being one-fifth, gradually falls off in force-producing value to one-seventh, one-ninth, and even one-eleventh.

Exactly the same thing must occur in animal labour, but has yet to be demonstrated.

It is very difficult to fix the number of foot tons of daily work which can be performed by a horse without loss of condition and weight. There are many circumstances which lead me to believe that about 3,000 foot tons per diem will be found to be the quantity.

Assuming that the total weight a horse would carry, including its own weight, amounted to 1,000 lb., then it would exert 3,000 foot tons in the time named in the following velocities:

						Foot tons.
9 hours	work at	3	miles per hour	exercises a force	equal to	3000
$5\frac{1}{2}$	"	4	"	"	"	3000
$2\frac{3}{4}$	"	6	"	"	"	3000
$1\frac{1}{2}$	"	8	"	"	"	3000
1	"	10	"	"	"	3000
8 min. 12 sec.		34	"	"	"	3000

In attempting to calculate the diet required for work, we are met by great difficulties, for, as stated above, though under ordinary work one-fifth of the potential energy in food is converted into labour, yet when great force is demanded this is not the case. Assuming that 3,000 foot tons is the normal daily work of a horse, and that one-fifth of the potential energy of food will produce it, making a total of 15,000 foot tons, it is found that when we wish to produce 4,500 tons of work, the potential energy required is five times the first 3,000, and seven times the next

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1,500, or 25,500 tons. If 6,000 foot tons has to be provided for, it will be five times the first 3,000, and nine times the next 3,000, or 42,000 foot tons.

To state this important point clearly, as far as is possible in the present state of our knowledge, derived from experiments on man, we say that 3,000 foot tons of work will be furnished by one-fifth of the total energy existing in the diet; but for all work *above* 3,000 foot tons, only one-seventh, one-ninth, or one eleventh of the energy existing in the food (over and above that required for the 3,000 foot tons) can be converted into work.

To produce 3,000 foot tons of work, the available potential energy in the food must equal	15,000 tons.
To produce 4,500 do.	25,500 ,,
To produce 6,000 do.	42,000 ,,

The following diet will produce rather more than 3,000 foot tons of actual work :

Digestible	Albuminoids	1·04 lb. =	576	foot tons of	labour.
,,	Starch ...	4·52 lb. =	1996	,,	,,
,,	Fat ...	·468 lb. =	566	,,	,,
	Total ...		3138	foot tons.	

The amount of proximate principles above stated will be found in 10 lb. oats; it is important to note, as corroborative of my opinion as to the normal daily work of a horse, that 10 lb. of oats is the mean amount which practical experience has shown to be necessary for daily work. The hay ration, of which about 12 lb. per day is the usual amount given to horses, is nearly wholly expended in maintaining the body temperature and *internal* work, such as the movement of the heart, bowels, lungs, etc., and my experiments show that this quantity is sufficient for the purpose. The hay, therefore, performs the vital or internal work; and the oats the external labour.

Lastly, the animal organism is not a mere machine which requires but an increase in fuel to develop an increase of work; there is a limit to absorption of the proximate principles—it is smallest for fats, next for albuminates, and largest for carbo-hydrates. If the work imposed upon a horse is larger than his system can meet, even where the food allowed is unlimited, it cannot be expected that the liberal allowance of food will permit him to do an unlimited amount of work.

The next point in feeding we have to consider is that which is of the most importance to the agriculturist, viz., the **Fattening of Animals.** Little was done in the scientific elucidation of this interesting subject until the classical labours of Lawes and Gilbert were published. The remarkable experiments of these observers, extending over many years, attracted the attention of agriculturists and scientific men. So thoroughly did these gentlemen work out the subject of the chemistry of feeding animals for the production of meat and manure, that they have well-nigh exhausted the subject. What we have to say on the matter is derived entirely from their observations.

In order that an animal may fatten, it is essential that it be supplied with more food than the system requires, so that the excess may be stored up in the form of meat. Experience has proved that liberal feeding is economical. If by liberal feeding an animal can be prepared for market in two years instead of three, there is a distinct saving in one year's keep. These are recognised facts, and need no further remark. There are certain conditions which influence fattening, and these are warmth, quietude, and rest. The way in which these act can be readily appreciated; by keeping animals warm, food which would otherwise be expended in maintaining the body-temperature during our winter months, is stored up in the system. Freedom from excitement is well recognised as an important factor; nervous, irritable animals cannot fatten, owing to the disturbed state of the system. The expenditure and body-waste which occur during exercise being a direct loss of body-tissue, the necessity of rest for fattening animals is clearly indicated.

Both oxen, sheep, and pigs contain from 3 per cent. to 4 per cent. less nitrogen in the fat than in the store condition; whilst, on the other hand, they contain about double the amount of non-nitrogenous substance in the fat than in the store condition. Both the water and salts diminish as the animal passes from the lean to the fat condition.

The quality of the meat depends upon the distribution and character of the fat deposited in the tissues. Some animals store up fat outside the carcase, others in the internal organs.

The guide as to the differences in the character and amount of food required by the different animals is the proportion of their internal organs.

For every 100 lb. of live weight of the ox, $11\frac{1}{2}$ lb. are for stomach and contents; whereas for sheep, the number is $7\frac{1}{2}$ lb.; and for pigs, $1\frac{1}{3}$ lb. The intestines and contents are, with the ox, $2\frac{3}{4}$ per cent. of his weight; with the sheep, $3\frac{1}{2}$ per cent.; and the pig, $6\frac{1}{4}$ per cent.

From these vast differences in the proportion of the digestive organs, great differences may naturally be expected to occur in the feeding. The small stomach of the pig is not intended to digest cellulose, whilst that of the ox is; sheep require less cellulose than the ox, and the pig more starch than either, to digest which his intestines are comparatively the largest.

To produce 100 lb. increase in live weight with oxen, it was found that 250 lb. oil-cake, 600 lb. clover chaff, and 3,500 lb. swedes were required; and the amount of each food-constituent stored up for 100 consumed was as follows: nitrogenous matter, 4·1; non-nitrogenous, 7·2; mineral matter, 1·9.

With sheep, to produce 100 lb. increase in live weight, 250 lb. oil-cake, 300 lb. clover chaff, and 4,000 lb. swedes were required; and the animal stored up for every 100 parts of each proximate principle consumed—nitrogenous matter, 4·2; non-nitrogenous, 9·4; mineral matter, 3·1.

To produce 100 lb. increase of live weight with pigs, 500 lb. barley meal were required; and the animal stored up for every 100 parts of food-constituent consumed—nitrogenous substance, 13·5; non-nitrogenous, 18·5; mineral, 7·3.

Lawes and Gilbert's tables show that the amount of dry substance of food required to produce a given weight is larger with the ox than with the sheep, and larger with the sheep than with the pig.

The dry substance of the food of the ox contains a larger proportion of indigestible matter than that of sheep, and that of sheep more than that of pigs. Oxen require from five to six, and sheep from three to four times as much time to add a given proportion to the weight of their bodies as pigs.

The greater part of the nitrogenous and mineral matter of the food is recovered in the manure; and the greater part of non-nitrogenous substance is lost by respiration and other exhalations; a much smaller proportion being retained in the increase or voided in the manure. For a given amount of increase produced, oxen void considerably more substance as manure, and expend more in respiration, etc., than sheep, and sheep very much more than pigs. For a given weight of dry substance consumed, oxen void more as manure than sheep, and sheep very much more than pigs; but oxen respire rather less than sheep, and sheep rather less than pigs.*

As an animal passes from the store to the fat condition, it is found that the increase in weight steadily decreases, although the same amount of food is consumed.

The manurial value of foods is not an hygienic point, but one closely connected with agriculture; practically it is found that if one food yields a richer manure than another it is the cheapest to feed on, though it may be by far the most expensive, for the reason that so much of it is returned again to the soil.

For fattening oxen, Wolff recommends at the commencement of fattening an albuminoid ratio of 1 : 7, increased to 1 : 5·5 when fattening sets in.

For sheep, the ratio should be 1 : 4—5; for pigs under six months, 1 : 4—5, and over six months, 1 : 5—6.†

The objects aimed at in the feeding of animals for the production of milk is a liberal allowance of food, but without any tendency to accumulate fat.

Foods containing much water will produce a large quantity of milk, but of a poor character. A poor watery diet is at once improved by the addition of nitrogenous material, such as linseed cake, brewers' grains, or corn; the effect of these on the richness of the milk is very great. The albuminoid ratio for the cow should be 1 : 5.

In order to be enabled to calculate diets, I have introduced the following table of analyses compiled from the best sources. In using this table the digestive co-efficients should be applied:

* 'The Chemistry of the Feeding of Animals.' A lecture delivered by Mr. (now Sir) J. B. Lawes, F.R.S.

† 'The Chemistry of the Farm.' R. Warrington, F.C.S.

Table for Calculating Diets.

Articles of diet.	In 100 parts.					
	Water.	Albuminates.	Fats.	Carbohydrates.	Cellulose.	Salts.
Grass before blossom ...	75·0	3·0	0·8	12·9	7·0	2·0
„ after „	69·0	2·5	0·7	15·0	11·5	2·0
Red Clover before blossom ...	83·0	3·3	0·7	7·7	4·5	1·5
„ „ in full „ ...	78·0	3·7	0·8	8·6	8·0	1·7
Lucern very young	81·0	4·5	0·6	7·8	5·0	1·7
„ in blossom	74·0	4·5	0·7	7·0	12·5	2·0
Meadow Hay medium quality	14·3	8·2	2·0	41·3	30·0	6·2
„ „ best „	14·59	10·11	2·34	40·90	25·52	6·54
Red Clover Hay full blossom	16·7	13·4	3·2	29·9	35·8	6·2
Lucern (young) Hay... ...	16·7	19·7	3·3	32·9	22·0	5·0
Lucern (in blossom) Hay ...	16·7	14·4	2·5	22·5	40·0	6·4
Vetches	82·0	3·1	0·6	7·6	5·5	1·8
Wheat Straw...	14·3	2·0	1·5	30·2	48·0	5·5
Rye „	14·3	1·5	1·3	27·0	54·0	3·2
Oat „	14·3	2·5	2·0	38·2	40·0	5·0
Barley „	14·3	3·0	1·4	32·7	43·0	7·0
Bean „	17·3	10·2	1·0	33·5	34·0	5·0
Oats	14·3	12·0	6·0	60·9	10·3	3·0
Barley...	14·3	9·5	2·5	66·6	7·0	2·6
„ Indian	12·9	11·46	1·25	65·3	7·0	2·09
Maize	14·4	10·0	7·0	68·0	5·5	2·1
Peas	14·3	22·4	2·5	52·3	9·2	2·5
Beans	14·5	25·5	2·0	45·5	11·5	3·5
Rice	14·6	7·5	0·5	76·5	0·9	0·5
Linseed	11·8	21·70	37·0	17·50	8·0	4·0
Millets, Indian	12·44	10·14	2·20	73·37		1·89
Gram	10·80	19·32	4·56	62·20		3·12
Lentils	12·70	24·57	1·01	59·43		2·29
Cooltee (Madras)	11·50	23·03	·76	61·85		2·86
Oorud	11·0	22·48	1·46	62·15		2·91
Bran	13·1	14·0	3·8	50·0	17·8	5·1
Carrots	85·0	1·5	·2	10·8	1·7	1·0
Linseed Cake...	12·4	27·3	12·8	34·5	6·5	6·1
Cotton „ whole seed ...	11·3	23·7	6·2	31·0	21.2	6·5
„ „ decorticated ...	9·3	41·2	16·0	16·4	8·9	8·0
Rape Cake	11·34	31·59	9·66	29·36	11·0	7·05
Ground Nut Cake	10·80	28·62	8·12	18·86	29·0	3·11
Potatoes	95·0	2·0	0·3	21·0	1·1	·9
Turnips	92·0	1·1	0·1	5·1	1·0	·8
Brewers' Grains	76·6	4·9	1·6	11·1	6·2	1·2
Malt Dust	9·5	23·7	2·2	44·9	12·5	6·8
Swedes	89·3	1·5	0·2	7·3	1·1	0·6
Mangels	88·5	1·2	0·1	8·2	1·0	1·0

The working of the table is simple, the rule being—Multiply the weight of food by the quantity of proximate principle in the column, and divide by 100.

Example I.—How much albuminoid matter is contained in 12 lb. of hay of medium quality?

$$8{\cdot}2 \times 12 = 98{\cdot}4 \div 100 = {\cdot}984 \text{ lb.} = 15{\cdot}744 \text{ oz.} = 15\tfrac{3}{4} \text{ oz.}$$

Example II.—How much cellulose is there in the same quantity of hay?

$$30 \times 12 = 360 \div 100 = 3{\cdot}6 \text{ lb.} = 3 \text{ lb. } 9\tfrac{1}{2} \text{ oz.}$$

Example III.—How much fat is there in 8 lb. of maize?

$$7 \times 8 = 56 \div 100 = {\cdot}56 \text{ lb.} = 9 \text{ oz.}$$

Example IV.—How much water is there in 40 lb. of mangels?

$$40 \times 88{\cdot}5 = 3540 \div 100 = 35{\cdot}4 \text{ lb.}$$

Diseases Connected with Food.

The connection between food and disease as cause and effect is well known. Throughout the whole category of disease-producing causes, there is no single factor which exercises so much influence. The reason of this is not difficult to seek: men feed their animals with as little discretion as they feed themselves. They are either overfed with highly nutritious food, or underfed with material of bad quality; or the food given them is at irregular intervals, badly prepared, or unsuited to the digestive organs of the animal. Another reason for the great importance of the subject of food in relation to diseases of the lower animals is that it is one of the three tangible causes we can handle. How seldom we hear of any epizooty that is not traceable directly or indirectly to food, and necessarily so, for we are not situated as is the human hygienist; we have not to consider the hundred and one breaches of hygienic rules committed by men, which may have a greater influence in the production of disease than even bad food has. Food of indifferent quality may not only produce disease, but will aggravate it when existing, or predispose to it should the conditions exist in the animal's system.

We will follow Parkes's division of the subject, and consider our matter under the heads of alterations in quantity, conditions of quality, conditions of digestion and assimilation.

Alterations in Quantity.

Excess of Food.—There can be no doubt that, generally speaking, all horses in the employment of people of means are overfed. There is a constant desire on the part of those concerned in their care and management to cram them with food, in order to produce that rotundity of barrel, and sleekness of coat, so pleasing to the eye. In some cases the amount of work expected from the animal may be just sufficient to prevent it suffering from the effects of over-feeding; but in others, particularly with a certain class of carriage-horse, and among the heavier breeds, the labour expended is insufficient to utilize all the elements of food, which collect in the system to a serious extent, and produce disease. From the above class are excluded entirely race-horses and hunters; both of these are called upon to make a certain effort, one which requires the utmost use of their powers, and experience has shown that this can only be satisfactorily obtained by the most liberal allowance of food. The army horse in England is well fed for the amount of work which is expected from him; but there is no doubt that in India his diet is greatly at fault, and most unsuited to the climate and for the amount of energy he has to expend. The fault lies in the fact that no grain is obtainable but that in which a very large proportion of albuminoids exists;

though this would be to an extent avoided if a better mixture of foods was obtained.

An excess of food leads to diseases of the blood, liver, and bowels. Only a certain amount can be absorbed by an animal, and all over and above this lies in the intestinal canal to undergo the process of putrefaction, attended with the elimination of gases, which of themselves, becoming absorbed, may produce serious changes in the blood, in addition to the excess of pabulum already in the tissues. The undigested food lying in the bowels produces diarrhœa, intestinal irritation, etc., and the evacuations are extremely fœtid. This fœtid condition of the evacuations would appear to be more marked with some grains than others; for instance, the fæces of a horse suffering from the effects of over-feeding with 'gram' produce a fœtor which is almost unbearable.

An excess of albuminates produces febrile symptoms, diarrhœa, congestion of the liver, and a condition of the system which we recognise as plethoric; there is sluggishness, legs perhaps swollen, eyes half-closed, not unlikely yellowness of the visible mucous membranes, urine coffee-coloured, etc.—such are the general symptoms of a horse suffering from an excess of albuminates in the system. An excess of starches and fats is very noticeable in pampered carriage-horses, and some of the heavier breeds, particularly, I think, the brewer's horse. These substances give rise to a large deposition of fat all over the body, and surrounding the heart; the fatty infiltration of heart and liver leads to fatty degeneration, the liver becomes enlarged and friable, rupture not unfrequently results, and the heart's action becomes so interfered with, that nothing but the slowest pace can be executed. The diseases due to an excess of food are very numerous. Symptomatic anthrax in cattle is attributed to a sudden removal from poor to rich pastures;

in Indian anthrax of the horse, I am convinced that those animals receiving an excess of food are more liable to the disease than those under-fed. Among abdominal complaints we find that tympany of the stomach of the horse and ox, ruptured stomach of the former, engorgement of the stomach producing that peculiar form of disease which might be termed gastric-apoplexy, lymphangitis, laminitis, colic, liver diseases, etc., can all be attributed in a greater or lesser degree to over-feeding.

Deficiency of Food produces very marked changes in the organism. This deficiency may be in the total amount of the elements required, or of one or more of them. A deficiency of albuminoids produces a decided loss of energy and muscular force, followed by languor and extreme debility. The deficiency of fats and starches produces less urgent symptoms. The loss in fats is not so well withstood as that of starches, but of the exact effects resulting from them we are not well informed.

A deficiency of food predisposes the system to disease. Glanders, farcy, and scabies are the first diseases to appear among horses which have been kept for some time on an insufficient quantity of food. Our various campaigns, particularly the Peninsula and Crimea, have proved this over and over again. Other diseases, such as dysentery, are said to occur to horses at this period. When the quantity of food supplied is insufficient to support the internal work of the body, starvation occurs. In cattle such diseases as hæmo-albuminuria and 'moor-ill,' are attributed to an insufficiency of food. The exact effect of a deficiency of any single element in producing disease is somewhat difficult to determine, but it is known as regards the saline matters that a deficiency of these produces certain diseases of bone, such as rickets; other nutritive changes in the skeleton are also probably caused in the same way. Nessler finds that horned cattle fed on foods deficient in albuminoids, and poor in sodium, phosphoric acid, and calcium, suffer from brittleness of the bones.*

It is a point of great practical importance to observe that animals which have for some time been existing on a deficiency of food should by very gradual degrees be brought back to the proper quantity. More harm, indeed, is supposed by some to occur by the sudden change from a poor to a rich diet, than from the continual effects of insufficient food. Certainly the symptomatic anthrax of cattle is generally attributed to a sudden change from a poor to a rich pasture.

Conditions of Digestibility and Assimilation.

This class includes many important points of an essentially practical character. A food which can be partaken of with impunity by one class of animal, proves detrimental to another, due to the fact that owing to the physiological arrangement of the body, or to some condition of which we know but little, the food does not agree with the system. We have many examples of this—for instance, the well-known fact of wheat, barley, and perhaps maize, producing laminitis in the horse; new hay and oats being purgative. Some forms of clover are charged with producing disease such as diarrhœa; and Fleming tells us that enzootic softening of the liver among horses in Egypt has been traced to feeding on trefoil. Potatoes produce in horses purging, though they are usually well borne by cattle. Buckwheat has been supposed to produce head symptoms, and parsnips to affect the eyes; but, perhaps, one of the most peculiar diseases produced by a food of this description is the paraplegia found in India, particularly in certain parts of the North-West Provinces, arising from the use of the

* *Journal of Chemical Society.*

Lathyrus sativus (Kecheree dal): both animals and man are affected by it, and the disease is incurable. It is also said to cause enteritis and colic in horses and cattle. The disease has been described by Messrs. Leather and Professors McCall and Williams as affecting horses in England and Scotland; the grain is brought home to this country as ballast, and its action on horses is to produce the most intense dyspnœa and roaring when put to work; the appetite is not affected, and when in the stable the animal appears in perfect health. Several fatal cases are recorded by these observers, whose articles in the *Veterinary Journal* and *Veterinarian*, April, 1885, and *Veterinarian*, November, 1886, may be consulted with great advantage. Acorns, which may be consumed by pigs and other animals with impunity, will, during certain years, cause grave disease.

To all these we must add those cases of indigestibility which occur so constantly to us in practice, where a food which has been agreeing with an animal, for years perhaps, suddenly, without any apparent cause, sets up disease. Take, for example, ordinary colic or tympany of the stomach and bowels of the horse. It is often impossible to say what produces this disturbance of the digestive functions. A horse has been receiving exactly the same amount and the same kind of grain and fodder from the day he joined the service; it agrees with him for some years, but one day he is seized with violent abdominal pain, and expires in a few hours from a rupture of the stomach, produced by the sudden evolution of gas from the contents of the organ. What caused the food to remain in the stomach and ferment instead of undergoing digestion? We know nothing of these causes, and can only speculate as to what may have been. This is a good example of disease produced by indigestion, where there is nothing, so far as can be detected, either in the quantity or quality of the food to account for it. A skin disease common in India is attributed by my friend V.-Major Adams* to feeding on green and wet grass. He has collected a large amount of evidence which supports him strongly, and we may here, I think, consider this as one of the forms of disease due to indigestion. There are, perhaps, other forms of skin disease produced by green fodder; and as, among men, some cannot partake of fish or other food without suffering from urticaria, so I believe I have noticed a similar condition in the lower animals. A sudden change of food no doubt exerts a considerable influence in the production of certain enzootic diseases, particularly among cattle; and Percivall tells us of the horses fed on growing wheat during the march of the English army on Paris after Waterloo, and the disastrous results attending it, owing to tympany of the stomach and intestines. Indigestibility of a food may be owing to its mode of preparation. Experience has shown that cooltee should be boiled; gram, peas, and beans crushed; and barley parched: if these conditions are not properly carried out, the food is rendered indigestible. Indigestibility may also be produced by errors in stable management, such as watering too close on the last feed.

Conditions of Quality.

This is a very important section, as it nearly covers the cause of disease amongst the lower animals. The quality of a food is affected by its mode of growth, care in saving and preservation, cleanliness, and the inroads of vegetable and animal parasites. If the land on which the food is grown be poor in quality, the produce will be in a similar condition; it will be poor in its chemical constituents, particularly those on which its nutritive value depends. Oats

* *Quarterly Journal of Veterinary Science in India*, vols. i. and ii., Nos. 1 and 8.

manured with cow's dung will produce 16 bushels for every bushel of seed sown, whilst on unmanured land there will be only 5 bushels produced for every bushel of seed. The formation of the soil affects in a considerable degree the produce and quality of the food. Oats reared on clay land are superior to any other. Rye flourishes best on a light sandy soil. A stiff clay produces a coarse barley, a light chalk a light grain, and a loamy land a full plump grain; these are only a few examples of many which might be quoted. The time of cutting influences the nutritive value of a food: hay cut late loses much of its properties; if cut too early it is prevented from reaching the full extent of its nutritive matters. Wheat cut about a fortnight before it is ripe contains the most starch and gluten, the bushel weighs heavier, and the straw contains its most nourishment; cut late, the ear contains more cellulose, consequently an increased amount of bran, and a diminished proportion of flour. The season affects the quality of the forage; for instance, in very wet years, and especially when lands have been flooded, parasitic diseases of plants are most common. The age of grain and forage, up to a certain time, enhances their value and quality; old hay is preferable to and more valuable than new, and the same applies to oats, beans, wheat, etc. Food badly saved and stored undergoes deterioration, which may range from slight diminution in nutritive principles or sourness, to mouldy decomposing and offensively smelling material. Cleanliness is an important condition of quality: gastric and intestinal diseases are produced by dirty feeding; colic, enteritis, impaction, rupture, and the various forms of intestinal and stomachical calculi are produced by this means. In the Madras Presidency the grain (cooltee) contains a large amount of gravel; even when every care is exercised a large quantity is weekly ingested with the food, and disorders from this cause are common. The gravel collects in the colon, and there are but few cases I can remember when, at *post-mortem* examination of any disease, this was not present. Miller's horses are said to be particularly prone to stomachical and intestinal calculi, caused by their being fed on bran and refuse-sweepings from the mill-floor, mixed with fine chips from the grinding-stones. These in the digestive canal become coated with the phosphates of lime and magnesia, eventually forming very large calculi. Oat-hair calculi, or dung-balls, are formed from the beard of the oat and barley, matted together by mucus and particles of food; the so-called mixed calculi are formed principally from the food. Any foreign substance taken in with food may form the nucleus of a calculus. I have seen, and others before me have described, a nail as the nucleus.

The **Parasites affecting Food** are animal and vegetable; the former are found usually among the grains, in their interior; the latter may be found in all kinds of food. The vegetable parasites are the most important, for not only is the nutritive value destroyed, but deleterious matter is added, which in some cases acts as a poison, producing the most serious results.

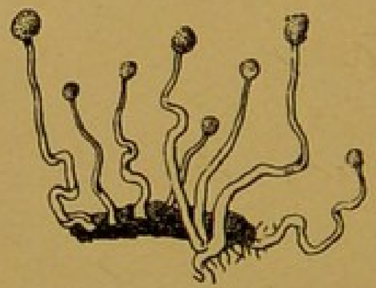
The vegetable parasites affecting food may exist on it at two different periods, viz., during the life of the plant, or after it has been cut. The first is the most important group, including such pests as Bunt, Rust, Mildew, Smut, and Ergot; whilst others, as the Mucors, Penicellium, and Aspergillus, develop generally after the death of the plant.

Bunt is caused by the fungus *Tilletia caries;* it affects the grasses, straws, and grains. It principally attacks the head of wheat, producing great damage, destroying the flour, and replacing it by a black or olive coloured powder of a fishy odour; it also affects the stems, causing the leaves to shrivel up, become pale, and lose their natural juices.

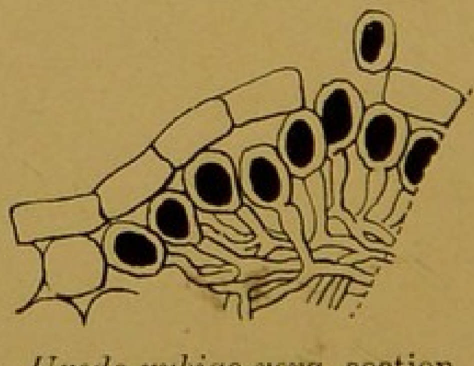
PARASITIC DISEASES OF GRASSES.

Spike of
Ergotised Rye.

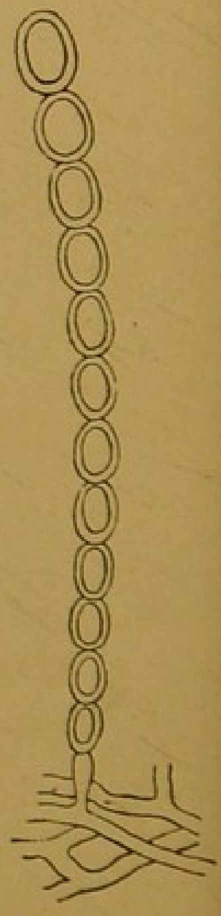
Stems of Sheep's Fescue Grass affected with
Isaria fuciformis.



Ergots germinating and
producing *Claviceps*
Purpurea.



Uredo rubigo-vera, section
through a pustule.



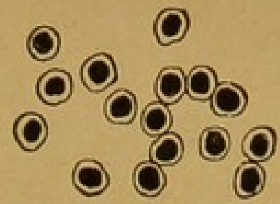
Odium monili-
oides, the early
condition of
Erysiphegra-
minis.

Copied from "Diseases of Field and Garden Crops."

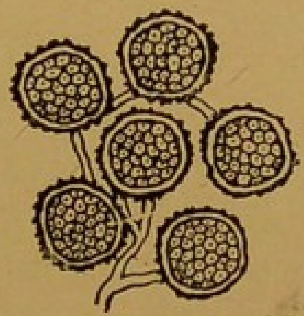
By W. G. Smith, F.L.S.

PARASITIC DISEASES OF GRASSES.

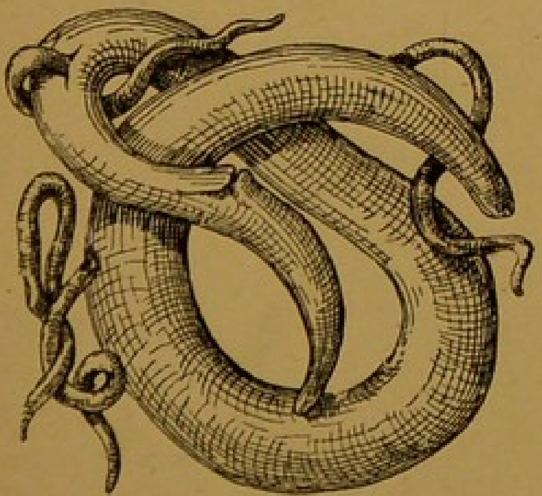
Panicle of Oats invaded by the fungus of Smut.



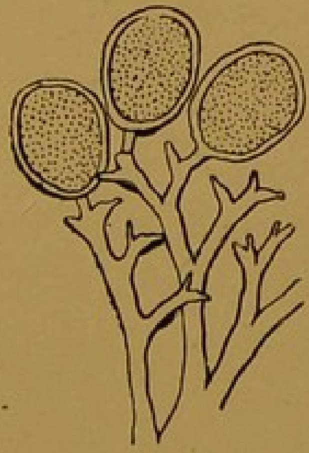
Spores of Smut.



Spores of Bunt.



Tylenchus tritici, the nematoid worms which produce Ear Cockle.



Clover mildew, *Peronospora trifoliorum*.

Copied from "Diseases of Field and Garden Crops."

By W. G. Smith, F.L.S.

Bunt is difficult to detect; the flowering head must be well examined to find the dark diseased seeds.

Smut is produced by the fungus *Ustilago carbo;* it is readily detected, has no odour, and animals dislike the straw affected with the disease. This fungus attacks the flowering heads and stems of many of the grasses, wheat, barley, oats, etc. It is at first a white deposit, which afterwards becomes a black mass.

Grass Mildew, grass blight, or white rust, is produced by the fungus *Erysiphe graminis.* It has a curious life-history, which has been most beautifully worked out by Mr. W. G. Smith.* This fungus forms on the stems of grasses a white mildewy patch sprinkled with black dots.

Straw Blight is closely allied to the grass mildew. This fungus attacks the stems of wheat, barley, and other grasses close to the ground, and is recognised by brownish spots on the straw, which go completely into the hollow of the stem.

Corn Mildew presents a most singular cycle of existence. Briefly, it consists of two kinds—a spring rust, or *Uredo;* and a summer and autumn variety (derived from the spring form) termed summer rust, or *Puccina.* There are two kinds of spring rust, each producing its own Puccina; we have the *Uredo rubigo-vera*, producing the *Puccina rubigo-vera*, and the *Uredo linearis*, producing the *Puccina graminis.*

The spring rust appears as little yellow patches, afterwards becoming black, affecting the leaves and stems. With the black spots the complete fungus, or *P. rubigo-vera*, is produced. Before this can again grow on grasses, it must pass through another family of plants. The summer rust

* 'Diseases of Field and Garden Crops.' This is a most excellent little work, on an obscure and interesting subject. We are much indebted to it for the above information.

is the most important; it is much larger than the spring form, and browner in colour. This fungus has also to pass through another family of plants on attaining maturity, before it can attack grasses as the Uredo.

Clover is subject to attacks of several fungi, of which the most important is the *Peronspora trifolium*, which produces what is known as 'Clover Sickness.' The fescues are liable to the attack of the fungus *Isaria fuciformis*, a new disease described by Mr. W. Smith. The fungus is of various shades of red, and of a mucous consistence. Cattle have been known to die from eating Isaria-affected grass.

Ear Cockle, Purples, or Peppercorn are the names given to a parasitic disease of the grains comprising the ear of wheat, oats and rye. The parasite is a nematode worm which converts the grain into a gall. The gall is dark externally, but internally is filled with a cottony mass consisting of coiled-up parasites.

Ergot is a fungoid disease of the Graminæ; it is popularly supposed to attack only the rye plant, but many other species of the Graminæ, as maize, wheat and grasses, are also affected. Ergot is produced by the *Claviceps purpurea* the mycelium of which attacks the ovary of the seed—this is the first or *sphacelia* stage; next the mycelium penetrates the ovary, forming a hard sclerotium termed the *Ergot stage*—this, when fully developed, drops out of the grass and lies dormant in the ground, usually from summer to spring. The sclerotia falling on damp ground germinate into small stalks with a rounded head. The heads contain the spores, which when carried into the air fall again on the rye or grasses, giving rise again to the sphacelia; and so the cycle is completed. (Murray.) The ergot is a horn-shaped, grooved body, of a purplish-black colour externally, white-violet internally, and from $\frac{1}{8}$ inch to 1 inch in length; it stands out prominently from the grain. Its odour is nauseous.

Mouldiness is caused by indifferent storing; grain and hay exposed to wet and moisture become covered with small fungi of the genus *Penicellium*, *Aspergillus*, *Mucor*, *Ascophora*, etc. Moisture dissolves out of the forage its nutritive properties, and the fungi complete the mischief. Hay changes colour under these circumstances, becoming brown, and its odour is unpleasant: mouldy hay produced by other causes than those above named, such as being kept too long, is, according to Mégnin, due to *Aspergillus candidus*, *Botrytis grisea*, *Torula herbariorum*, and *Eurotium herbarium*. These show themselves as a greenish-white or brownish fluff, covering the stems, leaves, and flowering head. *Sphæria herbarium* is another form of fungus affecting grass and hay undergoing mouldy change. It is characterized by small black or brown spots, which bear spores of a yellow, brown, or black colour. Mouldy hay breaks easily, and when dry, if shaken, gives off spores which cause great irritation to the respiratory passages. (Magne). Grain exposed to damp becomes mouldy, and covered with *Penicillium glaucum*, *Aspergillus glaucus*, *Mucor racemosus*, and *Ascophora mucedo*; the grain is thus deprived of its nutritive properties, and if the damp be excessive the starch in it becomes converted into sugar, and sprouting of the seed occurs. If ground grain undergoes mouldiness, it becomes lumpy, has a peculiar smell, and the fungi above named are visible on its surface. The fungi consist of a fine-branched mycelium of a whitish-yellow colour, bearing erect hyphæ of a bluish or greenish colour.

Club-root disease of turnips, mangles, etc. is produced by the fungus *Plasmodiophora Brassicæ*.

The effect on animals partaking of ergotized grain is remarkable. That singular affection of sheep, 'louping-ill,' is attributed to this cause. In this disease a peculiar train of nervous symptoms exists, which vary in degree according to whether the brain or spinal cord, or both, are affected. If the former, effusion into its substance and on its surface causes death rapidly; but when the cord only is affected, paralysis is the most urgent symptom, affecting more or less completely both hind limbs. In some forms of the disease there appears to be great nervous excitement and irritation.* Other diseases have been attributed to the effects of ergot; abortion is perhaps the most common result of its use, but in man a peculiar form of gangrene of the extremities is observed, the result of the action of ergot on the bloodvessels. The experiments which have been made on animals with ergot are rather disappointing: 'In 1811, twenty sheep ate 9 lb. of spurred rye daily for four weeks without any ill effects. In another instance twenty sheep consumed 13½ lb. daily for two months without injury. Thirty cows took together 27 lb. daily for three months with impunity, and two fat cows took in addition 9 lb. of ergot daily with no other obvious effect than that their milk gave a bad caseous cream which did not yield good butter.†

Enzootic paraplegia among horses is attributed to feeding on rye-grass which is probably ergotized.

The effects of mouldy fodder on animals are not clearly known; many cases of disease are attributed to this cause; such symptoms as loss of flesh, derangement of intestinal and urinary organs, followed by paralysis and death, have been believed to result from *Tilletia caries* and *Puccina graminis* found on damp straw. Rinderpest on the Steppes of Eastern Russia has been attributed to the poisonous mildew found on crops; the blight comes up as a thick yellow fog, continues for three or four days, and by this time the crops are badly affected with it. In appearance it

* *Veterinary Journal*, vol. xii., Nos. 68, 71.

† Pereira's 'Elements of Materia Medica.'

is a fine dust of a dark yellowish-brown colour, and besides being deposited on plants it falls into the water and occasions rinderpest among animals which drink it. Cholera at this place has been attributed to the same cause.* Gamgee tells us of a disease which was enzootic and epizootic in France and Scotland during the years 1854-56, due to horses feeding on grass which had become wet and musty: the symptoms were those of abdominal and cerebral derangement, producing the so-called 'stomach staggers' of English writers. In Scotland paralysis of the hind extremities was observed to follow the attack. Vety.-Captain Gillespie has recorded a most interesting enzootic of tympanic stomach and bowels, occurring amongst some horses of a battery of artillery in Afghanistan, caused by feeding on mouldy grass.† In Adam's *Wochenschrift*‡ is mentioned an outbreak where seven oxen were supposed to be poisoned by mouldy forage. The symptoms were at first referred to the intestinal canal, but in the course of a few days total paralysis of the hind-quarters occurred. Mouldy oats and bread have produced diabetes, paralysis and subsequent death in horses. Rust has produced serious disease amongst lambs, the stomach having on *post-mortem* examination been found filled with millions of the fungus-spores, which Dr. Taylor of Ipswich is inclined to think produced blood poisoning.§ Rust-spores have also been found in the lungs in a state of active growth.

In the summer of 1841 in Germany the leguminous plants, especially vetches, became subject to honey-dew, and all white horses, and even such as had only white

* *Veterinary Journal*, vol. vi., No. 31, translated from *Vossiche Zeitung*.

† *Quarterly Journal of Veterinary Science in India*, vol. ii., No. 5.

‡ *Veterinary Journal*, vol. vii., No. 40.

§ *North British Agriculturist*, Sept. 2, 1880.

marks, suffered from disease of the skin. The white portion in party-coloured horses became gangrenous, and separated from the dark portions, which continued sound. The dark-coloured horses which did, and the white ones which did not, partake of this food continued healthy. Youatt and others have related similar cases.*

Mouldy oats have caused paralysis in horses, and Professor Varnell states† that six horses died in three days from eating mouldy oats; there was a large amount of matted mycelium, and this, when given to other horses for experiment, killed them in thirty-six hours; paralysis of tongue and hind-quarters were the most marked symptoms; enteritis and removal of mucous membrane of stomach and intestines were the chief *post-mortem* appearances.

The Animal Parasites affecting Food belong to the class of Insecta and Arachnidans. Mégnin has very carefully investigated the subject, and his views are expressed in Magne's 'Agriculture Pratique,' from which we summarize the following:

An insect termed *Tenebrio mollitor* is found in lofts and in hay-stacks at their lowest part; its larval form feeds on the flour of the cereals, on bran, and on the flowering heads of grasses—all these it reduces to powder. The insect is about ½ inch long, the upper part of the body of a blackish-brown colour, the underneath reddish-brown. Its larval form is about ¼ inch long, and of a shining brown colour. *Botrichus rotundus* and *longus* are very small insects of a yellowish-brown colour; the latter is principally found in food, and is very destructive. *Ptinus fur* is also a small insect of a rather deep brown colour—its larvæ live within the stems of hay. The *Acari* which live on forage cause

* *Veterinary Record*, vol. vi., No 24.

† *Veterinarian*, Feb., 1862.

great mischief; the principal one, *Gamasus fenorum*, is of a yellow colour, and nearly round in shape. This parasite may produce a skin disease of the horse closely resembling mange. The small *Yellow* and *White Argas* are two more acari; the latter causes a skin disease of the horse. It has been found in large numbers on lucern. The *Acarus farina* is found in flour. There are other Arachnidans attacking forage, but not of such importance as those named. These parasites reduce the food to powder; what they do not eat is rendered brittle and soiled by their debris. They are easily detected by placing a pinch of dust on black paper, when the acari can be seen. The dust is also very irritating to the respiratory passages. *Psocus pulsatorius* and *P. veloce* are found in food; they do not attack it, however, but live on the acari, which they actively pursue. The weevil, *Calandra gramina*, completely destroys the flour of grains, reducing them to an empty shell. It is readily distinguished by the small hole in the grain, which floats when thrown into water.

The effect of these animal parasites is to destroy the food, which is converted into powder and rendered brittle and innutritious by the abstraction of its nutritive properties. It is also important to note that at least two of these parasites affect the skin of the horse. If food containing the acari be used only for a short time, the skin disease disappears; but if long continued the acari multiply rapidly, and the disease is difficult to eradicate.

Other conditions affecting the quality of food may be chemical or physical. Hæmo-albuminuria in cattle is attributed, amongst other causes, to frozen turnips; tympany, to turnips frozen or partially decomposed, dewy grass, etc., 'Moor evil,' to excessive astringency in food, such as in oak-shoots. That peculiar disease of the respiratory organs of the horse termed 'broken wind' is known to be induced through the agency of the digestive canal, such as, for instance, through coarse, innutritious, bulky fodder. Diabetes and nephritis in the horse, particularly the former disease, are common as the result of using damaged oats or mow-burned hay. We exclude from this section those articles which have been used as food and found to be poisonous, such as the Bearded Darnel grass, the Tulip plant, Yew, etc.

Diseases Due to Imperfect Preparation of Food.

This is certainly a cause affecting the health of animals. Practical experience has shown that certain foods require preparation before use. I think we all recognise the value of oat-crushing machines; the grain is by this means rendered more digestible, there is less loss, and a smaller amount produces the required energy. An old horse with imperfect teeth will starve if his oats are not crushed or scalded. Intestinal irritation is set up from the non-parching of barley or defective crushing of beans and gram. The crushing saves the stomach work, for the digestive juices may at once commence their operations on the flour without having first to dissolve the hard external covering. There is a French proverb which says that 'a good digestion commences in the kitchen'; apart from the question of whether the continual use of cooked food for horses is advantageous or harmful, there can be no doubt that the mode of preparation adopted must depend on the grain used. Raw potatoes are productive of intestinal irritation in horses; boiling or steaming before use prevents this. Oorud and Cooltee have also to be boiled before they are rendered fit for food. I am quite convinced that the use of boiled foods for horses predisposes to ruptured stomach, for the grain is readily 'bolted' and large quantities taken; in the stomach the mass ferments, and the walls of the stomach give way from the violence of the animal and pressure of the gas. Choking is common where feeding on uncrushed gram is practised; and among cattle, if roots are not sliced, the same accident is liable to occur.

VARIOUS ARTICLES USED AS FOOD.

Grass.

The grass tribe furnishes by far the largest number of articles used as food by animals, for however diverse in external appearance hay, oats, wheat, rice, rye, maize, barley, sugar-cane, and the millets may appear, yet they all come under the genus graminaceæ; we have many plants regarded generally as grasses which have no claim to the genus, such, for instance, as the clovers and sainfoin.

Grass, the natural food of herbivora, is made up of a large number of different species of the order Graminaceæ. Only one positively hurtful kind is known, and that is the Bearded Darnel. All grasses are not of the same feeding value, and some species in a meadow are instinctively rejected by animals. The effect of grass on the system, particularly of ruminants, is most marked in the production of flesh, milk, and wool.

Some pastures cause cattle to purge violently. Dr. Voelcker inquired into the reason of this many years ago, and came to the conclusion that it was due to immature herbage. In this condition grass contains more soluble mineral matter and organic acids, such as malic, citric, tartaric, etc.; it is these which produce an aperient effect. This is the explanation of the laxative properties of green food. Horses are unable to perform work on a grass diet alone, for the reason that sufficient nutriment is not contained in the bulk which the system needs. With the young animal grass is the first solid food taken; in this condition it corresponds with the requirements of the system and is easily digested.

For convenience of description, grasses are divided into natural and artificial. Natural grasses are true grasses; artificial, on the other hand, comprise the clovers, sainfoin, lucern, etc., plants which, as we have stated above, are, from a botanical point of view, not grasses at all. Natural grasses are again sub-divided into upland, meadow, and water-meadow grass. This division is partly an arbitrary one, for many grasses which grow on uplands grow also in meadows. As before shown, the soil on which the plant grows must considerably influence its value for feeding purposes; in rich soils the pastures are more permanent and the produce better, whereas in poor light soils the grass is not only difficult to maintain but poor in nutriment; and the tendency on such land is to the production of poorer grasses.

Grass in its natural state is seldom given to horses in England; circumstances force its use in India, but it is a well-known fact that in its natural condition it is not so useful as a food as when converted into hay. Clarke many years ago observed that, whether from the coldness of the soil or climate in Britain, grass does not possess such rich nourishment as to enable horses to perform active exercise on it with the same strength and vigour as is the case in warmer climates. The explanation probably lies in the individual difference of tropical and English grass, and to the fact that in India an endeavour is made to feed on one kind of grass of known value, whereas in England the pastures consist of a variety of grasses. Probably from the fact that green grass relaxes the bowels of horses, is based the idea of its cooling and cleansing properties; as such, however, it is universally recognised. Besides acting as a laxative, it possesses also diuretic properties; the effect of green meat on the system at certain times of the year is certainly salutary. Animals at work fed on grass and receiving only a small corn ration fall off in condition, sweat readily at work, and the belly becomes pendulous; they are in the condition known as 'soft,' and quite unfit for labour.

The following table exhibits the composition of grass according to the analysis of Kuhn and Grandeau.

TABLE SHOWING THE COMPOSITION OF GRASS.

	Water.	Nitrogenous Matter.	Fatty Matter.	Carbo-hydrates.	Lignin and Cellulose.	Salts.	Nitrogenous Ratio.
Meadow Grass (Grandeau)	78·35	5·24	0·96	9·66	3·72	2·07	1—2
Meadow Grass before flowering	75·00	3·00	0·80	12·10	7·00	2·10	1—4·3
Meadow Grass at the end of flowering ...	69·00	2·50	0·70	14·30	11·50	2·00	1—6
Meadow Grass (Kuhn)	72·00	3·10	0·80	12·10	10·00	2·00	1—4·1
Different sweet grasses (Kuhn) ...	70·80	2·60	0·70	11·70	12·10	2·10	1—4·7

If we compare these analyses with the analysis of hay, we shall find that to replace the nitrogenous, fatty and carbo-hydrate matter found in 100 parts of hay we shall require of grass the following proportions:

	Nitrogenous Matter.	Fatty Matter.	Carbo-hydrates.
Meadow Grass (Grandeau)	193	244	423
Grass before flowering	337	292	338
Grass after flowering ...	404	328	286
Meadow Grass (Kuhn)	274	375	316
Different sweet grasses	327	428	327

We may say that, roughly, 36 lb. grass will replace the nutriment in 10 lb. hay.

With regard to the saline matters found in grass, Wolff gives the following analysis:

TABLE SHOWING SALINE COMPOSITION OF FRESH AIR-DRIED GRASS—AVERAGE QUANTITY IN 1000 PARTS OF SUBSTANCE.

—	Water.	Ash.	Potash.	Soda.	Magnesia.	Lime.	Phosphoric Acid.	Sulphuric Acid.	Silica.	Chlorine.	Sulphur.
Meadow Grass in blossom ...	700	23·3	6·0	1·6	1·1	2·7	1·5	1·2	6·9	1·9	0·6
Young Grass	800	20·7	11·6	0·4	0·6	2·2	2·2	0·8	2·1	0·4	0·4
Rye Grass ...	700	21·3	5·3	0·9	0·5	1·6	1·7	0·8	8·4	1·1	0·7
Timothy Grass	700	21·0	6·1	0·6	0·8	2·0	2·3	0·8	7·5	1·1	0·8
Other Grasses	700	21·8	7·2	0·4	0·6	1·2	1·7	1·0	8·2	0·9	0·7
1 Ton of Meadow Grass will yield in pounds ...	1675	42	11·2	2·3	2·0	5·6	2·5	2·1	11·5	3·2	...

A consideration of the principal grasses found in hay must briefly occupy our attention. Though I fully appreciate the fact that some grasses are good and others inferior for forage purpose, yet I do not draw that hard and fast rule between good, inferior, and bad grasses, for the reason that I am convinced we know but little regarding the individual properties of the inferior grasses, until each species has been, by direct experiment, proved hurtful or innutritious; moreover, an inferior grass on one soil may be one of feeding value on another. The opinion I have expressed receives great support from a statement made by Mr. Sutton, in his beautifully illustrated

PLATE I.

FIG. 1.

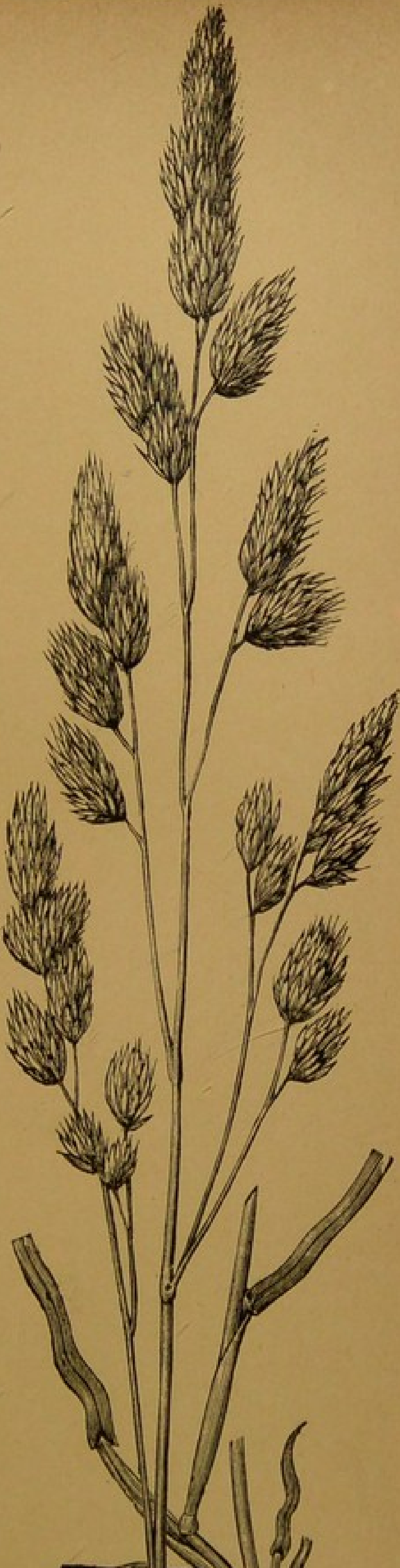
ALOPECURUS PRATENSIS.
(*Meadow Foxtail.*)

FIG. 2.

ANTHOXANTHUM ODORATUM.
(*Sweet Vernal.*)

(Dicksons.)

CYNOSURUS CRISTATUS.
(*Crested Dogstail.*)



DACTYLIS GLOMERATA.
(*Cocksfoot.*)

(Dicksons.)

work on 'Permanent and Temporary Pastures,'* where he says that Meadow Smooth Grass, an inferior grass with us, is the staple grass crop in America, whereas in New Zealand it is a useless weed. Yorkshire Fog, a grass carefully avoided by the English farmer, is much appreciated in New Zealand. The much abused couch grass is considered on the continent a valuable food. In selecting grasses for the production of hay and pastures, the peculiarities of the soil must be considered, so that those most suited to its formation may alone be cultivated. The best grasses, if planted in an unsuitable soil, become useless. Sutton tells us he has known pastures ruined through the indiscriminate introduction of Cocksfoot. The selection of grasses for pastures is the province of agriculture. What I have endeavoured to show is that hay containing so-called inferior grasses should not too hastily be condemned as second-rate, nor should it be judged entirely by the grasses which comprise it.

The following grasses are those most appreciated for pasturing and hay production: Meadow Foxtail, Sweet Vernal, Crested Dogstail, Rye Grass, Timothy, Cocksfoot, the Fescues, smooth and rough-stalked Meadow Grass, and yellow Oat Grass.

Alopecurus Pratensis, *Meadow Foxtail* (Plate I., Fig. 1). —Is deemed a most valuable grass; it is very hardy, blooms early, and has a large bottom growth.

Anthoxanthum Odoratum, *Sweet Vernal* (Plate I., Fig. 2).—An early spring crop with scanty leaves, contributing but little to hay. Its chief property is supposed to be that of giving to hay its peculiar fragrance, in which case its value is probably more tonic and stomachic.

Cynosurus Cristatus, *Crested Dogstail* (Plate II., Fig. 1).

* This book contains, amongst other valuable information, analyses of the principal grasses.

—A very hardy grass, much liked by sheep; but, for general purposes, it is falling in public favour.

Dactylis Glomerata, *Cocksfoot* (Plate II., Fig. 2).—Mr. F. de Laune, in his essay on 'Laying down Land to Permanent Grass' (*Journal Royal Agricultural Society*, vol. xviii., Part I.), says of it: 'This is by far the most valuable of all grasses; it grows in all soils, produces the greatest amount of keep, is the most nutritious grass, and seems to grow faster and stronger than any other.' The opinion of this authority has caused this grass to occupy a more important place than it has done hitherto. It grows rapidly, producing good bulk, and affording excellent pasturage. Sutton says it should not be found in upland hay, owing to its coarseness.

Festuca Ovina, *Sheep's Fescue* (Plate III., Fig. 1).—Is a valuable forage grass, but little use for hay; hardy, much liked by sheep, and said to produce a fine wool. It prefers a high, dry, poor sandy soil, and it is generally considered that where this grass is found such soil is healthy for pasturing sheep.

Festuca Duriuscula, *Hard Fescue* (Plate III., Fig. 2).—An excellent forage grass, constituting a great portion of some of the best pastures. Hay in which it is found is generally considered of superior quality. It is a wonderfully hardy grass, and is found to resist severe drought.

Festuca Pratensis, *Meadow Fescue* (Plate IV., Fig. 1).—Considered by some to be the most valuable of forage plants. It makes excellent hay, prefers a moist soil; it is one of the earliest grasses, and much appreciated by stock.

Festuca Elatior, *Tall Fescue* (Plate IV., Fig. 2).—A grass rising somewhat in public favour, though considered by Sutton to be unfit for hay, owing to its coarseness. It is liable to become ergotized; it yields largely, and is best suited to damp soils.

PLATE III.

FIG. 1.

FESTUCA OVINA.
(*Sheep's Fescue.*)

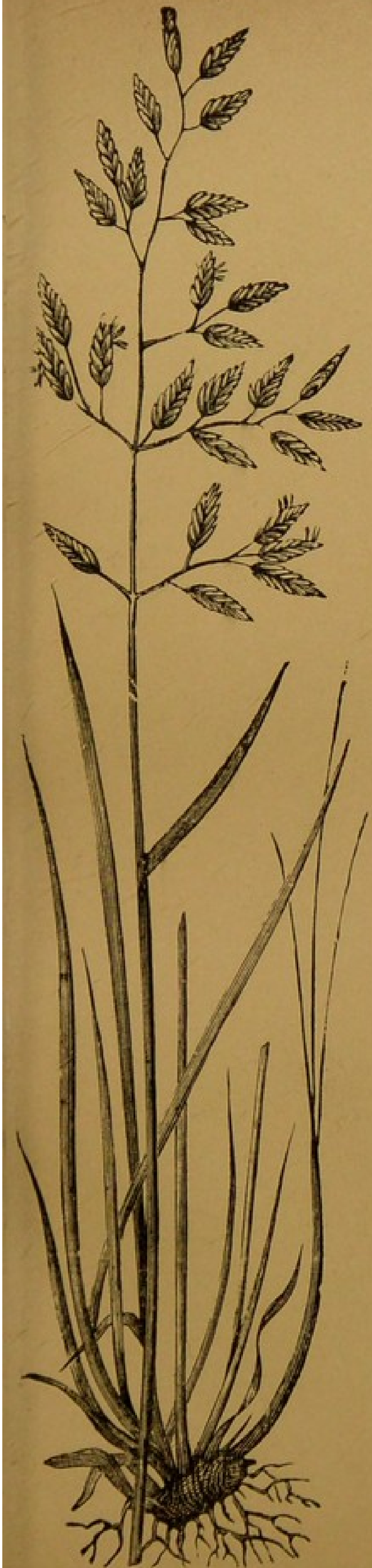
FIG. 2.

FESTUCA DURIUSCULA.
(*Hard Fescue.*)

(Dicksons.)

PLATE IV

Fig. 1.



Festuca Pratensis.
(*Meadow Fescue.*)

Fig. 2.

Festuca Elatior.
(*Tall Fescue.*)

(Dicksons.)

Lolium Italicum, *Italian Rye Grass* (Plate V., Fig. 1).—Is a heavily yielding, highly nutritious grass, much appreciated by cattle; it grows best in a damp soil, and is very hardy. It is biennial, and unfit for permanent pastures.

Lolium Perenne, *Perennial Rye Grass* (Plate V., Fig. 2).—The value of this grass is doubted by many. Sutton speaks in the highest terms of it, and says that it is next to Foxtail in nutritive properties, and that feeding experiments on cattle have proved this. Rye Grass chaffed is recommended by this observer as being substantial food for horses and cattle.

Phleum Pratense, *Timothy* or *Meadow Catstail* (Plate VI., Fig. 1).—On certain soils, as clay, this is a most valuable grass; it is exceedingly hardy, very nutritious, produces a bulky hay, and is much liked by horses and cattle.

Poa Pratensis, *Smooth-stalked Meadow Grass* (Plate VI., Fig. 2).—A grass of doubtful value; it is principally used for pasture purposes, and, being a very early grass, it has been much appreciated.

Poa Trivialis, *Rough-stalked Meadow Grass* (Plate VII., Fig. 1).—A valuable pasture grass in damp shaded places. It is considered the most valuable of the Poas; is of rapid growth, and most productive.

Avena Flavescens, *Yellow Oat Grass* (Plate VII., Fig. 2).—Is a valuable forage plant, especially on calcareous formations. Sheep and cattle are very fond of it.

I have before said how difficult it is to draw a hard and fast rule between some grasses, but the foregoing exhibits with fair correctness the good and useful plants. The grasses which should principally form a permanent pasture are: the Fescues, Cocksfoot, Foxtail, and Timothy.

The following grasses are worthless: Hair Grass, False Oat Grass, False Brome, Quaking Grass, Brome Grass, Yorkshire Fog, Barley Grass, Couch Grass.

Hay.

Hay is of three kinds, upland, meadow, and water-meadow.* The latter is unfit for horses, and of the two former the upland is considered the best. *Upland hay* is short, fine, of pleasant odour and taste, stem hard and crisp, and it is generally mixed with some of the artificial grasses, as clover; the colour varies, depending on its preparation, but it inclines to green: the flowering heads of the grasses should be plentiful. *Meadow hay* is long, stems rather hard, though in indifferent specimens these may be soft; compared with upland it is coarser, darker in colour, and the aroma greater, though this varies according to its preparation; the taste, owing to the coarseness of some of the grasses, is not so sweet. It consists also of a variety of grasses and other plants not belonging to the order. *Water-meadow hay* is long, hard, coarse, tasteless, without odour, and mixed up with water-plants—animals eat it with reluctance; it is neither good for labour, flesh, nor milk.

Very much depends on the mode of growth, and the time at which the hay is saved. Hay made from grasses growing in sheltered spots, as under trees and hedges, is insipid and of but little feeding value; and hay cut too late has lost a considerable amount of its nutriment. It is evident that a variety of hays exist in the market, and these, for convenience of description, may be divided into three classes.

1. The best hay is one year old, of a rather greenish tint,

* The best account of hay, and forage generally, with which I am acquainted, will be found in 'Horses and Stables,' by General Sir F. Fitzwygram, F.R.C.V.S. I am much indebted to this book for many practical hints on hay, and have summarised the information given on this subject.

PLATE V.

FIG. 1

LOLIUM ITALICUM.
(*Italian Rye Grass.*)

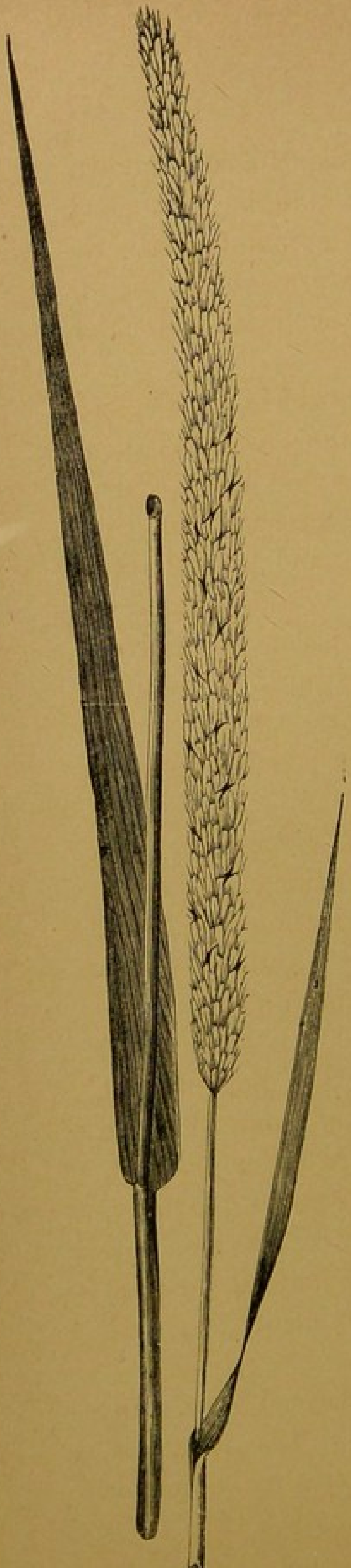
FIG. 2.

LOLIUM PERENNE.
(*Perennial Rye Grass.*)

(Dicksons.)

PLATE VI.

Fig. 1.



Phleum Pratense.
(*Timothy, or Catstail.*)

Fig. 2.

Poa Pratensis.
(*Smooth-stalked Meadow Grass.*)

(Dicksons.)

hard and long, clean, fresh, and possessing a well-known aroma and sweet taste. Its infusion should be of a good brown tint, and in the truss flowers are found partly retaining their colour; a large variety of grasses are found, and an abundance of flowering heads: such are the chief characteristics.

2. Hay of medium quality, if old, is tasteless, brittle, and dusty; or if affected in quality from other causes, is short and fine, deficient in a variety of grasses; or short, coarse, and dark in colour, aroma altered, taste perhaps pungent; the best grasses are not generally seen, and a few weeds are present.

3. Hay of bad quality is mouldy, brittle, offensively smelling, innutritious, perhaps dark brown in colour. If composed of water-meadow grass these are seen in abundance, giving a great coarseness to the truss, which is deficient in colour, aroma, and flavour.

The two last classes often insensibly verge into each other, but as a class they must remain distinct, as there is an undoubted hay of medium quality which, though unsuited for hard-worked or valuable animals, is yet useful for a certain class of horse, as not containing anything positively injurious, but simply, either through a bad season, bad sowing, or being a second crop, it lacks that nourishment contained in the best quality, but contains none of those hurtful properties found in hay of the third order. Again, hay originally of the best quality, will, if kept too long, lose much of its nourishment, and certainly become medium-class forage. By bad hay I mean it to be understood that in this I class all which is positively hurtful or possessed of no nutriment.

Hay when less than one year old is termed new. In this condition practical experience has shown that it is not fitted for feeding purposes, being liable to create abdominal disturbance, is difficult to digest, and produces purging, skin irritation, and urticaria. If we are obliged to use it, it should be given in small quantities, and mixed with old hay. Old hay is so called after its first year, and it retains its full nutritive properties for one year more. New hay is distinguished from old by its green colour, more powerful aroma, the fibres containing sap, particularly at the joints, and it is softer than old hay. A truss of old hay weighs heavier than new, owing to the amount of consolidation which has taken place in the rick. There are many conditions which affect these appearances, and it is not always easy to determine old or new hay. Sir F. Fitzwygram tells us that 'apart from the special knowledge of the growth of the year and the preceding year, no one rule can be given for distinguishing old from new hay.'*

I analysed a specimen of new hay, and found it to contain:

Water	16·000
Albuminoids	7·875
Fats	1·780
Carbo-hydrates...	68·325
Salts	6·020
	100·000

The second or third cutting of hay is termed the aftermath. It is greener than hay, softer and more flexible, contains weeds and roots; there is an absence of flowering heads, and the odour is less marked than in good hay, even

* The only certain plan of distinguishing between old and new hay is to ascertain the amount of moisture by drying at 212° F. For this purpose one pound of hay should be taken (unless a delicate balance is obtainable) and carefully dried in an oven for some hours; it should then be weighed again, and the difference between the two weights is the moisture. In new hay this is 16 % or more, in old hay it is about 13 % or 14 %.

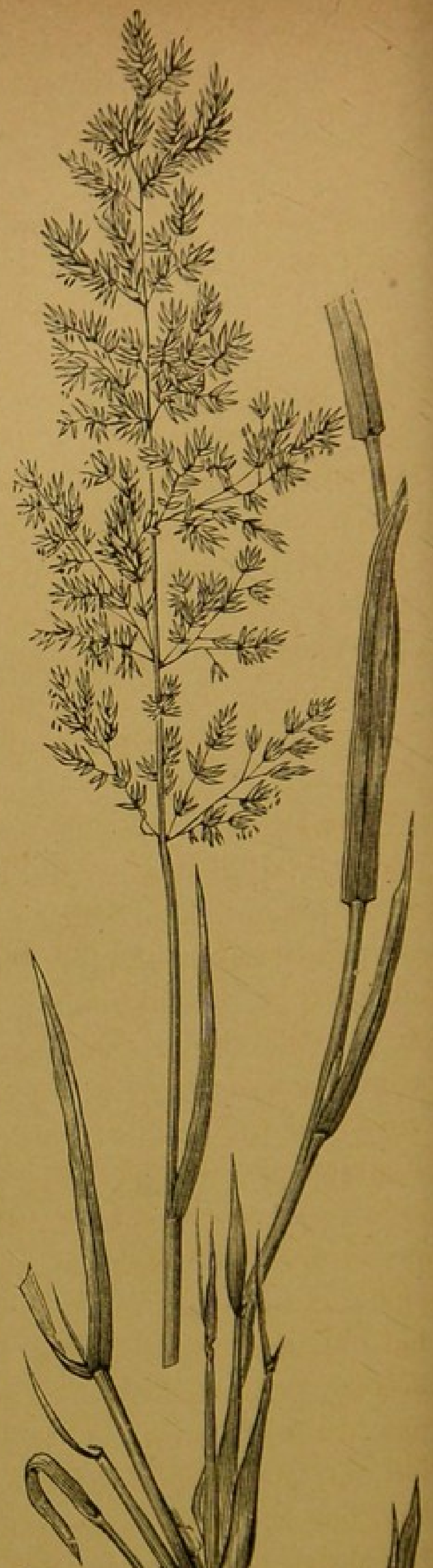
Fig. 1. PLATE VII. Fig. 2.

Poa Trivialis.
(*Rough-stalked Meadow Grass.*)

Avena Flavescens.
(*Golden Oat Grass.*)

(Dicksons.)

Poa Nemoralis.
(*Wood Meadow Grass.*)



Agrostis Stolonifera.
(*Fiorin.*)

(Dicksons.)

if well prepared, but badly saved it is entirely wanting in perfume. Owing to the greenness of the crop and the amount of moisture it contains, it is very difficult to save properly. Aftermath, according to chemical analysis, is rich in nitrogen and salts, but deficient in carbo-hydrates and hydro-carbons; it is considered useful feeding for cattle, either for milking or fattening purposes.

The theory of hay-making is important to understand from a dietetic point of view. Experience has shown that grass is best cut when in flower and before the seeds fall; but chemistry explains the reason of this, and elaborate experiments have been made to show the composition and value of the plant at its various stages of development.

The following are the results of these experiments: The stems and blades of grasses contain albuminates, carbo-hydrates, and hydro-carbons. The carbo-hydrates interest us principally in the process of hay-making; they are produced from the chlorophyll cells of the leaf. As the plant ripens the starch and sugar become less, and there is a conversion of these substances into cellulose; so that the riper the plant the more cellulose and the less carbo-hydrates it contains. The time, therefore, at which grass is cut affects considerably the quantity and quality of the produce. The weight is actually less when it is cut fully ripe; and experience shows that if cut soon after the plant has obtained its full height, before the carbo-hydrates have become converted into cellulose, before the albumen has passed into the seeds, and whilst flowering, before the seeds fall out, that this period not only yields a better quality of hay, but the land is less exhausted. In the rick, part of the starch under the process of fermentation becomes converted into sugar, and the latter into alcohol and acetic acid. Overheating in the stack produces a sour forage;

but the cellulose, by the same process, is acted upon and rendered more digestible.

According to Voelcker, the changes which occur in ricked hay are : the rise in temperature of damp hay is attended by a change in colour and a great loss of sugar, other soluble carbo-hydrates, and soluble albuminoids; whilst aldehyde and acetic acid are formed. Hosaus says that ammonia is formed. The loss of organic matter in dark brown hay is shown by the increase in the amount of ash.

The chief point to observe in hay-making is that the crop, once cut, should remain as short a time as possible in the field. If left to lie in the sun it loses its colour and flavour, and becomes dried up; a difference of an hour on a hot day is said to occasion a loss of 15 to 20 per cent. in the hay. If exposed to rain, much of its valuable properties are washed out of it; as much as 5 per cent. (out of 6 to 8½), it is said, may be removed in this manner; the saline matter also suffers from this cause. Hay should not be turned during wet or damp weather, for it is not only bruised, but it exposes another surface to the solvent action of the rain. The time at which the hay can be carried varies with the succulence of the grass, but if possible it should be the second, third, or fourth day. Uniformity of colour is obtained by careful turning and exposing all parts equally to the sun and air. The chlorophyll by exposure becomes oxidized, and the colour is changed. The longer the exposure the greater the loss of colour; hence to preserve the colour it should be ricked as early as safe. The peculiar aroma of hay is due to a volatile organic compound (though others attribute it to the sweet-scented vernal grass), which in badly-saved hay is destroyed. In England the greatest care is exercised to preserve the colour and aroma, and this is secured by repeated turning and rapid drying; in Scotland, where little natural hay is made (that principally produced being from clover and rye grass), less turning is done, and the crop is allowed to remain a week or ten days on the ground. Scotch hay consequently bears an indifferent name. Irish hay is poor in quality, owing to its being left in the fields for a considerable time exposed to the elements. The annual money loss from this cause has been computed at £1,500,000. When hay is stacked it undergoes a certain amount of heating which improves its flavour and nutritive properties; but if carried beyond a certain point deterioration occurs. Hay ricked in a damp or dewy state moulds and becomes rotten. Two tons of hay per acre is an average yield. Hay should be allowed to remain ricked for one year before use.

Hay may be badly saved, dusty, mow-burned, or musty; each of these conditions affects its nutritive value. and must be considered separately.

Badly-saved hay.—The damage may be slight, such as results from a single shower of rain; or the forage may be bleached, sapless, and deficient in aroma, the result of exposure to bad weather; it is a matter of degree, but when affected to any extent it is only fit for bedding.

Dusty hay arises from exposure to bad weather, or too long exposure to the sun; or it may be simply a process of dry decay produced by insects, which under other circumstances might have gone on to mouldiness.

Mow-burned hay is the result of fermentation in the stack, over and above that necessary for the development of the nutritive properties; when carried to this degree it affects the colour of the forage, turning it dark brown, the hay becomes dry and brittle, the taste is very pungent, and the odour powerful. Slightly mow-burned hay is not objected to by some horses, as it contains a large amount of sugar, and the aroma is not unpleasant; but when badly affected, the sugar becomes converted into acetic acid, and such hay will produce derangement of the digestive and urinary systems. Stewart observes that hay slightly damaged is partaken of with avidity at first, but after about a week the horses reject it in disgust. Mow-burned hay acts as a diuretic; the discharge of perfectly clear urine is copious, producing excessive thirst; the animal falls off in condition, becomes listless and weak, and is in the very state to contract any serious disorder to which it may be exposed. I analysed a specimen of slightly mow-burned hay, and found it to contain:

Moisture	13·80
Albuminoids	7·43
Fat	2·30
Carbo-hydrates	72·17
Ash	4·30
	100·00

Musty hay is that which has been exposed to wet and damp, either in the rick or before being stacked. Fungi are plentiful in it, the odour is unpleasant; it is dark and soft, and of a bitter taste. Mouldy hay is liable to produce disease. Whenever occasions arise in which it has to be used as food, it should be given in small quantities, after being dressed with a solution of common salt, and its action carefully watched.

Hay kept in lofts above stables not furnished with an air-tight roof is likely to become deteriorated from exposure to the emanations from the stable below.

Nutritive value of hay.—A great degree of difference exists in the amount of proximate principles contained in hay. This depends upon the growth, in which perhaps the soil plays the chief part; it is a well-known fact that certain pastures (or the hay grown on them) are celebrated for their fattening properties, whilst adjacent lands of the same formation produce grass or hay very inferior in nutritive value. The following table of analyses gives the composition of hay according to the views of each chemist.

	Boussingault.	Sanson.	Grandeau.	Garola.	Wolff.	Voelcker.	American Farming.		
							Full Bloom.	After Bloom.	Before Bloom.
Albuminoids	7·20	8·50	10·11	8·40	9·5	9·88	8·63	9·44	11·63
Carbo-hydrates	44·20	38·30	40·90	41·00	41·7	48·09	36·11	41·40	36·01
Lignin and Cellulose ...	24·20	29·30	25·52	26·80	28·7	31·80	31·21	24·18	20·10
Fats	3·80	3·00	2·34	2·90	2·6	2·99	4·22	4·55	4·31
Salts ...	7·60	6·02	6·54	6·70	5·8	7·24	4·66	6·19	5·30
Water ...	13·00	14·30	14·59	14·20	14·3	14·30	7·45	7·13	7·79

One hundred parts of hay dried at 212° Fahr. contain:

Carbon	45·8
Hydrogen	5·0
Oxygen	38·7
Nitrogen	1·5
Ashes	9·0
	100·0

The nitrogenous ratio of hay given in the above table is, commencing with Boussingault's analysis, $\frac{1}{6\cdot6}, \frac{1}{4\cdot8}, \frac{1}{4\cdot2}, \frac{1}{5\cdot2}, \frac{1}{5\cdot2}, \frac{1}{4\cdot6}, \frac{1}{5\cdot0}, \frac{1}{5\cdot1}$. We may take it, therefore, that the mean nitrogenous ratio of good hay is 1 : 5, and this, as we have shown before, is the most suitable physiological ratio. The mean fatty ratio of hay is 1 : 3, and the complete nutritive ratio 1 : 8·4.

The saline matters found in hay are of great importance. Wolff gives the following analysis:

TABLE SHOWING THE COMPOSITION OF THE SALINE MATTERS OF GRASS AND HAY.

	Per cent. of Ash.	Potash.	Soda.	Magnesia.	Lime.	Phosphoric Acid.	Sulphuric Acid.	Silica.	Chlorine.
Meadow Hay	7·78	25·6	7·0	4·9	11·6	6·2	5·1	29·6	8·0
Dead Ripe Hay ...	7·73	7·6	2·9	3·4	12·9	4·4	·7	63·1	5·7
Young Grass	9·32	56·2	1·8	2·8	10·7	10·5	4·0	10·3	2·0
Rye Grass in Flower	7·10	24·9	4·2	2·1	7·5	7·8	3·8	39·6	5·4
Timothy	7·01	28·8	2·7	3·7	9·4	10·8	3·9	35·6	5·0
Other Sweet Grasses	7·27	33·0	1·8	2·6	5·5	7·8	4·4	37·6	4·1

The soluble saline matters, such as the salts of the alkalies and the sulphates and chlorides of magnesium and lime, occur principally in the sap of the grass, whilst those matters insoluble in water, as silica, phosphate of lime, and magnesia, are found in the structure of the plant. By the union of the bases and acids in hay, we have formed those salts so essential to the nutrition of the body fluids and solids, and which not only play the part of carriers of nutritive matters into, but also conveyers of effete material out of the system.

We have previously shown that hay (or grass) is the natural food of herbivora, and this is proved not only by everyday facts, but from its chemical composition. The nitrogenous, fatty, starch and sugar bodies, and salts, are found in it in the proportion best suited to the wants of the system, and we have proved that in hay or grass alone is found all the nutriment necessary for animals doing slow work. Once, however, labour is enforced from them, the waste incurred is such that either more hay must be given than is suited to the physiological arrangement of the viscera, or else we must add to hay a food which contains the necessary principles in a small bulk. We establish hay, therefore, as the standard diet, and judge of the other foods from it as explained under the head of nutritive equivalents.

The quantity of hay given to horses varies with their work, and depends upon their other feeding. Racehorses supplied with an unlimited quantity of corn eat but little hay, not more than five or six pounds daily; large draught-horses may consume as much as twenty or thirty pounds. The mean allowance of hay for horses doing ordinary work and receiving corn, is about twelve pounds; the faster the work the less hay given, for the physiological reason that the action of the diaphragm and lungs must not be interfered with by distended intestines. Horses at work unlimited in their hay, especially if the corn allowance is small, fall off in condition, the belly becomes pendulous, the animal unthrifty and unfit for work. In this case an enormous amount of material is being taken into the system to supply the wants of it; but which, from its bulk and the digestive powers of the animal, is unfit for the purpose. Twelve pounds of medium hay per diem are necessary for the internal work of the body.

Artificial Grasses.

These constitute rather a large class, all of which are valuable for feeding purposes. They belong to the natural order Leguminosæ, and their chemical composition shows them to contain those substances necessary for nutrition.

The following table by Wolff shows their composition in the green state:

TABLE SHOWING COMPOSITION OF ARTIFICIAL GRASSES.

	Red Clover, Trifolium pratense.	White Clover, Trifolium repens.	Swedish Clover, Trifolium hybridum.	Italian Clover, Trifolium incarnatum.	Yellow Clover, Medicago lupulina.	Vetches.	Lucern, Medicago sativa.	Sainfoin, Onobrychis sativa.
Water	78·0	80·0	82·0	81·5	80·0	82·0	74·0	79·32
Albuminoids ...	3·7	3·5	3·3	2·7	3·5	3·1	4·5	3·42
Carbo-hydrates	8·6	8·0	6·3	6·7	9·0	7·6	7·0	7·43
Fats	·8	·8	·6	·6	·8	·6	·7	·40
Cellulose ...	8·0	6·0	6·6	7·5	6·0	5·5	12·5	8·10
Salts	1·7	2·0	1·8	1·6	1·5	1·8	2·0	1·73

The mineral matter in these plants consists of much the same as we before noticed in grasses; the potash is from 20 to 30 per cent.; magnesium, 10 to 15 per cent.; lime, 30 to 40 per cent.; phosphoric acid, 9 to 12 per cent.; sulphuric acid and silica, 2 to 6 per cent.

When these artificial grasses are converted into hay, the proportion of albuminoids per cent. is nearly equal to that of oats. The following table exhibits these analyses:

TABLE SHOWING COMPOSITION OF ARTIFICIAL HAY.

	Red Clover Hay.	White Clover.	Swedish Clover.	Italian Clover.	Yellow Clover.	Vetches.	Lucern.	Sainfoin.
Water	16·7	16·7	16·7	16·7	16·7	16·7	16·7	14·2
Albuminoids ...	13·4	14·9	15·3	12·2	14·6	14·2	19·7	14·8
Carbo-hydrates	29·9	34·3	29·2	30·1	36·5	35·3	32·9	35·7
Fats	3·2	3·5	3·3	3·0	3·3	2·5	3·3	3·3
Cellulose ...	35·8	25·6	30·5	33·8	26·2	25·5	22·0	26·4
Salts	6·2	8·5	8·3	7·2	6·0	8·3	8·7	6·2

In its chemical composition artificial is distinguished from natural hay by its containing a larger amount of albuminoids, but less fats and carbo-hydrates; of the mineral matter the phosphates in the artificial grasses are less than in the natural.

The nitrogenous ratio is much too high for these foods to be used alone, or in large quantities; the ratio is usually about 1 : 2·5 but in the analysis given of lucern it is 1 : 1·3. All these artificial grasses require to be mixed with hay, and given in small quantities. Broken wind and other diseases of the air-passages have been attributed to an undue allowance of clover. Stomach staggers has been said to be produced by vetches. Trifolium hybridum, 'alsike clover,' has been known to produce derangement of the liver and bowels, to blister the mouth, and cause great prostration of the vital powers.* Trifolium incarnatum has caused death by an accumulation of the dry, husky, prickly, and indigestible heads in the bowels; this was produced by cutting too late after blossoming.† Owing to the amount of moisture in clover, there is great difficulty in converting it into hay, the result is that much of it is mouldy and rank, and as such is liable to produce disease of the bowels, etc. The trefoils are said to contain an acrid principle very irritating to the kidneys.

All this only shows us that artificial grasses, useful as they are, must be given with caution and their effects observed.

A variety of artificial grass, used largely on the Continent, and termed Lupine, has for some time been known as very poisonous to animals. The poisonous principle is called lupinotoxine, and is fatal in small doses; by some it is attributed to fungi, by others to the phosphorus contained in it, which produces fatty degeneration of the liver. Sheep

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* For a full account of these interesting cases see the *Veterinary Record*, vol. iv., p. 345; vol. v., p. 20.

† *Veterinary Journal*, vol. iii., No. 14.

suffering from the effects of lupine poisoning are constipated, the conjunctiva becomes yellow, and irritation of the bladder is present. The disease is very fatal.

The following are the artificial grasses generally in use, with a few short notes on their value as food.* Yarrow or common milfoil, *Achillea millefolium*, is highly astringent, liked by sheep, but more useful as a condiment than for feeding. Wild chicory or succory, *Chicorium intibus*, liked by cattle, but said to impart an unpleasant taste to milk. Common Birdsfoot Trefoil, *Lotus corniculatus*, a valuable food, highly nutritious, and said to be equal to the clovers; it yields a great bulk of herbage, and withstands drought. Greater Birdsfoot Trefoil, *Lotus major*, yields more herbage than the last, and is equally valuable. Common yellow clover, or trefoil, *Medicago lupulina*, is not relished by cattle. Lucern, *Medicago sativa*, a valuable fodder, yielding good crops for eight or more years. Common sainfoin, *Onobrychis sativa*, an important forage crop, not unlike lucern in its habits of growth; it lasts for eight or ten years. It is said by Sutton to be free from the danger of producing tympany. Common parsley, *Petroselinum sativum*, eaten particularly by sheep, and believed to act as a preventive to hæmo-albuminuria and 'rot.' Hybrid or alsike clover, *Trifolium hybridum*, considered one of the best perennial clovers, is found to thrive on 'clover-sick' lands. Scarlet, crimson, or Italian clover, *Trifolium incarnatum*, a valuable food, yielding abundantly. Red clover, *Trifolium pratense*, a luxuriant fodder, but the land on which it grows soon becomes 'clover-sick.' White or Dutch clover, *Trifolium repens*, an excellent fodder; when too common in meadows is supposed to produce diarrhœa in cattle. Vetches afford excellent feeding; the seed is usually sown with rye, oat,

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* This portion is compiled chiefly from a pamphlet on 'Grasses,' by Mr. J. McKenzie, Seedsman, Cork.

or Italian rye grass, as the stems do not stand erect. Common whin, furze, or gorse, *Ulex europæus*, a well-known shrub, affording after preparation fair feeding for cattle. In the Peninsula our cavalry had little else for their horses. It has been used extensively in Wales and Scotland as an ordinary article of forage. The succulent shoots are cut off, and the plants so bruised as to prevent the prickles proving hurtful. The daily allowance of furze should be from 18 to 26 lb. One acre is sufficient for six horses for four months. It takes two years for furze to grow.*

The amount of artificial forage which should be given to horses must vary according to circumstances; in its green state it should be used sparingly, especially with horses which are brought on to it for the first time, as it is liable to undergo fermentation in the intestinal canal and cause tympany; it also produces azoturia. In the form of hay a sparing use should be observed, remembering its highly stimulating properties (we refer here particularly to the use of clover). One-third to two-thirds hay would be a judicious mixture for ordinary use. Lucern is a valuable food in the infirmary stable. An Egyptian clover is thought very highly of in that country; I.V.S. Meyrick, C.B., informs me that the Egyptians put their horses through a course of it every year, with the object of preventing liver disorders, and he pertinently suggests that the chlorophyll may have this effect.

The feeding value of these artificial grasses causes much difference of opinion; some people assert that the clovers are the best, others point to lucern and sainfoin. It is again important to note that owing to the indigestion produced by the consumption of large quantities of these plants in a green state, they should only be used in moderate quantities

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* Stewart's 'Stable Economy.'

and mixed with chaff, or otherwise they are all liable to produce abdominal disease ; in a judicious proportion they produce a gentle laxative effect, and by this and their diuretic action are cooling to the system.

Straw.

The straws used as fodder are derived from two natural orders of plants, one the Graminaceæ, the other the Leguminosæ. To the first belongs straw obtained from wheat, rye, oats, barley, rice, maize, and millets ; to the other class belongs the straw of beans and peas.

The straws of the cereals are those generally in use ; if intended for fodder they should be cut before the plant is too old, otherwise the amount of nutriment decreases owing to an increase in the indigestible fibre. The best straw should be long, clean, of a yellow colour, sweetish or insipid taste, and of a pleasant odour.

The following table from Grandeau and Wolff exhibits an analysis of the various straws :

TABLE SHOWING ANALYSIS OF CEREAL STRAWS.

—	Water.	Nitrogenous Matter.	Fatty Matter.	Carbo-hydrates.	Cellulose.	Salts.
Wheat Straw ...	13·55	3·03	1·10	40·90	37·48	3·94
Oat " ...	13·63	4·55	1·64	36·95	37·97	5·26
Barley " ...	13·31	3·57	1·90	32·07	42·00	7·15
Maize " ...	14·00	3·00	1·10	37·90	40·00	4·00
Rye " ...	13·00	3·61	1·35	33·42	44·65	3·97

In the above analysis I think the nitrogenous matter is over-estimated ; Wolff puts it at from $1\frac{1}{2}$ to $2\frac{1}{2}$ per cent., and I think this is more correct. As previously noted in other cases, the composition must vary according to the age of the plant. In oat straw analysed by Voelcker before maturity, he found the nitrogenous matter to equal 8·49 per cent.; later it was 4·08 per cent.; and when long past maturity it was 3·65 per cent. The mean nutritive relation of the straws is about 1 : 10·8, although Boussingault from his analysis made it 1 : 20·5.

The straws are deficient in nitrogenous matter, contain an excess of cellulose, but are rich in carbo-hydrates; they are useful in diets for giving bulk, in furnishing carbo-hydrates, and from their nature, when mixed in a chopped condition with grain, cause it to undergo mastication. Wheat straw is considered the best; its chemical composition shows it to be inferior to the others, but there is an agreeable taste about it which causes it to be preferred by most horses. Oat straw is considered more digestible than the others, its nutritive relation is much better, and Voelcker states that the cellulose and indigestible fibre are better balanced than in the other straws, and unhesitatingly declares that it is the most nourishing of all. Barley straw is considered very indigestible; rice straw and the straw of the millets are in general use in India; we have no analysis to hand of either, but the first is certainly poor in nitrogenous matter. The straw of the millets is much appreciated in Southern India for cattle feeding; working animals get little else.

Straw is seldom used for feeding horses excepting in the form of chaff; for cattle it is much appreciated, being useful in affording bulk as well as nutriment. There can be no doubt of its value in supplementing the hay ration, when the latter is, through bad seasons, dear and poor. In France, wheat straw for feeding horses is largely used; for fast working animals it would have to be given chopped, and, moreover, the bulk would have to be carefully regulated, or else digestive and pulmonary changes would occur.

The leguminous straws consist of pea and bean straw. The following is their composition according to Grandeau :

TABLE SHOWING ANALYSIS OF PEA AND BEAN STRAW.

—	Water.	Nitrogenous Matter.	Fatty Matter.	Carbo-hydrates.	Cellulose.	Salts.	Nitrogenous Ratio.
Pea Straw ...	14·28	7·56	2·17	29·39	42·47	4·13	1—4·1
Bean ,, ...	17·28	12·01	1·31	31·80	30·67	6·39	1—2·8

It will be observed that these straws are very nitrogenous and are nearly equal to hay ; their feeding value is consequently high, and the following table exhibits the proportion which would have to be exhibited to render them equal to 100 parts of the best hay :

	Nitrogenous Matter.	Fatty Matter	Carbo-hydrates.
Pea Straw	133	107	139
Bean ,, ...	84	178	128

These straws should be cut before they are past maturity, or else the indigestible fibre is largely increased.

For feeding purposes, pea is preferred to bean straw ; both, however, are woody, and contain a large amount of lignin ; they are less easily digested than those of the cereals on this account, still their nitrogenous matter renders them useful for feeding purposes.

THE GRAINS.

Oats.

The cultivation of oats is carried on principally in Scotland ; in that country it obtains an importance greater than that of wheat. The reason lies in the climate and soil, that of Scotland being most suitable for their production ;

wheat does not flourish when sown after clover or grass, whereas oats never succeed better than when on land of this sort. There are about sixty varieties of oat, of which twelve are in general use; of these, the four best are the Potato, Hopetoun, Sand and Early Angus. The potato is suited for good rich land, Sandy for medium land, Common Black Oats for poor land, and Black Tartary for rich moory soil.

Oats is the grain *par excellence* for horses; this has been established over and over again by practical observation, and we explain the reason of it by saying that in oats the principles necessary for nutrition exist in the best balanced condition. The nitrogenous matters are double the fatty, and the immediate principles are so arranged that a larger amount is absorbed into the system than from any other grain. The nitrogenous ratio is, taken as a mean, 1 : 5, which we have previously shown is the same as that in good hay, and the proportion best suited to the requirements of the system. These are the reasons which explain the superiority of oats over all other grains.

The analysis of oats, according to different observers, is as follows:

TABLE SHOWING THE ANALYSIS OF OATS.

—	Kuhn.	Grandeau.	Boussingault.	Wolff.	Irish Farming.	Warrington.	Stonehenge.	Mayne.	Scotch Oats dried at 212° F. Norton.
Water	13·7	12·52	14·00	14·3	14·0	13·0	12·5	14·0	—
Nitrogenous Matter ...	12·0	12·66	11·90	12·0	11·5	12·9	11·4	10·60	19·91
Fatty Matter ...	6·0	6·09	5·50	6·0	6·0	6·0	6·0	5·50	7·38
Carbo-hydrates	56·6	54·30	60·50	60·9	58·8	53·8	53·0	61·90	68·68
Cellulose and Lignin ...	9·0	11·01	4·20	10·3	7·0	10·8	20·0	4·10	2·28
Salts	2·7	3·42	3·90	3·0	3·0	3·5	2·5	3·90	2·60

My analysis of good sound oats, weighing 42 lb. per bushel, shows them to contain:

Moisture	11·40
Albuminoids	14·50
Fat	6·72
Carbo-hydrates	65·08
Salts	2·30
	100·00

In black oats I found 7·89 per cent. albuminoids.

One hundred parts of oats dried at 212° F. contain:

Carbon	50·7
Hydrogen	6·4
Oxygen	36·7
Nitrogen	2·2
Ashes	4·0
	100·0

Wagner states that 17·6 per cent. of the total nitrogen in oats is not in the form of albuminoids, but as nitric and nitrous acids, and alkaloids (amides).

The ash of oats is composed, according to Wolff, of potash, 15·9 per cent.; soda, 3·8 per cent.; magnesia, 7·3 per cent.; lime, 3·8 per cent.; phosphoric acid, 20·7 per cent.; sulphuric acid, 1·6 per cent.; silica, 46·4 per cent.

The nitrogenous ratio of oats from the above analyses is 1 : 5·2, 1 : 4·7, 1 : 5·5, 1 : 6·3, etc.; the mean ratio is therefore fixed at 1 : 5, which is that found in good hay; the following table will show how many parts of oats it takes to replace the nutritive matter found in 100 of hay:

Nitrogenous Matter.	Fatty Matter.	Carbo-hydrates.	Phosphoric Acid.
67	69	71	69

Oats and other grains are essentially concentrated food; they are readily digested, have very little cellulose, and a small quantity possesses all the principles necessary for the nutrition of the organism.

Stewart's description of what good oats should be cannot be bettered: 'Good oats are about one year old, plump, short, hard, rattling when poured into the manger, sweet, clean, free from chaff and dust, and weighing about 40 lb. per bushel.' To these characteristics Fitzwygram adds others: 'They have a clean and almost metallic lustre; each oat in a well-grown sample is nearly of the same size; there are but few small or imperfect grains; the hard pressure of the nail on the oat should leave no impression; the kernel when pressed between the teeth should chip rather than tear; the skin should be thin. The smell of good oats is earthy, the flour sweetish to the taste.' The weight of oats is an indication of their value. Light oats, such as 36 lb. a bushel, have a thick husk, and a diminished proportion of flour and salts.

New Oats are such until they are a year old; in this condition they are indigestible, often purgative, and from not affording the necessary nutriment a horse fed on them falls off in condition. 'New oats are detected by their earthy smell; the husk is shiny and bright, presenting almost a glazed appearance in the black variety; the taste is fresh and somewhat milky, and the flour when in the mouth readily adheres together; they are softer than old oats: when of the bearded variety the beards are well preserved, and the skin of the kernel is covered with very fine prickly down composed of minute hairs. *Old Oats* have lost their earthy smell; the shiny glazed appearance of the husk has disappeared; the ends of the husks and points of the kernel are a little darkened; in the mouth the flour feels dry and not easily moistened; the taste is slightly bitter; the ends of the grain are shorter and sharper, due to friction against each other, which also removes the beards; the husk is very tight on the kernel, and the latter is smooth and without the hairs' (Fitzwygram). By drying, the hurtful properties are got rid of; thus, after being kept a year they are fit for use and wholesome. Drying is sometimes hastened artificially by the aid of heat, this is known as *Kiln-drying.* This process has for its object the conversion of new oats into old by hardening the flour; or else the attempted preservation (by drying) of oats which have become damaged. Kiln-dried oats may be recognised by their smell and taste; their colour is reddish, and the husk has a loose and shrivelled appearance about the ends (Fitzwygram). In those specimens of kiln-dried oats which I have seen, there was nothing to betray the drying process. The oats were, however, in good condition. Various methods are adopted to get rid of the tell-tale appearance of damaged kiln-dried oats; they are mixed with good oats to disguise the smell, and are bleached to destroy the reddish colour. Kiln-dried oats are generally dangerous to use; it is not the actual process of drying which injures them, but the fact that only damaged varieties usually undergo this baking.

Foxy Oats are those which have undergone fermentation, owing to their being damp when stored; when dried they are of a red colour, peculiar smell, bitter taste, and they produce serious changes in the urinary organs. Percivall tells us: 'During the three years of occupation the British Army continued in France after the battle of Waterloo, Mr. Castley, V.S., 12th Lancers, had occur to him some well-marked cases of this description. They arose from the unwholesomeness of the oats served out to the cavalry, which were issued from the stores where they had lain in such enormous heaps as in a short time not only to heat, but to become literally "half rotten." This at one time caused diabetes (insipidus ?) to a "frightful extent."' Musty and foxy oats have been blamed for producing nephritis.

Fumigated Oats are those which have been artificially coloured by exposure to sulphurous acid gas for the purpose of improving their appearance and increasing their value, or to get rid of the red colour of damaged oats. The deception may be detected by the characteristic odour of sulphur being obtained by rubbing the oats in the hands until they are warm. The poorest oats absorb the largest quantity of sulphur. *Bad Oats* are those damaged at harvest, musty, dirty, mixed with dirt and rubbish, damaged by insects, rain, frost, etc. The smell is disagreeable; they have a bitter taste, and produce diabetes.

Mode of Administration.—Oats are given whole or crushed; mixed with other grain, or given alone as circumstances require. Crushing is useful; it prevents waste where an animal has a weak digestion or imperfect teeth, and would be more generally practised but for the trouble of preparation. In Australia oats are given principally in the straw; the objections against this practice are those urged by Stewart, viz., that it is impossible to say how much the horse gets, and the process is wasteful.

The daily allowance of oats depends on the work required; racehorses and hunters receive as much as they can consume, which will average about 16 lb. per diem. Saddle-horses, 10 lb. to 12 lb.; army horses, 10 lb.; cart-horses, 10 lb. to 14 lb. When beans or peas are added to the corn, an equal weight of oats is usually deducted.

Oats should weigh from 40 to 44 lb. per bushel; the Government contract weight is 38 lb. per bushel; many inferior kinds are as low as 32 lb.

The method of weighing a bushel requires some practice; low-class dealers, by touching the measure, filling slowly, and other devices, make a specimen of oats weigh heavier than it really is. The measure should be filled rapidly, nothing should touch it, and the strike should be applied at once.

Oats yield 1 ton of grain, and 1½ tons of straw per acre.

Barley.

Barley is extensively cultivated in Britain, and is second in importance to wheat: as a diet for horses it is seldom used, and there are many opinions as to its dietetic value. In India, on the contrary, it is largely used for feeding purposes, also in other parts of Asia, and in some European countries. There are three kinds of barley in the market, of which the Chevalier is the most esteemed; it yields 54 lb. to 56 lb. per bushel. Stewart is rather in favour of barley as food for horses, and says that in a mixture it has none of the objectionable properties attributed to it. Barley has been considered as laxative, heating, indigestible, colic-producing, etc.; probably most grains used for the first time produce in horses the same effect; much depends on its mode of preparation; parched, as in India, it is good feeding. Stewart speaks of it as being boiled; given in the raw state it is certainly productive of disease, colic and flatulency being common. The awns on the barley, particularly of the common varieties, are considered to cause intestinal irritation, even enteritis and death. In the Crimea barley was blamed for producing laminitis. Raw barley has caused at various times serious mortality among sheep; in the malted form it was found to agree with them.*

The following is the composition of this grain:

* *Veterinarian*, vol. xli., 1868.

COMPOSITION OF BARLEY.

—	Kühn.	Grandeau.	Payen.	Wolff.	Nepal Barley.	Bombay Barley.	To equal the nutriment found in 100 parts of hay it would be necessary to give of barley the following proportions:—
Water ...	14·3	13·07	13·32	14·3	12·90	8·00	
Nitrogenous Matter ...	10·0	12·09	11·24	9·5	11·46	10·94	Nitrogenous Matter ... 62
Fatty Matters	2·3	2·09	2·39	2·5	1·25	1·65	
Carbo-hydrates ...	64·1	64·97	66·25	66·6	72·30	77·14	Fatty Matter ... 135
Cellulose ...	7·1	5·14	4·12	7·0	...	...	
Salts ...	2·2	2·64	2·68	2·6	2·90	2·27	Carbo-hydrates ... 67

The Nepal barley given above was analysed in the husked condition, the Bombay barley was unhusked. Good barley should have a thin, clean, and wrinkled husk closely adhering to the kernel, and should weigh from 53 lb. to 58 lb. per bushel. Barley contains nearly the same proportion of albuminoids as oats, but the fat is very much less, whilst the carbo-hydrates are larger. The nitrogenous ratio of barley is about 1 : 6.

Modes of Preparation.—Barley should be given ground, or better still, parched. The latter process facilitates its digestion owing to the bursting of the starch granules, and seems to remove from the grain the principle which causes it to disagree with horses. It has been given after being steeped in water for twelve hours; in the boiled state horses appear to like it, and in the condition known as malted are extremely fond of it.

Dark coloured or spotted barley which is unfit for malting is quite fit for feeding purposes.

Brewer's Grains.

Malting consists in steeping barley in water until it germinates; the starch is converted into sugar, and the latter by brewing into alcohol. There are several processes for it to go through before it becomes beer, and a certain amount of refuse is left during one of them which is termed 'grains.' These grains are much appreciated by dairy-men for feeding purposes, as they markedly increase the supply of milk. The following table shows an analysis of the brewer's malt and refuse :

—	Grains.	Grains.	Malt Sprouts.	Fresh Malt with Sprouts.	Dry Malt without Sprouts.
Water	76·6	77·65	8·0	47·5	4·2
Nitrogenous Matter ...	4·9	4·62	23·0	6·5	8·8
Fatty Matter	1·6	1·53	2·5	1·5	2·5
Carbo-hydrates	11·1	10·28	44·7	39·5	76·3
Cellulose	6·2	4·77	17·5	4·3	8·0
Salts	1·2	1·15	6·8	1·7	2·7

Grains should be given to horses in moderate quantities; they are supposed to produce fatty degeneration of the liver, and I think, from what I have seen, that there is some truth in it. Stewart says they are blamed for producing staggers and laminitis. Malt and sprouts are partaken of freely by horses; but I should be inclined to considerably limit the quantity given, and mix it with other food. Grains are useful in the case of a delicate feeder; from 10 to 20 lb. daily may be given to milch cows.

Maize.

This grain is largely used for feeding purposes in America and South Africa. Within late years it has found its way into the European markets, and by some is strongly recommended, on account of its cheapness, as a substitute for oats.

The chemical composition of maize is as follows:

COMPOSITION OF MAIZE.

—	Kühn.	Grandeau.	Payen.	Indian variety.	Wolff.
Water	12·7	12·38	12·54	12·90	14·4
Nitrogenous Matter... ...	10·6	9·94	10·93	9·23	10·0
Fatty Matter	6·8	5·56	7·70	1·59	7·0
Carbo-hydrates	61·0	65·40	62·58	74·63	68·0
Cellulose	7·6	4·22	15·16	...	5·5
Salts	1·3	2·47	1·09	1·66	2·1

To equal the nutriment found in 100 parts of hay it would be necessary to give of maize the following proportion:

Nitrogenous matter, 58; fatty matter, 38; carbo hydrates, 62 parts.

Maize contains less nitrogenous matter than oats, but is very rich in fat—in fact, contains more than any other cereal. The amount shown opposite the Indian variety is perhaps an error; if it is not, and is a fair sample, it shows that less fatty matter is developed in the grain by growing on Indian soil. The carbo-hydrates are large, the salts deficient, so much so that as a food for young growing animals maize should never be used without adding the necessary salts artificially.

Mode of Preparation.—It should be given crushed and mixed with chaff to ensure its mastication, otherwise it is likely to produce indigestion, particularly if the animal be worked immediately after being fed with it. It has been very much blamed for producing laminitis; but I am assured that in the Cape, where it was used entirely for feeding purposes, it had not that effect. Maize undoubtedly is a useful food, and better still when mixed with another. It was adopted in Paris by the Omnibus Company, and found by its assimilation and digestibility to be equal to an equivalent quantity of oats; though in the *Veterinary Journal* for 1879, it is stated that an attempt made to feed army horses entirely upon maize had failed, and it was reported that in whatever proportion it was substituted for oats, there was a diminution in muscle and energy. In Austria, 5,200 army horses were fed partly on maize for six months; they improved as regards their coats, but lost energy and sweated profusely at work. These observations do not agree with South African experience.

Wheat.

This is the most dangerous cereal to give horses; the animals are fond of it, and if allowed will gorge themselves, and the results are then disastrous. We have mentioned Percivall's historic account of what occurred to the horses of some regiments after the battle of Waterloo, when the animals became affected with colic and frightful tympany, the result of being turned into a field of growing wheat. Wheat has been severely blamed as a producer of laminitis. Green wheat is given to horses, especially those out of condition, with marked beneficial effects. I.V.S. Meyrick, C.B., speaks very highly of it for this purpose; he says that 10 lb. given daily to a horse out of condition will in the course of weeks produce a most complete and beneficial change. As a general grain for feeding it is never used; perhaps its price precludes it. Stewart speaks of it being given in quantities of 4 lb. daily mixed with other corn, and says that in this way it will produce no harm.

In some experiments made lately by Dr. Voelcker, the value of wheat for sheep feeding was demonstrated; about 11 oz. of whole grain were given daily.

TABLE SHOWING THE ANALYSIS OF WHEAT.

Water ...	14·0	14·4	15·0	In order to supply the same nutriment found in 100 parts of hay, it is necessary to give of wheat the following proportions :
Nitrogenous Matter ...	14·6	13·0	10·8	
Fatty Matter	1·2	1·5	2·0	
Carbo-hydrates ...	66·9	67·6	70·5	Nitrogenous matter, 48 Fatty matter, 290
Cellulose ...	1·7	3·0	2·0	Carbo-hydrates, 66
Salts ...	1·6	2·0	1·7	

The fat in wheat is very small.

There are two envelopes to a grain of wheat. The outside one consists of cellulose; within this there is a layer of rich nitrogenous matter termed *cerealine*, and within this is contained the flour. It is to this layer of cerealine that bran owes any of its nutritive properties; it gives a dark colour and soft feel to bread, and is therefore not liked for this purpose, though a process has been devised to separate the outer skin only in grinding, and to save the cerealine.

One hundred parts of wheat will, according to Letheby, yield 70 to 80 parts of good flour, 2 parts of *specks*, 2 to 3 parts of *sharps*, about 3 of *fine pollard*, from 3 to 6 of *coarse pollard*, and from 4 to 10 of *bran*.

Wheat should always be mixed with chaff in order to ensure its complete mastication.

Bran.

This is the envelope of wheat after grinding; it should only consist of the external and internal coats, ~~but sometimes, particularly with Indian~~ bran, owing to indifferent grinding, it contains much of the flour. There are two kinds, a fine variety termed pollard, and a coarse termed bran. An analysis of bran according to different chemists shows it to consist as follows :

ANALYSIS OF BRAN.

—	Payen.	Millon.	Kühn.	Grandeau.	Warington.	Wolff.
Water	13·90	13·90	13·40	12·80	14·0	13·1
Nitrogenous Matter	18·77	14·90	14·00	13·82	14·2	14·0
Fatty Matter ...	4·00	3·60	3·80	3·59	4·2	3·8
Carbo-hydrates ...	48·26	51·00	45·00	55·91	50·4	50·0
Cellulose	8·78	10·49	18·30	8·65	11·1	17·8
Salts	6·29	5·70	6·19	5·23	6·1	5·1

The nitrogenous ratio of bran varies from 1 : 2·8 to 1 : 4·3.

The salts found in bran are the following: Total salts 6·43 per cent. Of this amount potash represents 24 per cent.; soda, 6 per cent.; magnesia, 16·8 per cent.; lime, 4·7 per cent.; phosphoric acid, 51·8 per cent.; silica, 1·1 per cent. Phosphate of magnesia is the most marked salt.

Analysis shows bran to be rich in nitrogenous matter; this is the *cerealine* before spoken of. The fats are much larger than in wheat, but the cellulose is very great. Bran may be taken as an example of a food, which, if we depended on chemical analysis to determine nutritive value, we should be greatly deceived by. We know practically that bran is useless as a food given alone—that it is a useful adjunct to many is undeniable; but its gentle laxative effect is generally what we desire to bring about, and it is this which explains why it is valueless for feeding purposes. Its laxative effect is said to be due to the mechanical irritation caused by the husk; I think it very probable that there are other reasons to account for it, but which I am at present unable to definitely state; they are perhaps connected with the fermentation which the gluten undergoes.

Bran contains cerealine and another nitrogenous principle which acts on starch, converting it into sugar. The addition of bran to food may assist in the digestion of starchy principles.

Bran should have a pleasant odour, be of a yellowish tint, free from dust and dirt; when rubbed between the hands it should slightly whiten them from the flour it contains. Sawdust and sand are the principal adulterations; the latter can be readily detected by putting some of the bran in water, when the sand falls to the bottom.

Bran forms an important article of sick-diet, and the practice of administering it to horses weekly, as is regularly carried out in most big establishments and in the service, is attended with the best results. Given in large quantities it undergoes fermentation in the stomach, producing colic and not unfrequently ruptured stomach. It is stated that where bran forms a regular article of daily diet it is likely to produce intestinal calculi, of the ammonio-magnesium-phosphate variety. This is undoubtedly true. The bran contains in large quantities magnesium phosphate, and this is the explanation of millers' horses becoming so often affected with intestinal calculi. A bran mash should be made with boiling water, and remain covered up until cool enough to eat. Bran keeps sweet but for a short time; in India a few days is sufficient to render it sour. It likewise possesses the power of absorbing water to a great extent, which causes it to undergo rapid change; it becomes musty, caked in masses, and quite unfit for food.

Rye.

This is seldom used for feeding purposes, excepting on the Continent of Europe. Soils on which rye grows are poor and generally useless for any other crops. In North America it is used as corn for horses, being coarsely ground and sprinkled over straw and clover chaff. Given in this way it is said to be good feeding ('British Husbandry').

An analysis of rye shows it to consist of water, 15 per cent.; nitrogenous matter, 10·7 per cent.; fatty matter, 2·0 per cent.; carbo-hydrates, 66·9 per cent.; cellulose, 3·1 per cent.; salts, 2·0 per cent.

Rye is most subject to the attacks of ergot.

Rice.

This cereal is rarely used as a feeding grain; it is extensively cultivated all over India and Burmah, and requires for its growth a great deal of moisture, some varieties growing in several feet of water. Rice in the husk is known as paddy. The following shows its chemical composition:

Water, 13·00; nitrogenous matter, 7·44; fatty matter, ·07; carbo-hydrates, 77·63; cellulose, ·5; salts, 1·23.

The greatest deficiency in rice is the fat. Experience teaches this to the rice-feeding population, who always add fat of some sort to their food. I have no experience in feeding with this grain; it is, however, largely used in Burmah, where the ponies, I believe, receive nothing else; in Assam, also, it is given. Captain Hayes speaks highly of a mixture of gram and rice, and says it is excellent for feeding purposes. The rice is given in the form of paddy, raw, and in a broken state.

Millets.

The millets form the staple food of the people of Southern India; there are many kinds, Jowar or Jowaree, Cholum or Cumboo (*Sorghum vulgare*); Bajra (*Penicillaria spicata*); Chamay, Chenoo (*Panicum miliaceum*); Koda (*Paspalum Scrobiculatum*); Surwah or Shegapoo Thenee (*Panicum frumentaceum*); Kakum or Hicana (*Panicum stalicum*); Little Millet (*Panicum miliare*); Raggee, Murha or Maud (*Eleusine coracana*); Kiery (*Amaranthus frumentaceus*).

I have given the native names where possible (some of which are Bengal, others Madras terms), as the millets are widely diffused, and are constantly in some form or other being used in India for the feeding of animals.

Jowaree is of three kinds—a white, red, and yellow variety. The millets are more nutritious than rice; they contain more nitrogenous matter and much more fat.

The following table shows their chemical composition:

TABLE SHOWING AN ANALYSIS OF THE MILLETS.

—	*Jowaree* White.	*Jowaree* Red.	*Bajra.*	*Panicum Miliaceum.*	*P. Colo-rium.*	*Raggee.*
Water	12·70	12·00	12·40	12·00	11·96	11·16
Nitrogenous Matter ...	9·18	9·51	10·14	12·60	9·64	5·76
Fatty Matter	1·99	2·15	2·20	3·62	·60	·50
Carbo-hydrates and Cellulose ...	74·53	74·71	73·37	70·43	75·76	79·94
Salts	1·69	1·63	1·89	1·35	2·04	2·64

The parts of the millet most used as food for animals are the green stalks with young flowering heads, or the straws after threshing. The stalks may be given chopped, and are said to be good feeding mixed with the ordinary ration of grass. In the form of straw, particularly Raggee straw, it is largely used as food by the natives for their working cattle. I.V.S. Meyrick tells us* that the Belooch mares in the Western Punjab receive scarcely any other grain than Jowaree, and perform the severest marches on it.

Pulse.

The next class of food we have to consider are the pulses.

* 'Stable Management and the Prevention of Disease amongst Horses in India.'

They are a large and important group, belonging to the order Leguminosæ, and are composed of *peas, beans, and lentils.*

Peas (*Pisum*).

These belong to the natural order Leguminosæ, and are composed of many species; others, such as *lathyrus*, are closely allied to it. The peas in use are the common garden pea, *Pisum sativum;* and the field pea, *P. arvense.* It is this latter which is used for feeding purposes; it is of a grayish colour; the soils on which it flourishes are limited, but it requires a light and calcareous land. Peas are considered much more indigestible than beans, and more likely to create abdominal disturbance, such as tympany and colic. The following table exhibits their analysis:

TABLE SHOWING ANALYSIS OF PEAS.

—		Grandeau.	Kühn.	Wolff.	To replace the nutriment found in 100 parts of hay it will be necessary to give of peas the following quantities: — Nitrogenous matter, 32 parts; fatty matter, 190; carbohydrates, 72.
Water	9·25	13·92	13·20	14·3	
Nitrogenous Matter	22·15	22·72	22·40	22·4	
Fatty Matter ...	2·00	2·01	3·00	2·5	
Carbo-hydrates	61·10	54·27	52·60	52·3	
Cellulose ...	3·10	4·51	6·40	9·2	
Salts	2·50	2·57	2·40	2·5	

It will be observed that peas are highly nitrogenous, contain in proportion but few carbo-hydrates, and are deficient in salts; the phosphoric acid is not more than ·85 per cent.

Peas should be one year old before being used; they should weigh 64 lb. to the bushel, and be sound, sweet, and free from weevils. They should be given split or crushed.

Gram (*Cicer arietinum*).

This grain, which is so largely used in India, belongs to the pea tribe. It is the chief horse food of the greater part of the Peninsula. The plant which produces it is a small one with a purple or violet coloured flower. It is a remarkably albuminous food, though the least so of all the pulses, and the nitrogenous ratio is very high, showing the food is badly balanced.

TABLE SHOWING ANALYSES OF GRAM.

——	Bengal.	Bombay.	Bombay.	Madras (husked).	Sahranpore (white variety).
Water	10·80	10·86	12·24	11·30	12·20
Nitrogenous Matter	19·32	21·17	18·05	21·04	20·13
Fatty Matter ...	4·56	4·47	4·95	4·31	4·63
Carbo-hydrates ...	62·20	60·11	61·70	60·45	60·24
Salts	3·12	3·39	3·05	2·90	2·80

These analyses are taken from the catalogue of the Great Exhibition.

Gram is of a reddish-brown or yellow colour, hard, when crushed splits into symmetrical halves; if good it sinks in water, hollow grains float; the taste is like that of a pea; the grain should be kept for at least six months before use. Its mode of administration varies, but it is usually given ground, and should then be slightly damped and given either with or without bran or chaff. The method of soaking it for horses, after being crushed, is injurious, for it rapidly becomes sour, and in the softened condition is readily bolted by most animals, and may produce choking or indigestion. I have seen the whole grain soaked for some hours, and then given when soft; in this manner it does not ferment, and it is the best method of administration when it cannot be ground. Gram is very heating; many horses cannot digest it properly, and it passes through them whole. Only a certain amount can be digested by any horse—this quantity does not probably exceed 10 lb. per diem; if more than this be given the undigested gram ferments, causes diarrhœa of a most fœtid character, and if long continued produces liver disorder.

PIGEON PEA (*Cajanus indicus*), COMMON PEA (*Pisum sativum*), LENTILS (*Ervum lens*), and VETCH (*Lathyrus sativus*).

These are rarely used as food for animals; they are largely consumed by the natives of India, and are known to them as 'dhol.' They are taken with rice, and supply the nitrogenous element to these grain-feeding races. The following is their composition:

—	Pigeon Pea.	Common Pea.	Lentils.	Vetches.
Water	10·77	12·70	12·70	10·10
Nitrogenous Matter	20·19	25·20	24·57	31·50
Fatty Matter	1·32	1·10	1·01	·95
Carbo-hydrates	64·32	58·38	59·43	54·26
Salts	3·40	2·53	2·29	3·19

The lentils and vetch are not favourites with the natives; the latter, though largely eaten by some of the people of the N.W. Provinces, provokes an incurable paraplegia. The grain is known to the natives as 'Khessaree dhal;' they are perfectly aware of its poisonous properties on both themselves and their animals, but they partake of it on account of its cheapness. Horses and bullocks suffer from enteritis as the result of its use, and others lose control over the hind-limbs, becoming paralysed. As previously noticed, page 156, this pulse has lately produced paralytic disease among horses in the north of England.

Dr. Lindley states that the seeds of *Ervum ervilia*, mixed with flour and made into bread, produce weakness of the extremities, especially of the lower limbs, and render horses almost paralytic.

I fed a donkey on 'Khessaree dhal' for some time, but I did not succeed in producing paralysis.

The Bean Tribe (*Faba*).

This also belongs to the natural order Leguminosæ; it is composed of the genera Faba, Phaseolus, Dolichos and Soja. They are all distinguished by the large proportion of nitrogenous substances which they contain. Beans are generally badly saved—the result is many are mouldy; they are also very liable to the attack of the weevil, which destroys the flour. The beans preferred are the short stout ones; they should be at least a year old, or else they excite indigestion and other diseases, and they must be sound and sweet. The general effect of beans on the intestinal canal is to produce constipation.

TABLE SHOWING ANALYSES OF BEANS.

—	Grandeau.	Boussingault.	Grandeau. Horse beans.		Wolff.	
Water	16·00	14·80	12·50	16·16	14·5	The nitrogenous ratio varies from 1—1·7 to 1—2·1.
Nitrogenous Matter	24·40	26·30	29·70	24·88	25·5	
Fatty Matter ...	1·50	2·20	2·00	1·67	2·0	
Carbo-hydrates	51·50	49·50	49·90	47·16	45·5	
Cellulose ...	3·00	3·70	2·90	6·85	11·5	
Salts	3·60	3·50	3·00	3·28	3·52	

The various kinds of bean used for feeding purposes are the common horse bean, the tick bean, the Heligoland, and winter bean. Beans weigh about 63 lb. per bushel, and a good crop yields 1 ton of grain and 1½ tons of straw per acre.

Beans from their highly nitrogenous composition are used as an additional food for animals which undergo severe and prolonged exertion; for this purpose they are crushed and mixed with the ordinary ration of oats. The quantity given is from 2 to 3 lb. daily.

GHOT WALL (*Lablab vulgaris*); CHOWLEE (*Dolichos einensis*); GUWAR (*Dolichos fabæformis*); BHOOT (*Soja hispida*, *Dolichos soja*); OORUD (*Phaseolus radiatus*); MOTE (*Phaseolus aconitifolius*); MOONG (*Phaseolus mungo*).

All these Indian grains belong to the bean tribe; they are more or less used for feeding purposes, but more commonly used by the natives for their own food. The following is their composition.

—	Ghot Wall.	Chowlee.	Guwar.	Bhoot.	Oorud.	Moong.	Mote.
Water	10·81	12·24	11·75	8·12	11·00	9·20	11·22
Nitrogenous Matter	24·55	24·00	29·80	40·63	22·48	24·70	23·80
Fatty Matter ...	·81	1·41	1·40	17·71	1·46	1·48	·64
Carbo-hydrates	60·81	59·02	53·89	29·54	62·15	60·36	60·78
Salts	3·02	3·13	3·16	4·00	2·91	3·26	3·56

Bhoot corresponds to the Chinese bean known as Salmca; it is cultivated in the north of India, and is the most highly nitrogenous food known. It is also remarkable for the enormous quantity of fat it contains, and the small amount of carbo-hydrates. Mote is used in the Bombay and some parts of the Bengal Presidency; it is a favourite grain with native horse-dealers, and is given in a boiled condition. Guwar is used in the Deccan for feeding purposes; it is a very hard grain, and is given boiled.

Cooltee (*Dolichos uniflorus*).

This is the chief horse grain of the Madras Presidency, and is very largely cultivated. It is a small gray or brown bean, very hard, and turns deep brown or nearly black on boiling. Its composition shows it to be a highly nitrogenous food; the fats are, however, deficient.

TABLE SHOWING ANALYSES OF COOLTEE.

Water	11·30	11·50	12·03	11·00
Nitrogenous matter	23·47	23·03	23·27	20·95
Fatty matter	·87	·76	2·20	1·95
Carbo-hydrates	61·02	61·85	59·38	56·72
Salts	3·34	2·86	3·19	3·22

The third analysis in the table is according to Parkes, the grain being unhusked; the fourth is an analysis made by Professor Church.

Cooltee requires a soil containing lime; the plant itself is very hardy, and grows well on poor soils. The grain should not be used for at least six months. Cooltee should be carefully cleaned by sifting and washing before being used, as owing to the mode of gathering the grain is mixed with gravel and stones. Neglect of these precautions causes a large accumulation of gravel in the intestines; I have seen the double colon half filled with it, and most horses fed on cooltee have gravel in their bowels.

Cooltee is prepared by being boiled. I have known it given ground very fine, or parched, but the process appears unsatisfactory. The boiling requires care and attention. The quantity of cooltee given daily should not exceed 10 lb. The grain is a useful one for animals out of condition, or those with a weak digestion; but to feed healthy horses on cooked food all their lives I believe to be a mistake, and I am convinced it is a fruitful factor in the production of ruptured stomach.

OLEAGINOUS GRAINS.

Linseed.

This class is represented by linseed, hemp seed, and rape seed. None of these are used entirely for feeding purposes, but only as useful adjuncts. Linseed is excellent for sick or debilitated horses. For animals out of condition it acts sometimes in the most surprising manner, and it is well known to have a good effect on the coat and skin. Linseed may be given whole, ground, or boiled; the latter is generally preferred for sick or debilitated animals. For ordinary feeding 1 lb. per diem mixed with the other food will be found sufficient; in cases of debility, or with sick horses, more or less than this may be required. In boiling linseed it should just be kept covered with water and boiled until it assumes a sticky mass; it can then be mixed with the other food. For sick horses, as pointed out by I. V. S. Meyrick, C.B., steaming is preferable to boiling, as the grains are not burst, and the oil consequently not liberated to disgust the patient; 1 lb. of linseed to 2 quarts of boiling water is the proper proportion, to stand covered up until cool; the resulting emulsion can then be used. Stewart recommends its use for a cough, and says that it should be boiled and given in a bran mash with 2 or 3 oz. of coarse sugar.

TABLE SHOWING ANALYSES OF LINSEED.

—	Boussingault.	Grandeau.	Kühn.
Water	12·50	12·15	11·80
Nitrogenous matter	20·50	22·36	21·70
Fatty matter ...	39·00	33·13	37·00
Carbo-hydrates ...	19·00	22·42	17·50
Cellulose	3·20	5·68	8·00
Salts	6·00	4·26	4·00
Phosphoric Acid ...	2·41	...	1·90

The nitrogenous ratio varies from 1 : 2·5 to 1 : 2·9. Its relative value to 100 parts of hay would be: Nitrogenous matter 35, Fatty matter 9·7, Carbo-hydrates 233. It is rich in Nitrogenous and Fatty matters, but very deficient in Carbo-hydrates.

Oil Cakes.

These are the residues left after the expression by machinery of the oil from the seeds. As their name implies, they are rich in oily matter, but none the less so in nitrogenous material and salts. The nutritive relation is in all cases high. The principal cakes in use are linseed, cotton, rape; there are others, as poppy, gold of pleasure, hemp, beech-nut, etc.

TABLE SHOWING ANALYSES OF OIL CAKES.

—	LINSEED CAKE.				RAPE CAKE.			
	Coussingault.	Kühn.	Grandeau.	Wolff.	Boussingault.	Kühn.	Grandeau.	Wolff.
Water	13·40	11·50	12·19	11·50	10·50	15·00	11·34	15·00
Nitrogenous matter	32·70	28·30	29·48	28·30	30·70	28·30	31·59	28·30
Fatty matter ...	6·00	10·00	9·88	10·00	10·00	9·50	9·66	9·00
Carbo-hydrates ...	33·20	31·50	29·91	41·30	32·50	24·30	29·36	33·50
Cellulose	5·10	11·00	9·69	11·00	9·40	15·80	11·00	15·80
Salts	8·30	7·70	8·85	7·90	7·70	7·10	7·05	7·40

—	Cotton Cake.					
	Not Decorticated.			Decorticated.		
Water	10·00	11·30	11·50	10·00	10·00	9·30
Nitrogenous matter	23·50	23·70	24·60	41·20	40·90	41·20
Fatty matter ...	6·60	6·20	6·20	14·00	16·40	16·00
Carbo-hydrates ...	32·00	31·00	30·28	18·00	15·80	16·40
Cellulose	21·10	21·20	20·80	9·00	9·00	8·90
Salts	6·80	6·50	6·70	7·80	7·90	8·00

The nitrogenous ratio of these cakes is very high. The mean ratio of linseed cake would be about 1 : 1·3; of rape cake, 1 : 1·2; of undecorticated cotton cake, 1 : 1·6, and of the decorticated variety, 1 : 0·8.

The nutritive equivalent to 100 parts of hay would be as follows:

	Nitrogenous matter.	Fatty matter.	Carbo-hydrates.
Linseed cake	26	50	115
Rape cake	27	30	117
Cotton cake...	36	45	119

The cakes procurable in India are the ground-nut and cocoanut cakes; the former is very largely used for feeding purposes. It is obtained by expression of the seeds found in the underground pods of the *Arachis hypogœa*, a leguminous plant largely grown in the Madras Presidency; the oil is exported in large quantities to France, where it is used in the sardine trade. The cake is a pleasant-smelling one, and presents the following composition:

ANALYSES OF GROUND-NUT CAKE.

	Prof. Church.		Prof. Tuson.		Dr. Voelcker.	Dr. Anderson.
——	Decorticated.	Undecorticated.	Decorticated.	Undecorticated.		
Water	9·3	8·1	9·58	9·28	10·80	10·84
Nitrogenous matter	43·4	30·5	42·81	32·81	28·62	30·33
Fatty matter ...	5·6	8·8	7·40	6·99	8·12	9·80
Carbo-hydrates ...	31·4	27·8	27·63	23·67	18·86	45·50
Cellulose	5·2	19·1	7·87	23·80	29·00	
Salts	5·2	5·7	4·71	3·45	3·11	3·53

The value of feeding cakes cannot be over-estimated; without them the British agriculturist could not produce the prime beef and mutton which are his speciality. For milch cows they are unrivalled, and for horses doing hard work on food deficient in fats, or with animals much pulled down and debilitated, these cakes are most useful in restoring condition.

Linseed Cake is obtained as the result of crushing the seeds of the flax plant for the extraction of their oil.

Rape Cake is obtained after the rape seeds have been crushed and the oil, Colza, expressed. This cake is not such a favourite as linseed, having a hot taste, and is said not to agree so well with cattle and sheep. It is recommended to place it in boiling water before use.

Cotton Cake is obtained from the seeds of the cotton plant. In the *undecorticated* condition it was found that the husks gave rise to intestinal irritation; but greater care has now been taken in its manufacture, and it can be used with safety. When the husk is removed from the seed the cake is known as *decorticated*.

Ground-Nut Cake is most favourably spoken of. It contains a large quantity of oil not expressed owing to defective native machinery, and some specimens are likely from this cause to become rancid.

The oil cakes are very rich in phosphoric acid. Linseed contains 2·37 per cent.; rape, 3·14 per cent.; and cotton, 2·86 per cent. Owing to this, and the large amount of nitrogen and potash they contain, the cakes yield the richest manure.

The other cakes used for feeding are poppy, hemp, and cocoanut. None of these are, however, in such favour as linseed. Oil-cake is imported in large quantities into Great Britain, and it is subject to great adulteration. The following article on adulteration of cakes appears in the 'Encyclopædia Britannica' from the pen of Dr. Letheby.

Adulteration of Cakes.

'In a recent trial where the question of adulteration was raised, a linseed cake-maker stated in evidence that his ordinary oil-cake consisted of 50 parts ground sesame cake, 20 parts of bran, and 30 of linseed and linseed siftings. To prevent the detection of this fraud by an examination of the cake with the naked eye, it is customary to powder the materials very fine by means of a machine called a "Buffein Machine," after which they are thoroughly mixed together and pressed into a cake. It would seem, indeed, that pure linseed cake is not saleable, except in a few localities, as in the neighbourhood of Gainsborough and in the agricultural centres of Lincolnshire and Norfolk, where the genuine cake is appreciated. Elsewhere the adulterated article commands a ready sale on account of its low price, and thus encouragement is given to the use of all sorts of adulterating agents, as earth-nut, cotton, beech, and sesame, bran, rice husks, oat-dust, and other such worthless matter. Very recently this important subject has been treated by

Dr. Voelcker in a paper "On the characters of pure and mixed Linseed Cakes," which was published in the *Journal of the Royal Agricultural Society of England* (Vol. iv., Part 1). Some of the impurities of linseed cake may be due to the accidental presence of the seeds of various weeds and wild plants, which the careless farmer has allowed to grow upon his land. Most of these, however, are easily removed by one or two siftings; but the siftings are not thrown away; they are used for adulterating other samples of linseed—making the second, third, and even fourth qualities of Riga and St. Petersburg seed. Occasionally the siftings are sent out to sea in barges to meet the vessels coming from the north with linseed on board; there the mixture is made, and when the vessels reach the port for which they are destined, the cargo is sold for genuine linseed 'as imported.' But besides these impurities, the linseed cake of commerce contains a large proportion of other cakes, as rape, earth-nut, decorticated and undecorticated cotton seed, beech-nut, hemp-seed, cocoanut, cocoa, palm-nut, palm kernels, niger seed, sesame or teal seed, poppy, castor-oil, bassia, curcas, indigo seed, olive, etc., besides bran, acorns, carob beans, and the husks or shades of earth-nut, oats, barley, rice, and other refuse. Some of these things are actually poisonous to cattle, as in the case of castor-oil cake, curcas bean, purging flax, wild mustard, wild radish, etc.; others are of doubtful quality, as corn cockle, darnel, indigo seed, earth-nut, etc., and many are disagreeable to the taste, on account of rancidity and other properties, as cocoanut cake, palm-nut cake, bassia cake, etc., while many are so charged with woody matters as to be indigestible and irritating in their action, as cotton, olive, palm-nut, husks of rice, cocoa-nut fibre, sawdust, etc. These impurities are sometimes easily recognised by the naked eye, or by a lens of low power. At other times the colour of the cake is an indication of its impurity. The taste of it also is frequently characteristic; for while linseed has a sweet mucilaginous taste, rape seed is turnipy, mustard acrid, dodder like garlic, bassia bitter, etc. Then again the action of a little warm water will develop the flavour of impurities—rape giving off a strong odour of turnip, mustard its well known acrid flavour, wild radish and other impurities their characteristic smells. When examined chemically it is found that adulterated and dirty cakes show a deficiency of oil and albuminous matter, and a large excess of woody fibre and mineral substance. In good cake the moisture ranges from 10 to 14 per cent., the oil from 10 to 15, the albuminous matter from 25 to 35, the mucilage, sugar, and digestible fibre from 20 to 30 per cent., the woody fibre from 9 to 14 per cent., and the mineral matter or ash from 6 to 8 per cent. Cake that has been shipped too fresh is apt to heat and become mouldy; in which case it will lose its fine aroma, and be of inferior quality; it may even be injurious to animals feeding on it.'—(*Encyclopædia Britannica.*)

Church * found that the waste bran from tin-plate works was sold cheap and used for feeding cakes.

The various agricultural journals are constantly calling the attention of farmers to the tricks practised on them by makers of spurious feeding-cakes. Cheap cakes are sure to be adulterated; it would be impossible to sell the pure article at the price advertised: for instance, a cake containing 95 per cent. linseed is worth at least £8 per ton, and yet a farmer will buy cake, labelled pure, at £6 per ton on account of its cheapness! A cheap cake is sure to be a very dear one. The farmer should deal only with firms of known integrity, and a guarantee of purity should accompany all consignments.

A good linseed cake should not be too pale in colour, and

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* *Agricultural Gazette*, 1875.

should be hard and difficult to break. A soft easily broken cake is sure to be adulterated ; even if the cake be hard, a pale colour must be regarded with great suspicion (Johnson).—*Veterinarian*, 1864.

ROOTS.

Various so-called roots are used for feeding purposes, particularly amongst cattle. The most common in use are the Mangel-Wurzel, Swedes, Kohl-Rabi, Potatoes, Turnips and Carrots.

The chief value of these foods, particularly the mangel and swede, lies in the fact of their containing a readily digestible carbo-hydrate, starch and sugar. These foods are highly valued by the agriculturist for meat and milk production.

Frozen roots are very prone to produce tympanites in cattle, and a diet of roots has been blamed for producing abortion in cows.

The composition of roots is as follows:

Food.	Water.	Albuminoids.	Fat.	Carbo-hydrates.	Cellulose.	Salts.	Phosphoric Acid.
Potatoes	74·61	2·17	0·15	21·23	0·73	1·12	0·15
Mangels	88·50	1·20	0·10	8·20	1·00	1·00	—
Swedes	89·30	1·50	0·20	7·30	1·10	0·60	—
Turnips	92·50	0·80	0·20	5·70	0·30	0·50	0·03
Carrots	84·37	1·28	0·24	11·38	1·62	1·11	—

POTATOES as food for horses have been used in agricultural districts. Given raw they produce indigestion, colic, and even enteritis. Cases of death from this cause have been recorded in the veterinary periodicals. If potatoes are given they should be boiled or steamed : potatoes would be unfit for any but slow worked horses.

SWEDES are said to be very fattening for horses, and to produce a glossy coat, loose skin, and induce an appetite. Given in the raw state they are said by Stewart to cause indigestion, and he recommends that they should be boiled.

MANGELS are highly esteemed as a cattle food. They are often given whole, and as a result are the most common cause of choking in cattle. They should be sliced, or better still pulped, for which purpose there are many machines in the market.

CARROTS are excellent food for horses, and none better for promoting appetite in the sick and debilitated animal. They are stated to be slightly diuretic and laxative; they improve the coat and skin, and are most beneficial in cases of broken wind and chronic cough. As an alterative they are of great value. Carrots should be washed, and either sliced or grated up. Horses are so greedy after them that unless this precaution is adopted they are liable to produce choking.

We have thus named the chief foods used in feeding animals; our next step is to consider their modes of preparation and preservation.

The Preservation and Preparation of Foods.

ENSILAGE.

The process of ensilage, though known for centuries, has only lately been revived, and as a method of storing fodder is soon likely to assume most important proportions in this kingdom. The process is essentially the storing of fodder in a green state without access of air. The report of the Ensilage Commission, which has lately been published, will give us the most condensed and reliable information regarding this important economic process.

The Commissioners say :—

'The advantages which are claimed for the process of ensilage may be classed under three heads :—1. In rendering the farmer independent of weather in saving his crops. 2. In increasing the productive capabilities of farms: (a) In greater weight of forage saved, (b) In greater available variety and rotation of crops, (c) In increased facility for storage. 3. In connection with feeding: (a) Dairy stock, (b) Breeding stock, (c) Store stock, (d) Fatting stock, (e) Farm horses.

'1. Independence of Weather in Saving Crops :—In this respect it has been abundantly proved to us that ensilage is of great economic value. In Scotland, in Ireland, and in the north and west of England, few seasons occur in which more or less difficulty is not experienced in reducing green fodder crops to a sufficiently dry condition for stacking in the ordinary way. This is especially the case with second crops of clover and aftermath. The loss occurring through ineffectual attempts to dry such crops, or through their inferior condition when carried, is often very considerable, and it is obvious that any system which enables a farmer to store these in good condition for future use must be a great saving of expense and anxiety.

'2. Advantages in Increasing the Productive Capabilities of Farms :—(a) In greater weight of forage saved. It is obvious that unless the forage in a weighty condition be of more feeding value per acre than when saved in a less weighty form there can be no gain to the farmer. It has been contended that the loss of weight in the process of drying is simply loss of water by evaporation, and that by avoiding this nothing is saved. If such were truly the case, dry forage should give the same feeding results per acre as green forage. No practical farmer would contend that it does so, and the difference is especially noticeable in the case of dairy stock. So far as we have been able to ascertain the opinion of competent men on this subject, we estimate the value of green forage well preserved in a silo at somewhat more than one-third, weight for weight, of the value of the same material made into hay under favourable conditions. The very wide difference of value between good and bad silage cannot be too strongly insisted upon. It is found that grass well preserved in a silo, after deduction for loss, will yield approximately five times the weight of the same grass made into hay. We have therefore, say, five tons of silage, which, taken at one-third the value of hay per ton, yields a profit of over 60 per cent. as compared with one ton of hay. If we take it at one-fourth, it still leaves a profit of 25 per cent. Any waste that may occur to reduce the weight of nutritious forage, whether by evaporation or by excess of chemical change, must necessarily affect this calculation, which is based upon the highest degree of perfect preservation so far known to be attainable.

'(b) In Available Variety and Rotation of Crops:—By the process of ensilage many crops can be preserved which would not otherwise be found profitable if used in the form of green forage. Rye, oats, millet, maize, barley, and even wheat, if cut about the time of attaining their full development, but before the seed begins to harden, have been successfully used as food for cattle through the medium of the silo. Such of these crops as are found to reach the required condition before the middle of June, if cut before that time, will leave the land free for a second sowing, and thus increase its capabilities of annual production, while maintaining the fertility of the soil. Where land is well treated, maize, buckwheat, or in some parts of England also turnips, can be sown after green rye or oats are cut and carried, and thus a second crop may be secured for preservation in the silo, or for consumption by sheep on the land.

'(c) In Increased Facility for Storage:—This advantage has been forcibly impressed upon us. It enables farmers to guard themselves against emergencies, such as frequently arise in our climate through prolonged cold in February, March, and April, causing great scarcity of food for cattle and sheep, where the supply of roots is inadequate.

'3. Advantages connected with Feeding:—(a) Dairy Stock:—We have received the strongest evidence of the undoubted advantage of the system for the feeding of dairy stock. The effect of dry winter food given to such stock has always been to reduce in quantity and to deteriorate in quality milk, cream, and butter, as compared with the same products resulting from green summer food. Although the degree of perfection attainable in summer has not been reached, it has been at least much more nearly approached by ensilage than by the use of hay and other dry foods, while at the same time the objections inseparable from the employment of roots for this purpose have been overcome. A sensible improvement in the colour of butter has been especially noticed.

'(b) Breeding Stock:—Green fodder preserved by ensilage has been successfully employed in feeding sheep and cattle at the time of breeding, and as it has been shown to increase the flow of milk it will undoubtedly be found useful for this purpose, although the proportion of its admixture with other kinds of food must always require care and judgment.

'(c) Store Stock:—It forms a complete and wholesome food for store stock.

'(d) Fatting Stock:—The value of this process for the purpose of forming flesh and fat has not yet perhaps been so widely demonstrated as in the case of dairy produce. At the same time the results attained show that it compares favourably with the use of roots, and if given in proper proportions with other food, it affords a cheap substitute for the same bulk, which would otherwise be required in some different form. The advantage of its use is most apparent in the degree to which it enables a farmer profitably to consume straw chaff, rough hay chaff, and other dry materials, which, without admixture with some kind of moist food, would not be palatable or advantageous to the growth of stock.

'(e) Farm Horses: — Strong as the evidence has been of the advantage of ensilage for keeping all stock in healthy condition, farm horses have by no means been excepted. We have received highly satisfactory accounts from several quarters of the health of working teams when given a limited proportion of silage mixed with other food.

'Among the plans of silos which have been submitted to us, those which consist of external walls, either above or below ground, whether of concrete or of stone, brick, or clay lump, cemented within, appear to be the most efficient; but in all cases the absence of air depends upon two conditions; first, upon its expulsion from the mass of forage ensiled, and secondly, upon its exclusion when this is covered. Whatever may be put into a silo, it should be thoroughly well trodden in, and rammed down at the edges into a compact mass; with this object the advantage of rounding off the corners has been impressed upon us by some witnesses. To secure the exclusion of the outer air, it has been found useful to cover the mass with close-fitting boarded lids or shutters, in one or more divisions, with a layer of bran, sawdust, or earth above them. Weights, being required above this layer to keep the mass compact, may be applied either in the form of any convenient dead weight, such as bricks, boxes, or baskets of stones, etc., or of mechanical pressure exercised by means of various systems of chains, screws, or levers. Instances are known of silos being successfully weighted without the use of boards, by simply covering the ensiled material with rushes, ferns, or other waste substances, and above these with dry earth or sand to the depth of nine inches or a foot.

'As in the case of all important innovations, it is not surprising that the introduction of the system of ensilage into this country has been met by a considerable amount of prejudice and incredulity. During the progress of our inquiry we have endeavoured amply to discount all exaggerated estimates of its merits. After summing up the mass of evidence which has reached us, we can without hesitation affirm that it has been abundantly and conclusively proved to our satisfaction that this system of preserving green fodder crops promises great advantages to the practical farmer, and if carried out with a reasonable amount of care and efficiency, should not only provide him with the means of ensuring himself to a great extent against unfavourable seasons, and of materially improving the quantity and quality of his dairy produce, but should also enable him to increase appreciably the number of live stock that can be profitably kept upon any given acreage, whether of pasture or arable land, and proportionately the amount of manure available to fertilise it.'—(*Report of Ensilage Commission.*)

Ensilage is of two kinds, known as sweet and bitter silage. The cause of the difference between these two is the nature of the fermentation which occurs; this is regulated by the temperature to which the mass is allowed to rise. The bacteria which produce acid fermentation are destroyed by a temperature of 125° F.; therefore when sweet silage is required, an endeavour is made to obtain it, by filling the silo slowly, and allowing the temperature to rise above 125°; whereas by rapid filling of the silo, and covering up and weighting the mass, the rise in temperature is avoided and sour silage results. Sour silage seems most generally preferred as it produces a larger bulk and more succulent food.

By the process of ensilage the fodder increases in nutritive value if care be taken in its selection. Good well matured green food will make the best silage, whereas over-ripe or immature food will never make anything worth calling ensilage.*

A large number of analyses of ensilage have been made, and we select the mean result of 37 analyses made by Dr. Voelcker for a prize offered by the Ensilage Society, through the enterprise of Mr. M. Sutton, and published in the *Field*.

Water	71·42
Volatile Acid (calculated as Acetic Acid) ...	·28
Non-volatile Acid (calculated as Lactic Acid)	·42
Albuminous Compounds	3·17
Indigestible Woody Fibre	9·33
Digestible Cellular Fibre	10·39
Soluble Carbo-hydrates, Extractive Matter, etc.	2·53
Mineral Matter	2·46
	100·00

Much difference of opinion exists as to the chemical changes occurring in the silo. Sutton† found that the effect of the silo was to increase the soluble flesh and fat formers, and increase the digestible fibre by 20 per cent., whereas Lloyd‡ found that the fat, but particularly the mineral matter, was increased; the decrease in indigestible

* For a detailed account of the chemical changes occurring in ensilage, consult an able article by Dr. Voelcker, F.R.S., 'Journal of the Royal Agricultural Society of England,' No. 40, Part. II.

† *Chemical News*, June, 1883. ‡ Ibid., May, 1884.

and increase in digestible fibre described by some was not observed, and there was a loss of 1·7 per cent. of the organic matter placed in the silo, chiefly due to the decomposition of starch, sugar, and mucilage.

The amount of silage which can be given daily will depend upon the other food used, but about 40 lbs. is an average quantity; it may be given chaffed, and mixed with straw chaff.

There are several methods of preparing food, such as cutting, bruising, slicing or pulping, boiling, steaming, etc., which must be briefly considered.

Chaff-cutting.—The advantages and disadvantages of this have been much argued: those in favour of the process say that it causes less waste to convert the fodder into chaff; that added to corn it makes the horse masticate his food better, prevents him bolting it, and that a more accurate distribution of food is effected. Another argument used in its favour, but an exceedingly bad one, is that it causes the consumption of damaged fodder which the horse would otherwise not touch.

Mixing chaff with the feed of corn is undoubtedly a wise proceeding, as it ensures its mastication and deliberate ingestion; to convert all the fodder into chaff is a mistake, excepting for animals who get but little rest from work, and which are thereby saved some time in feeding by having the food ready chopped for them. The length which chaff should be cut must depend upon its use; if for mixing with corn, lengths of an inch are advisable, for ordinary nose bag purposes it might be cut a little longer.

Chaff is recommended for horses suffering from 'broken wind,' and so useful is it in this affection that the French have recorded complete cures of the disease from its use.

The use of the chaff-cutter in the winter feeding of farm stock is being much appreciated on economic grounds;

there is a great saving in converting the hay and straw into chaff, and mixing them with the other food given; by effecting this saving a long winter may be successfully tided over.

Crushing.—Respecting the crushing of food, there can be no doubt of its advantage from a point of economy and utility. The various cattle cakes are best given crushed; roots, too, if pulped, are wholly digested, and choking is prevented. It is when we come, however, to the crushing of grain that we appear to obtain important dietetic advantages; peas, beans, oats, gram and barley, if crushed, are more easily digested; the horse obtains from them a larger amount of nutriment, for the reason that the digestive juices can act on the material at once instead of having to first dissolve the coats of the grain. Whole grains often found in the excreta of animals are quite prevented by the process of crushing. The prevention of stomach and intestinal disorders is certainly obtained by crushing such foods as peas, beans, barley, and gram.

Boiling.—Some foods are boiled; potatoes, for instance, are rendered more digestible by this process. Agricultural horses, particularly in years gone by, received boiled foods during regular periods of the year. Boiled foods appear to improve the condition of the skin, and to promote the formation of fat. I am convinced that one boiled food, viz. cooltee, which is used for horses in Southern India, is a fruitful source of ruptured stomach. I can only account for it by the ease with which it is bolted, and the indigestion and consequent fermentation which this sets up. Chaff mixed with it causes the animal to masticate the grain. Boiled foods are supposed to promote soft condition; I cannot, however, subscribe to this view, after several years' practical experience of them. The irritating properties of barley appear to be removed by parching, which is best carried out on a large iron plate. Another method of preparing barley is by steeping it and then allowing it to sprout; in this way it is said to be excellent feeding for cattle.

The Principles of Feeding.

The principles which guide us in the feeding of animals are determined by the anatomical arrangement of their digestive system, and by the uses to which they are put; the former we have already dealt with, it is with regard to the latter that we have more particularly to speak. Looking at the matter from a plain practical point of view, a horse must be considered as a machine out of which it is desired to obtain the greatest amount of work at the smallest expense and the least risk; a cow may be regarded as a milk-making and breeding machine; oxen as meat-making; sheep as wool, tallow, and mutton making; pigs as bacon and ham producing.

The food given must meet these several requirements; it must be wholesome, abundant, clean and sweet, the hours of feeding regular, the quantity given proportional to the arrangements of the viscera; the mode of preparation found by practical experience to be the best must be adhered to, and cleanliness in preparation and administration must be observed.

Horses.—There are certain physiological processes connected with digestion in the horse which have their hygienic aspect. The experiments to determine them were made by Colin; some of these, from my own observations on digestion, I can fully bear out. Others we must accept entirely on the authority of this great veterinary physiologist.

The length of time occupied during stomach digestion is generally in proportion to the amount of nitrogen contained in the food; thus hay and straw pass out of the stomach more rapidly than oats. If hay be given before oats, it will be found that in the stomach they are arranged in the order of their arrival. Thus the hay would occupy the greater, and the oats the lesser curvature, and there would be no mixing of the foods excepting at the pylorus. The line of demarcation between the two is very sharp.

If oats be given before hay, the former is deposited in the greater and the latter in the lesser curvature of the stomach, and the foods remain distinct excepting at the pylorus.

Hay is invariably found during the early part of digestion to pass out of the stomach quicker than oats; but towards the end of the process the latter pass out more quickly than the hay, which appears to remain behind as ballast, and may not enter the intestine for six or eight hours.

According to Colin's experiments, hay given after oats causes the latter to be sent into the intestines before being fully acted on in the stomach; he argues, therefore, that the logical method is to give hay first, and then the corn ration.

Although the food arranges itself in layers in the stomach, in the order in which it arrives, yet these layers can be broken up by the ingestion of a quantity of water, which at the same time carries into the intestines portions of food unfit for intestinal digestion. Water given in small quantities does not disturb this arrangement of layers.

In feeding with a mixture of foods such as chaff, roots, crushed corn, etc., it was found that in the stomach the different foods still remained mixed, and passed into the intestines together, that containing the most moisture passing in first. It is disadvantageous, therefore, to mix foods of different degrees of digestibility, for the reason that as they all pass into the intestines together, much of the matter in one food remains unacted upon by the gastric juice.

The stomach begins to empty itself very early after the commencement of a meal; as soon as the viscus has attained a certain volume material passes out, and the amount so passing corresponds with the quantity being then eaten, so that its capacity remains the same. From this we learn the fact that feeds should be small in bulk, otherwise ingesta is sent into the intestines before being properly prepared. When the feed is finished the passage of material into the small intestines slackens considerably, and in course of time becomes so feeble that several hours will elapse before the stomach completely empties itself. The drier the food the greater difficulty is there in passing the pylorus.

The feeding of horses is determined by the nature of their work; the velocity with which this is performed must regulate the bulk of food they receive. It is evident that severe labour cannot be performed on a full stomach, for the pressure exerted on the diaphragm, and the interference with the process of digestion, will certainly occasion disease. It is also certain that the food required by working horses should, comparatively, be compressed into a small bulk, otherwise too great a time is occupied in abstracting from it the necessary nutriment; give, therefore, food of a concentrated kind an hour or so before work, and withhold all bulk in the shape of hay. The smallness of the stomach points to frequent feeding, and in small quantities; the great capacity for water, and the small stomach, explains the golden rule of experience that watering before feeding should be invariable. The fermentable nature of the food points to the necessity for due mastication and proper admixture with saliva; the general inability to vomit more than warns us of the great dangers to which the animal is exposed should stomach derangement occur; and the extreme sympathy existing between the digestive organs, the skin, feet, nervous, lymphatic, and urinary systems, shows us how many diseases of quite an opposite character may be dependent on the food given. I need only mention broken wind, laminitis, diabetes, lymphangitis, paralysis, congestion of the brain, diarrhœa, etc.

Horses performing slow work are necessarily dieted differently from those performing fast work. Work of a laborious nature, be it in the hunting-field or between the shafts of a heavy cart, cannot be performed on a full stomach—distress is rapidly brought about by the pressure of the stomach against the diaphragm, and the consequent obstruction to the free action of the lungs; if urged beyond this, rupture of the diaphragm or stomach may be produced. During fast work the stomach should practically be empty. Horses should, therefore, be fed one or two hours before they are required, and the food given should be of a concentrated character, such as oats. Work should not be too prolonged; exhaustion soon occurs. After severe work the appetite must be tempted, especially as very often all food is refused; in such cases a stimulant, preferably alcoholic, may be administered, and it often happens that the appetite returns in a short time. With slow or moderate work the same extreme care need not be exercised with regard to abstinence before going out; but even here a distended stomach may prove dangerous, especially for animals performing draught-work. I have known horses die of ruptured stomach through being worked immediately after a full feed.

After prolonged abstinence feeding in small quantities should be observed; many of our cases of colic are due to the ravenous manner in which a horse, that has fasted over his time, swallows his food. It is usually considered that a horse should not fast more than three or four hours.

Regularity in feeding is a great preventive of dietetic diseases; three, or if possible four, times a day should be practised, in small quantities at a time. Fodder should principally be given to saddle and harness horses after their work is performed, and arranged so that something is left them to take quietly during the evening and night.

Bulk is essential to the proper performance of intestinal digestion, but it should be introduced gradually. Given in excess we have the condition known as gorged stomach, with its attendant brain symptoms. This disease was very common years ago, but is now nearly banished through attention to hygienic rules.

It is perfectly impossible to keep up condition and vigour on concentrated foods alone. The intestines must contain a certain amount of bulk to favour digestion and assimilation. Without this bulk the horse soon becomes tucked up and hollow in the flank, and Stewart believes that such a condition is a common cause of wind-sucking and crib-biting.

Horses that work the greater part of the day must be fed as opportunity offers, though regularity in this respect should, as far as possible, be maintained. The necessity for chopped fodder for these animals is patent to all ; it ensures due mastication of the grain, and affords the animal its hay with half the labour of feeding saved.

Sudden changes of diet should be avoided ; horses fresh from grass must be gradually brought on to the usual stable food. In the same way animals which it is intended to turn out, should have their corn ration reduced and replaced by succulent herbage.

The necessity of increasing or reducing the corn ration to correspond with the work performed is another point of practical importance ; beans added to oats will produce the most highly nitrogenous diet a horse can assimilate. Where a reduction in diet is required, mashes of bran are substituted for the whole or part of the corn ration. The wisdom of adopting this measure once a week for all horses, particularly those receiving highly nitrogenous food, is very marked. Neglect of this precaution is a common cause of lymphangitis and azoturia, particularly among the heavier breeds.

Food of a bad, musty, coarse, or bulky nature is a fruitful factor in the production of that singular disease, broken wind.

The conformation of a horse affects in no slight degree his capacity for assimilating food. Animals with narrow chests, badly 'ribbed up,' and of a light mealy colour, are notoriously 'bad doers'; they never look well, are prone to derangement of the digestive organs, purge on the slightest provocation, and are generally known amongst horsemen as 'washy.' They require careful dieting; new oats or hay should never be given them; their work should be light, and they must not be worked soon after feeding; in winter their water must have the chill taken off; the body should be kept warm; crushed oats may be found advantageous; but with every care it is often a matter of extreme difficulty to either get the work out of them, or make them presentable in appearance.

A horse can live 25 days without food if sufficient water be supplied; if no water be given he will barely live 11 days.

Foals are weaned about the fifth or sixth month; up to this time they require little else than the mare's milk; but from now the diet should consist of grass, hay, and corn. The principle of feeding foals may be shortly summed up—give them as much as they care to eat. The general feeling on the subject is to give as much as will support life, and no more. The absurdity of such a system cannot too freely be condemned; if the foal be underfed, how is it possible that it can ever grow into anything but a long-legged, narrow-chested, light-bodied weed, utterly useless for any purpose? No better example can be followed in the matter of feeding foals than that set by the breeder of blood stock. The effects of liberal feeding are here wonderfully shown; a two-year-old thoroughbred horse is as fully developed and furnished as a half-bred one is at four or five years of age; nothing but good feeding has produced this.

The feeding of Cattle must be considered under two heads—first, that of milch cows; and secondly, of cattle intended for fattening.

The proper feeding of cows is a most important matter. In collecting the various dietaries recommended by men of experience, it is singular to find so little uniformity. It only shows us that the success of feeding does not depend upon the details so much as upon the general principles which are observed.

It is essential that the cow should be kept in good condition; the income must equal the expenditure; the storing up of fat must be avoided. This would defeat two special objects—milk supply, and breeding capabilities. The food given must be wholesome and nutritious; sufficient must be allowed, but care should be taken, particularly in feeding with grains, that so much is not given as to pall on the palate. Stinting must therefore be practised with regard to the most favourite foods, or disgust will occur. Feeding at regular hours is essential, otherwise the animals are kept in a restless condition, and the supply of milk will be affected; not only should regularity be observed in feeding, but also in milking and watering. Exposure to cold should be avoided, as a decrease in the yield of milk will at once occur.

Some foods impart a taste to the milk. This is particularly the case with turnips and cabbages, especially if these be given on an empty stomach. Bulk is essential for the due performance of the digestive functions; a cow requires about one-sixtieth of its weight in food.

Distiller's grains are more valued than brewer's grains for milk production. Their actual effect on this secretion is to increase the proportion of water—the milk is, therefore, poorer in solids; it is said that the milk of cows fed on grains 'turns' readily. However this may be, grains are considered a very important article in the London dairy.

The routine of feeding will vary nearly everywhere. For winter feeding in London dairies the cows are given, usually after the early morning milking, $\frac{3}{4}$ bushel of grains, followed by about $4\frac{1}{2}$ lbs. hay; about nine o'clock they receive 30 lbs. of sliced or pulped mangels (if the latter, they are usually mixed with chaff; if the former, another $4\frac{1}{2}$ lbs. hay is given), and the animals left undisturbed; about two o'clock they receive another $\frac{3}{4}$ bushel of grains, followed by $4\frac{1}{2}$ lbs. hay; about five o'clock they are watered, it being usual to only water them once in twenty-four hours; in the evening they receive another $4\frac{1}{2}$ lbs. hay, and are then left for the night. In some places 2 lbs. or 3 lbs. of crushed oil-cake are given daily in addition to this diet. The summer feeding is principally artificial grasses and grains, with a proportion of oil-cake. About 1 cwt. of the green grass is given. This system of feeding is by no means adopted everywhere; each dairy-man has his own views on the subject; still the outline given is what actually occurs in some of the largest dairies.

Fattening Cattle are stall-fed during the winter, and pastured or soiled during the summer. Whilst at pasture they receive 2 lbs. to 3 lbs. of oil-cake daily, or a certain amount of grain. Care is taken not to overstock the pastures, and the animals are constantly shifted to afford a fresh bite. Rich pastures should be reserved for animals full in flesh; sheep, from biting closer and picking out the sweetest herbage, should not be pastured with cattle. Soiling is advocated as a more economical means of feeding and fattening, with less destruction of the pastures. The animals should be practically unlimited in the amount given, but no waste should occur if the process is intended to be economical. The green food, when brought home, should not lie in a heap, or fermentation will occur.

A poor diet, such as that of turnips, is said to be the most common cause of hæmo-albuminuria.

When stall-feeding commences, the animals must be gradually brought on to the change in diet, which is now to be of the richest nature. The same conditions regarding regularity in feeding, warmth, etc., mentioned for dairy stock, is also essential for those fattening; roots, straw, hay, oil-cake and corn are the principal foods used. The straw should be chaffed, the roots pulped or sliced, the oil-cake crushed.

Calves are usually reared from the pail. The custom is to remove them from the mother at once, and they receive her milk until it is fit for use. Their diet is new milk for three or four weeks; and later, old milk warmed up and mixed with some easily digestible food. Calf meal, which may be anything, is often given; unless the composition of the meal is known, it would be better to trust to oatmeal, or linseed gruel, or cake-dust. The cooking of these substances should be carefully observed. Skim-milk being deficient in fat, the food supplied must meet the loss. The chief danger to which the young animal is exposed is that of diarrhœa, which is extremely fatal. It is due to the coagulation of the milk in the stomach, and subsequent decomposition. When this occurs it is advisable to boil the milk before giving. The calf is weaned at eight to ten weeks old; hay should now be given it, cake-dust or linseed, a few pulped roots or oil-cake finely broken; and thus it is gradually brought on to solid food.

This purely artificial method of rearing calves is the outcome of practical experience; the cow is a milk-making machine; anything which reduces the supply is financially a loss. This method of rearing calves is to avoid as far as possible reducing the secretion of milk, and practical experience warrants the custom.

Sheep require good winter keep, hay and roots, with oil-cake or grain; in summer they are pastured and receive cake or grain. Wheat has been successfully tried by Dr. Voelcker for feeding purposes; it was found to be the cheapest and best food. If cake be given it should be crushed; roots should be sliced or pulped, especially for those animals where changes in the teeth are occurring. The same care must be exercised in pasturing sheep as cattle; bring them gradually on to rich pastures; do not overstock the land. Low water-logged pastures are to be avoided; they are a prolific source of fluke disease.

Fattening Pigs should be fed regularly; filthy surroundings are by no means essential to the process of fattening; the amount of food given should be as much as they can consume; the feeding-troughs should be kept clean. Maize, barley-meal, grains, and dairy-refuse, potatoes, roots, cabbage, etc., are amongst some of the principal foods used. The food should be varied in character, as the appetite becomes fastidious. The pig is the most economical meat-making machine, for experiment has proved that 22¾ lbs. in live weight may be produced from 112 lbs. of maize.

CHAPTER V.

STABLES.

Stable construction has undergone considerable change during the last twenty-five years; many of our military stables are models of their kind, and most of those of the upper classes are, as regards construction, all that could be desired. The low dark dens, apparently contrived with the object of excluding all light and air, in which, years ago, valuable horses were placed, have quite disappeared, excepting from cities, where they still exist for the reception of cab-horses and others of that class.

Sanitary science has done much in the improvement of stable construction; but much more remains to be done amongst the stables of tradesmen, cab-proprietors, and others in large towns. I think the London cab-stable is typical of all that is abominable in stable construction, ventilation, and drainage: the suffocating foul warmth, the irritating ammoniacal gases, the entire absence of all ventilation, the low roof, the narrow stall, the abode of glanders and other horrors, and the collection of all that is vile; such will exist until the law steps in and prevents men from breeding disease amongst their own animals, and endangering the lives and property of others.

Materials and General Principles of Stable Construction.

A general knowledge of materials and principles of stable construction is a point of some importance to the veterinary surgeon; it must not be supposed that it places him in the position of the architect or builder, but it puts him in possession of certain facts connected with building which have their sanitary aspect, and it enables him. in conjunction with his knowledge of hygiene, to give an opinion on buildings for the reception of animals which will be possessed of practical worth.

Iron is much used in the construction of stables; it should be remembered that it is subject to certain influences of moisture and temperature, and can only be used in short lengths, unless it be properly protected, owing to its contraction and expansion. Wrought-iron is liable to rapid decay through moisture, and cast-iron is very brittle and liable to fracture under a transverse strain; it will, however, stand compression. Iron is much used in stable-fittings as pillars, mangers, and supports of all kind; as galvanized iron it is used for roofing.

There can be no doubt, on hygienic grounds, that the employment of iron in the construction of buildings is attended with the best results; in case of fire the destruction is much less; and where contagious disease has existed the stables are much more easily disinfected.

Timber.—The wood employed in building is generally fir, pine, oak, and deal. The best woods are marked by an absence of porous grain, spongy heart, and dead knots. Timber shrinks and swells in the direction of its thickness, absorbs moisture by the end of its fibres, and is subject to rapid decay.

Stone.—The least absorbent stone must be used, as an absorbent one undergoes rapid disintegration. Building in stone is more difficult than in brick, and for this reason stone buildings should be subject to close scrutiny, in order to detect imperfections of construction.

Bricks.—The average size of a brick is $9 \times 4\frac{1}{2} \times 2\frac{1}{2}$, and owing to the uniformity in its size, the thickness of a wall is described as consisting of so many bricks; for example, a 9-inch wall is a one-brick wall. There are three different kinds of brick—those made from pure clays, those from loamy or sandy clay, and those from marl, which latter contains an amount of lime. Fire-bricks are made from clay containing no lime or magnesia. The colour of bricks depends upon the extent to which they are burned, and the amount of iron and lime they contain. Brick absorbs less moisture than stone of equal hardness. An ordinary brick will hold about sixteen ounces of water; the Indian sun-dried brick will absorb considerably more than this.

Tiles may be plain or curved; the flat tile absorbs more moisture than the curved or pantile, and they do not last the same length of time; they are, however, a very warm covering, which the pantile is not. A tile absorbs about five ounces of water in ten minutes.

Slates.—The best slates are of a bluish-gray colour, and feel hard and rough; an absorbent slate feels greasy and smooth, and is blue or black in colour; a light gray slate is stony.

Concrete is a mixture of broken stone or gravel held together by lime. The best concrete is made from gravel and Portland cement. Concrete makes an excellent resisting surface on a yielding soil, and so is most suitable as a foundation.

Foundations.—The best soil for a foundation is a hard gravel, which should be of the same resistance throughout. Under the influence of moisture clayey soils expand and contract, and a foundation can only be obtained by the use of concrete; this must be carried below the level of the subsoil water. Springy ground must be drained, and a concrete foundation formed. The depth of foundation depends entirely on the soil; a simple footing only is required in rock or hard gravel, and the depth of this must be increased as the resisting power of the ground becomes less.

Walls may be solid or hollow; the first are usually nine inches in thickness, and the chief principles in building them are that no two bricks touch each other, that the mortar fills up all interstices, and that all the walls be carried up together. A hollow wall consists of two skins of brickwork, between which is a space of a few inches. The skins are connected by iron bands. This hollow wall is supposed to make the place warmer and drier, as no moisture can penetrate the inside wall. The hollow, however, harbours vermin. Damp-proof courses are impervious bricks built in the wall close to the ground; they prevent the damp striking up, and keep the walls of the building dry; they may be perforated to allow of ventilation. Fig. 26 shows one of these bricks made of vitrified ware.

In the tropics mud-walls are often used; and it is wonderful how well they withstand the effects of the weather.

Wooden walls are seldom used; in the army there are still some wooden stables left, and they are miserably cold

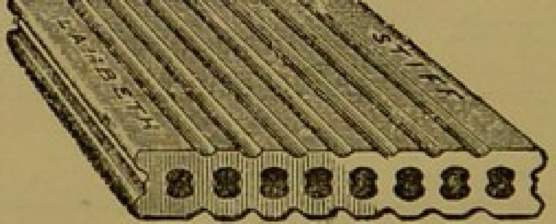


Fig. 26.—Vitrified Damp-proof Course.

in winter, admit rain during wet weather, and are very hot in summer.

The **Roof** may be of tile, slate, thatch, or of galvanized iron; if tiles are used the pantile should be adopted, either set on the plain tile with mortar in between, or, if for use in the tropics, the pantile laid on bamboo, which makes a fair ventilating roof. A slate roof is an excellent water-proof cover, but for durability there is nothing like galvanized iron; it is considered, however, to be a cold covering in winter, and hot in summer.

Military Stables.

There is usually very little choice of site in the construction of army stables; the site for the barracks is selected, and the stables must be within it. Still such points as the soil, surroundings, and water-supply must be considered.

Soil.—Damp soils are proverbially unhealthy; the healthiness of a soil is in an inverse proportion to the amount of water it contains. Pettenkofer, quoted by Parkes, mentions a case where the horses of two royal stables, near Munich, suffered very unequally from a form of fever, though both were under identical stable management. It was found that in the unhealthy stable the subsoil water was only $2\frac{1}{2}$ feet from the surface, whereas in the healthy building it was from 5 to 6 feet. The previously unhealthy stable, after drainage had reduced the level of the ground-water, became as healthy as the other.

Wet soil, besides being cold and damp, favours the decomposition of animal and vegetable bodies.

Stables built in a hollow are likely to be damp, and those which are underground, as some civil stables are in London, are certain to be so; the excess of moisture in their walls is a fruitful cause of unhealthiness. Diseases of the respiratory passages will be the result of wet or damp stables.

The soil should be gravelly, or sand of good depth, or chalk unmixed with clay. Clay, marl, shallow sands with a substratum of clay, alluvial, and made soils should be avoided. The surroundings of the barracks should be open, and not situated in a thickly populated district closed in on all sides; nothing should interfere with the free supply of air; a certain amount of elevation should be obtained to ensure drainage, and the water-supply should be convenient, abundant, and pure.

The soil may be such that proper drainage of it will render it healthy, or the military exigencies of the case may be such as to demand its being occupied whether healthy or not. A perfect system of subsoil drainage should then be established at a depth of from 4 to 12 feet below the foundation, depending on the character of the soil; the foundation should then be laid on concrete.

The site, therefore, for stables should be dry, elevated, easy of drainage, a gravelly soil, water-supply convenient and good.

Aspect.—No rule can be laid down in stating the aspect which stables should occupy; broadside on to prevailing, and end on to deleterious winds is recommended for the tropics by Veterinary-Major R. Poyser. I should think that aspect which gives the greatest shelter from the coldest winds would be the best general statement.

Position.—The stables should be in blocks arranged *en échelon.* Many of our old military stables appear to have been arranged with the object of completely excluding the wind, and we find several of them built in the shape of a square. It may be at once stated that anything in the form of a square is radically bad, from the fact of the obstruction thus offered to the thorough flushing out of the buildings with air. If we cannot have our stables built *en échelon*, owing to the amount of space this form occupies, we must have them built in parallel rows, taking care that they are not crowded together, and that the distance between each is at least twice the greatest height of the nearest building.

The following figures will give an idea of the various block plans. Figs. 27, 28, and 29 are the worst forms, Fig. 29 being particularly bad. Fig. 30 is a good plan, but Fig. 31 is the very best that can be adopted.

Troop-stables should not be crowded together—too much space between them is impossible from a hygienic point; the amount of air required by each animal should come to

Fig. 27.

Fig. 28.

Fig. 29.

Bad Block Plans.

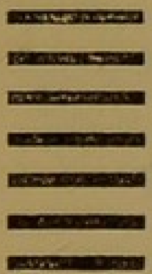


Fig. 30.

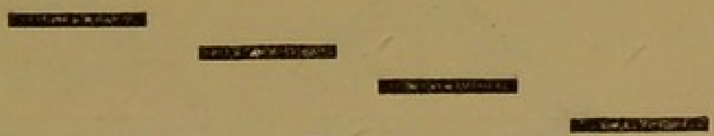


Fig. 31.

Good Block Plans.

it unmixed with the products, gaseous or solid, of the neighbouring stable. Again, in the event of an epizootic disease occurring, the probability of infection is reduced to a minimum by stables being situated well apart and *en échelon*.

There are two distinct types of troop-stable, the old and new; the former has been in use for years, the latter was the outcome of veterinary science, and the labours of the Barrack and Hospital Improvement Commission. The Commission did great service in pointing out the serious sanitary defects of our old stables, and the suggestion of an improved type. They describe the old stables as a contrivance for subjecting horses to the necessity of breathing air contaminated with their own excretions.

The old troop-stable was a low, dark, brick and mortar structure, holding from fourteen to eighteen horses arranged in two rows, with a passage down the centre, and their heads to the walls dividing the stables from each other. The stable was about 40 feet long, 28 feet wide, 10 or 11 feet high, with a superficial area of about 70 square feet, and cubical contents of 770 feet per horse. The ceiling was flat and closed, with the men's rooms over them. There was an entire absence of roof-ventilation, and the only air which entered the stable came through the opposite doors and windows, and these were 40 feet apart. The only horses which got fresh air were those in the corners by the doors and windows. Fig. 32 (copied

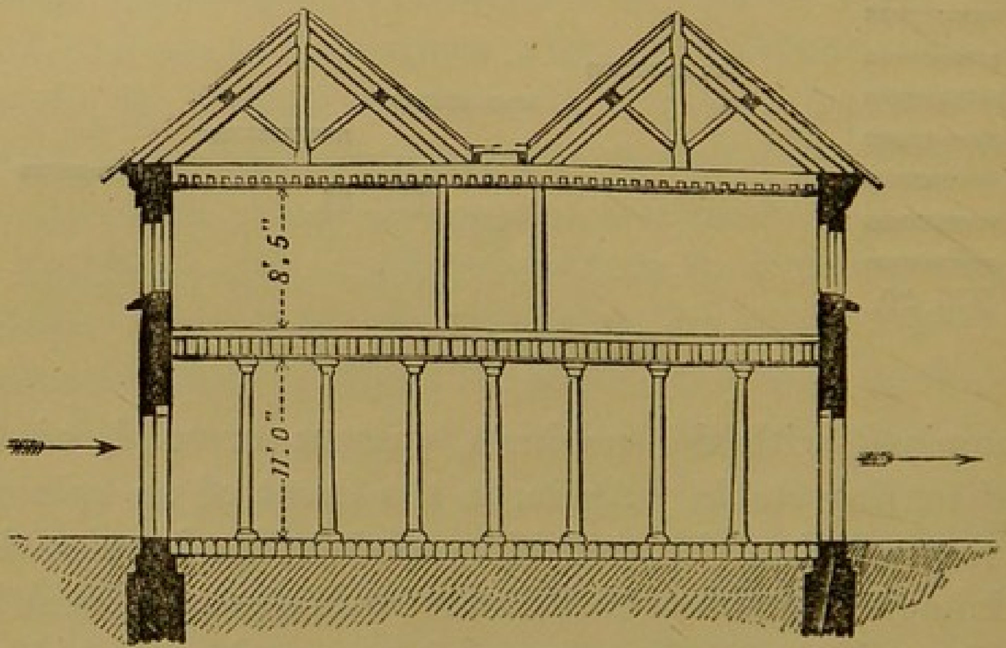


Fig. 32.—Section of Old Pattern Troop Stable.

from the 'Report on Cavalry Stables'), showing a section of the old stables at Hounslow Barracks, will give an idea of this type of building. The paving and drainage was most defective, and the percolation of urine great. Some of the stables in the Woolwich Barracks are on this principle, but if anything worse; for here we find that the opposite doors and windows are 65 feet apart, that there is a division wall with arches carried across the stable at its centre, effectually obstructing any current of air, and that there are no less than two stories of men's rooms above the stable.

Ventilation in all these stables was only effected by opposite doors and windows; the shorter the distance between these, and the fewer the number of horses in the stable, the less polluted was the air.

The position of the stalls in the stables above described, where the windows were very far apart and the number of horses between them great, is known as the transverse arrangement, and as such we have already described it under 'Ventilation.' It is the very worst form of stable that could have been devised.

York Barracks contains a stable built on some of these insanitary principles, the only difference being that the stalls run longitudinally instead of transversely to the stable; there is a wall up the centre of the building, on either side of which the animals are placed facing each other; only two horses instead of six or eight are thus placed between opposite doors and windows, but the dividing centre wall interferes considerably with the free perflation of air. It is a long single stable, 334½ feet long and 35 feet wide; height, 12 feet; holds 102 horses, and affords to each 100 square feet of superficial area and 1,200 feet of cubic space. The ceilings are closed and fire-proof, men's rooms overhead, and foul-air shafts run up the division walls.

Such is a description of these closed-roof stables, which may be found all over the United Kingdom. The first pattern described, of which we took the Hounslow and Woolwich barracks as types, were the buildings in which glanders and farcy were rife, and destroyed a large percentage of our horses; and the mortality cannot be wondered at when we consider the almost entire absence of ventilation, the deficient cubic space and superficial area, bad paving, defective drainage, and the distance between opposite doors and windows, all of which faults were pointed out by the Commission.

The open-roofed stable, a few of which existed twenty-five years ago, attracted at once the attention of the Commission. The one at York is 173 feet long, 29 feet wide; holds 60 horses; height to spring of roof, 10½ feet; superficial area, 83 square feet, and 1,200 cubic feet for each horse. There is a window to every two stalls, ridge-ventilation from end to end, and a passage down the centre of the stable 10 feet wide, the horses having their heads turned to the outside walls.

The above-described stable laid the foundation of our model troop-stable, which well deserves its name; it ensures light, ample cubic space and superficial area, good drainage, free diffusion of air, and a clean floor.

The **Model Troop-Stable** (see Fig. 33, from 'Report on Cavalry Stables,' which shows a transverse section of the

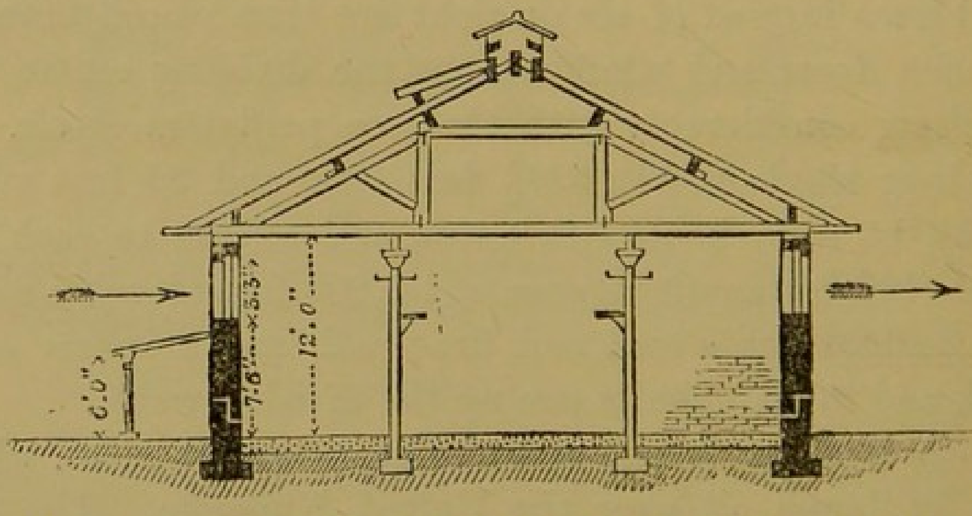


Fig. 33.—Section on A B, Fig. 34, of Model Troop Stable.

building), is arranged for forty-eight horses; the length of the stable is 143 feet 8 inches; breadth, 33 feet; height of side walls to spring of roof, 12 feet; total height, 20 feet 6 inches. Each horse is arranged to have 1,605 cubic feet of air, and 100 superficial feet of space.

At each end of the stable there is a large door and window, and in the centre of the stable a door on either side (see plan of building, Fig. 34).

The stalls are 5 feet 6 inches wide, 9 feet 6 inches in length, and the width of the passage between the stalls is 14 feet. The horses' heads are turned to the outer

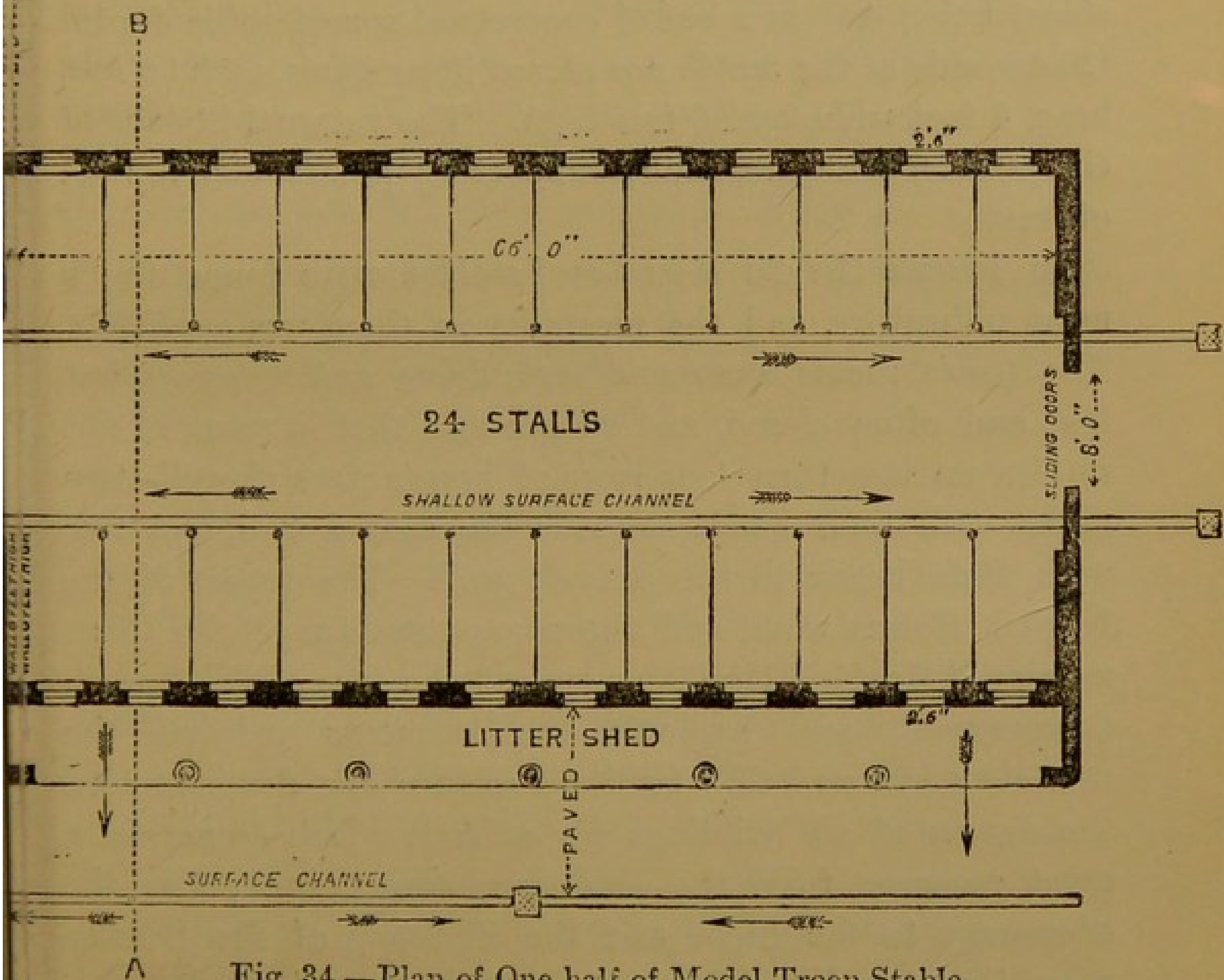


Fig. 34.—Plan of One-half of Model Troop Stable.

walls, and these contain a window 3 feet 4 inches high by 2 feet $6\frac{3}{4}$ inches wide over the head of each horse; an air-brick is placed between every stall 6 inches from the ground, and a course of air-bricks is carried around the eaves of the building. The roof is open at the ridge by means of a louvre, which allows 4 square feet of ventilating outlet per head, and a continuous skylight is carried along on one side of it.

The drainage is surface only, carried completely outside by a shallow impervious drain with a rapid slope; this drain passes behind the line of stalls, and is conducted in a straight line outside the stable to be discharged into an underground drain 12 feet from its wall. The flooring is stone, being laid on a bed of concrete of considerable depth. On one side of the stable are placed litter sheds, each 66 feet long, 6 feet wide, and 6 feet high. The internal fittings of this stable, mangers, bails, supporting pillars etc. are all of iron.

In France the old closed-roof stables were found to be most unhealthy, and the mortality in them was appalling. The men's rooms were overhead, doors and windows but few, and often closed, and we are told that in some of the stables no less than four rows of horses were placed—two ranks with their heads towards the centre wall, and two with their heads to the outside wall. The report of the English Commission, and the representations of the Commission d'Hygiène Hippique, opened the eyes of the French Government, and hygienic improvements reduced the mortality by one-half. Sanitary science has demonstrated the danger of all buildings for animals which do not, in a great measure, fulfil the conditions enumerated; also the advantage to the State and the efficiency of the Service when these conditions are not ignored or overlooked.

The inside walls of our troop-stables are whitewashed. It would be a great improvement to have the walls cemented, and so render them impermeable to moisture, easy to clean, and readily disinfected when necessary. No woodwork should be used for boarding the walls; the reason of this is obvious. The colour of the inside walls should not be white—the glare from this is too great; the white colour should be tempered with a neutral tint. The influence, if any, which whitewashed walls may have in the production of cataract amongst army horses is a point which, I think, demands inquiry.

Mangers and Hay-racks.—In our new pattern-stable these are combined. There can be no doubt of the advantages of this, for I can conceive no more inconvenient place for a horse to feed from than an overhead rack, and it is, moreover, a cause of conjunctivitis, from seeds and dust dropping into the eyes. Both manger and rack are of iron.

Pillars for supporting the roof and giving attachment to the bails are hollow and of cast-iron. They are a fruitful source of injury; thickened hind-legs being common from kicking the post.

Divisions.—The stalls are divided by iron bails, which are fixed into the front wall, and hook on to the pillar by means of a chain. The attachment is so arranged that in the event of a horse getting under the bail he liberates himself by upward pressure; and when he gets over it, a very common accident, he can be set free at once by pulling up the link. The late Staff Veterinary Surgeon Partridge invented a spring hook which released itself when a pressure exceeding two hundred pounds was placed on the bail.

I have the greatest objection to bails; they are a fruitful source of injury, either by horses getting under or over them; they teach horses to kick; a timid animal takes its rest badly, especially if one of the horses on either side of it is inclined to be playful, for he runs a risk of getting trodden on or otherwise injured when down, and prefers standing to sleep rather than take his rest in the ordinary manner. Although I condemn bails I have nothing better to offer in their place; wooden stall-divisions are out of the question in military stables, for every man and horse must be seen at a glance; and more than this, they would, in a large stable, considerably obstruct the free circulation of air. Colonel Russell, late 12th Royal Lancers, informs me that in some of the stables of the Austrian Cavalry stall-partitions are made of coarse grass matting nearly touching the ground, and if struck, swing but slightly; the structure being non-resisting the horse can do himself no damage. These partitions should prove useful, particularly in a remount stable; and if made of small rope would be more lasting and cleaner-looking.

There is nothing in the present bail to prevent a broken leg; in the case of notorious kickers a piece of wood about 3 feet long and 2 feet deep has been hung on to the bail. It is made strong and very heavy, and has undoubtedly saved many a limb. This protection should always be adopted in the case of kickers.

All bails should be hung from above and not from pillars; this would do away with heel-posts, which are a constant source of injury. The saddles should be kept in proper saddle-rooms. This is the method adopted in the new barracks of the Belgians, and the authorities are convinced that the leather work of the saddlery lasts longer by not being exposed in the stable.

Doors.—For the ordinary troop-stable sliding-doors are the best, 8 feet wide and 9 feet high; they require no latch or bolt, and a handle let in flush with the surface of the wood for pulling them backwards and forwards will be found to be out of harm's way. In the model stable there is a fanlight over each door, and a space left between the bottom of the door and ground for ventilation purposes.

Paving.—One of the most perplexing problems in stable construction, whether for military or civil horses, is the subject of flooring. Some material must be placed down which is hard, yet not slippery, non-absorbent, readily cleaned, and perfectly water-tight; durable, and not expensive.

The old stable-flooring, and one which still exists in some buildings, is the round stone set in mortar. This stone was objectionable to walk over; the mortar soon gave way and allowed of the percolation of urine and liquid manure; the ground beneath became saturated with the products of decomposition; the stones sunk unequally, leaving a big space where urine and stable-washings collected; and the gaseous emanations from the flooring added considerably to the already impure atmosphere.

No matter what material is to be used for paving, it may be stated as a rule to which there is no exception, that a bed of concrete must first be laid down to form an unyielding and impervious foundation.

The floor of the stable should be 2 feet higher than the outside ground; this is to allow of perfect drainage by providing for its fall, also to prevent the damp from soaking in through the walls near the outside ground.

Depending on the nature of the soil, whether springy or dry, a layer of small stones, granite if possible, should be evenly laid to the depth of one or more feet, and well rammed; on top of this should be placed one foot of good concrete. In laying this concrete care must be observed that it slopes gradually from the head of the stall to the heel-post, in order to provide for the surface drainage. The exact amount of this slope has caused much expression of opinion—1 in 80, 1 in 36, 1 in 30, have been variously recommended. The great argument against excessive slope is the strain it causes on the flexor tendons of the fore-legs, and on the hind-quarters. Theoretically this is of course correct; but I have never met with, nor heard of, a case of lameness arising from an excessively sloping stall. I consider, however, that the slope of 1 in 30 is much more than is required, and consequently open to objection; the fall of 1 in 80 I do not consider sufficient for a floor only slanting in one direction, and I should prefer to see 1 in 57 (in round numbers 1 in 60), or exactly a fall of 2 inches in a stall 9 feet 6 inches long.

Some stable-floors are so arranged that there is not only a slope from the front, but from the sides towards the centre. This, for military stables, is objectionable; it is bad enough to place the horse a little uphill without making his stall slope inwards; it means that he gets a level footing nowhere. For civil stables the case is different; these horses are bedded down during the day, and the sloping floor is thus rendered more even. The central drain which the sloping sides make, can only be of use in the stall occupied by the gelding; but he does not urinate under his nose, as the centre drain carried up to near the head of the stall in some stables would imply; and the mare's urine passes almost at once into the drain which runs behind the stall, so that with her the centre-stall drain is unnecessary.

The concrete substructure having been laid with a slope of 1 in 60 from front to rear, the paving material is placed on it. In the army this consists of square-cut granite stones securely laid in cement, the joints between each stone being carefully concreted. This makes a durable flooring, but becomes, through friction, smooth and slippery; this could be to a great extent prevented by the use of sand.

Indian Military Stables.

It is only within the last twenty or thirty years that stables have been built for our mounted troops in India. Many parts are still without them; in Madras there is only stable accommodation for five mounted corps in the whole Presidency. All animals for which stable accommodation is not provided have to stand in open lines, and thus we have on a very large scale the interesting experiment of the influence of shelter on sickness and mortality. At Bangalore, for example, we have only one corps stabled, and that is the regiment of British Cavalry. One battery of Horse Artillery, two of Field, and the regiment of Native Cavalry, are all in open lines. As the horses of the British cavalry and artillery are of the same breed (Australians), and as the conditions of feeding and general stable management are much the same throughout the service, it places the animals thus stabled and unstabled under almost identical conditions, excepting as regards shelter. From careful observation I am bound to confess that I can see no important difference as the result of shelter. It is surprising how well horses will look exposed to wind, rain, cold, and heat; standing on ground scorchingly hot, or up to their fetlocks in mud and wet during the rains. The stabled horse's coat is brighter, smoother, and compares favourably with the rusty, sunburnt coat of the exposed animal; but I do not think that the stabled horse is less prone to disease than the other. Provided both are receiving the best management, I see no difference in the health enjoyed.

My experience in regarding stables as possessing no influence over disease quite coincides with that of old Indian officers, who ridicule such occidental civilization for troop horses, and tell us that in the olden days shelter was not provided, and no animals enjoyed better health. Be it remembered, however, that in those days troops were mounted on Asiatic horses, and not on animals which are quite as foreign to the country as the Englishman himself.

I do not for one moment intend it to be understood that stables in India are unnecessary, for no one appreciates more than I do the additional comfort that shelter against tropical weather ensures a horse, which comfort must, perhaps imperceptibly, tell in the long-run.

There is one thing connected with the exposure of the Australian horse in open lines that I would briefly mention, and it is, that no horse for his first year, and better still for his first two or three years, be left exposed to the vicissitudes of open lines. This is the period of his acclimatization, and he should certainly be under cover if we wish to keep him in health, and turn out a serviceable animal.

The opinion I have offered as to stables exercising no influence on sickness and mortality can only apply to Southern India. Great differences are met with in a continent the size of Hindostan, and we find that Inspecting Veterinary Surgeon Meyrick, C.B., strongly advocates shelter for horses as preventing sickness; and he tells us that at Jhansie, in 1878, during the hot season, both Australian and stud-bred horses standing in open lines were severely affected by the heat. They all lost condition, and many lives were saved only by giving those animals most affected shelter from the intense heat.

I have experienced the heat of Bengal, and can quite believe in the necessity of protection from the sun; but south of the Godavery horses may certainly be exposed to all weathers, and, provided they receive good stable management, no palpable harm seems to arise from it. Nevertheless, I would tie no animal by head and heel in a blazing sun, or expose him to 2 inches of rain at night, if I could possibly obtain any cover for him. It appeals very much to one's feelings to see a fine body of horses in open lines with not a tree anywhere, and the sun at the meridian.

Choice and Situation of Stables.—It is very necessary that a proper site should be selected for building upon, and, as regards space, we have much more choice in the matter than we have at home; unfortunately, as regards the quality of the soil, we have not the same selection. Enormous tracts of land throughout India are alluvial; along the course of the Ganges, Brahmaputra, Indus, Nerbudda, Godavery, Kistna, etc., we have this alluvial soil. This is particularly the case in Bengal, where large portions of the continent consist of material containing the animal and vegetable débris of centuries. As a result, all alluvial soils are unhealthy; and though in many cases we have no choice in the matter, having to accept a site for military reasons, yet much may be done in arranging for the drainage of the place to render it more healthy. The position selected should, if possible, be an elevated one to allow of drainage; low-lying places should be avoided; valleys are unhealthy, for they are usually filled with decomposing vegetable matter, and are damp; the foot of hills is not judicious, unless the drainage from them be diverted. Whatever place is selected, water must be convenient. Place the stables on the most elevated ground; at Secunderabad our lines were built on a slope—the drainage was most complete; at Bangalore the stables were below the level of the barracks, and in the rainy season the storm-drainage, after washing the barrack-square, came pouring down the side of each troop-stable, flooding the whole place. If the soil is granitic or gravelly, as it is in the greater part of Southern India, the foundation will require no treatment; but if it be clayey, marly, or alluvial, a foundation of concrete or kunkur should be prepared for the walls to rest on.

The vegetation surrounding should be disturbed as little as possible; herbage particularly should not be interfered with; brushwood should be removed, also any trees that may be so situated as to interfere with the free perflation of air. Trees in or near lines are very convenient and useful as shelter; therefore much judgment must be exercised in their removal, particularly when we consider the influence of leaves in purifying the air. The stables should not have any other buildings near them, and bazaars should be rigidly excluded from the site.

Aspect.—I should place stables end on to the monsoon wind, and broadside on to the hot wind. Hot winds are certainly healthy, and there is not the same objection to placing the stables broadside on to them as there is to the wind which brings up heavy storms, and rain that drifts right through a building. Veterinary-Major Poyser* recommends that the stables should be placed broadside on to prevailing, and end on to deleterious winds if these blow from opposite quarters.

The lines should be built *en échelon*, as before described; the stables should not cover each other; but if, from want of space or other reasons, this cannot be obtained, the distance between the blocks should be considerably increased.

In arranging the ground-plan of Indian troop-stables it must be remembered that space should be allotted for outside standings. This is a peculiarity in Indian lines that we have not to take into consideration at home; we must provide outside standings where the horses can be placed during the nights of the hot and the days of the cool weather. V.-Major Poyser recommends that these standings should be placed at the end of the stables, and not between them, as is the custom. The advantages are that the buildings are allowed free perflation, there being nothing to interrupt the current of air through the whole of the blocks, and the horses have the advantage of a complete change of ground. There should be a double set of outside lines.

Stable-construction.—As at home, we have two distinct types of stable, the old and the new. The former was of mud or masonry, and either tiled or thatched; the internal arrangements differed considerably, depending on the caprice

* In his excellent Prize Essay on 'Stable Management in India.'

of the builder. These buildings practically amounted to nothing more than a shed, often too low, with no roof-ventilation, and with a flooring of ordinary earth which when moist became mud. The buildings were situated close together, and from their arrangement the free perflation of air was interfered with; bazaars and native lines were much too close; underground drains often existed in the stalls, with an earthen vessel buried to receive the urine which was never emptied; the condition in which the ground was rendered as the result of this abominable practice cannot be described.

The new Indian troop-stable is built on no fixed plan. The only points in common are that they give each horse a larger superficial area and cubic space, the building is constructed of sound material, and more attention is paid to the nature and quality of the flooring. Brickwork and tiled roofs are used.

V.-Major Poyser, in speaking of the construction of troop-stables for India, would do away entirely with masonry and use iron supporting pillars; the roof to be double, galvanized iron outside, wood planking inside; distance between each, 20 inches; a passage down the centre, $7\frac{1}{2}$ feet wide; a veranda on either side, $7\frac{1}{2}$ feet wide; greater cubic space, 3,000 feet, and superficial area, 200 feet per head. The ventilation to be ridge from end to end. Standing-room for each horse, 15 feet $\times$ 8 feet. No mangers or feeding-troughs, nothing to interfere with the free circulation of air. The glare and flies are excluded by a bamboo curtain, which can be pulled up and down.

All who are interested in Indian troop-stable construction and management should carefully study V.-Major Poyser's essay, which contains a vast amount of useful information; this paper has done much to attract attention to the subject, and we may hope has laid the foundation for the construction of stables in India suited to the requirements of the country.

Indian troop-stables should be sheds open all round, of good height, with ridge-ventilation. No large pillars or dividing walls; nothing, in fact, to interfere with the free circulation of air, and the buildings should be sufficiently deep to keep out drifting rain.

Flooring.—One of the greatest difficulties in Indian stables is the flooring. The floors are made of earth, permeable or fairly impermeable, depending upon the local supply. Much more care is now exercised in the choice of material; but at one time any rubbish at hand, without reference to its permeability, was used; alluvial soil teeming with organic matter was often laid down. To one unacquainted with India the question suggests itself why stone or impermeable brick-flooring is not used? Stone is not found everywhere, and when obtainable, as it readily is all over Southern India, it cannot be used, for the reason that the Indian Government *give their horses no bedding*; and if a granite floor were used, the horses would be constantly bruising themselves, and but few would lie down. Again, the impermeable stable-flooring sold by the manufacturers in England would cost an enormous sum by the time it arrived in India, so expense also precludes its use. Earth-floorings are consequently the only ones known, and much attention has been paid by the profession to render them as impermeable, durable, and non-absorbent as possible.

Throughout the upper part of India large beds of impure calcium carbonate (kunkur) exist. This material, when wetted and well rammed, makes a fairly water-tight floor.

Inspecting Veterinary Surgeon Meyrick, C.B., recommends a mixture of clay, kunkur, and sand; these materials are finely divided, and made into a kind of stiff mortar before being laid down. Veter.-Major R. Poyser recommends a mixture of clay and sand, in the proportion of one of the former to ten of the latter; it sets very hard and firm, after wetting and thorough ramming. Vety.-Major W. S. Adams uses a mixture of gravel and clay, in the proportion of one part clay to two of gravel; this, after wetting and ramming, is impervious to moisture, and becomes so hard that he has told me it turns the picks when the stalls are being dug up.

Whatever material we select, and at times we have no great choice, the chief points to bear in mind are that it is placed down wet, thoroughly rammed, of good thickness, allowed some weeks to dry, and removed at regular periods, depending on the state of percolation. The thickness of any flooring should not be less than 1 foot; it should have a slope of 1 in 60. Constant examination of the stalls is required to ascertain their condition, and the whole flooring should be removed once a year at least, or every six months if sanction can be obtained. There is much art in laying a floor properly; constant ramming is required, so that cracks may be closed up as they form; but the whole labour will be thrown away if the horses are placed in the stable before it is dry. For floorings to last a year, or even six months, they should be constantly repaired, holes filled up, etc.

To prevent soiling the floors vessels are often used for the horses to urinate into, and, ridiculous as this may appear to people who have never been in India, it is a very good plan for keeping stalls dry. This is not such an impracticable system as it sounds. I think, however, that a more practical one is the following, which I saw carried out at the Remount Depôt, Oossoor. Every horse brought out to water passed on to a manure-heap outside the lines; here he halted, and passed his urine; he then walked on to the trough and watered. The horses knew this system perfectly and liked it because, the litter being soft, their legs were not wetted. As they came out three times a day to water, the stalls were principally soiled at night, and this no system can prevent.

Internal fittings, posts, saddle-racks, etc., are unnecessary; they take up room, and unless placed out of harm's way are liable to cause injury. Unlike in England, saddles are not kept in the stable, but in specially provided saddle-rooms.

Feeding-troughs.—English mangers are unknown; horses are fed either from nose-bags, mud-troughs placed on the ground, or out of an earthenware vessel fixed in a mud-stand. The nose-bag is a most objectionable arrangement; it becomes filthy, sour, discoloured, and induces bolting; yet every horse in the Madras army is fed from a nose-bag, excepting when commanding officers use any unauthorized method. Feeding out of a little mud trough placed on the ground is a useful plan, and so is the earthen vessel fixed in the mud-stand. There can be no doubt that a combined water and feeding-trough, made of galvanized iron with an enamelled lining, is the correct thing. I have seen the feeding-trough in use, and it answers admirably; to make it complete I should add another partition, make it round at the bottom instead of square, fit it with handles, fix it in a mud-bed either on the floor or any height above it, and a very useful portable manger would be formed; by means of the handles it can be easily lifted out of its bed, and taken outside to be cleaned or filled.

Outside Lines.—We have previously explained the necessity of having outside lines (if possible a double set), and the position these should occupy. It only remains to say that the flooring requires the same attention as that of the stables; but that any clayey material is objectionable to use in its formation, as during rainy weather it becomes a quagmire. These outside lines should not be limited in length or breadth; if the room is obtainable have 12 feet from head-peg to head-peg; the more space between the horses the cooler they will be. I have been surprised at times to see how horses in open lines are packed together with the regulation distance between each head-peg; it probably looks smarter, but that is a very poor argument in favour of its adoption.

Civil Stables.

We have a very large variety of building which serves the purpose of stables in civil life. Perhaps the best classification will be into upper, middle, and lower class stables. In our first class we have the handsomely-fitted stables of the wealthy. In the second class will be found the ordinary private stables of our towns and cities. In the third class will come cab-stables and the stables of small tradesmen; farm-stables and the buildings erected by large companies for the accommodation of their horses.

Upper-class Stables.—Stable-building and construction has been brought to such perfection from point of material and design, that as much may be spent over their erection as over the building of several ordinary houses. In London and elsewhere we have large establishments which make it their business to undertake the construction and fitting of stables. Some of their work is extremely nice; and an animal can, in the present day, be lodged in quite a palatial residence.

Site.—In choosing a site for a private stable the rules previously laid down (p. 245) hold good. Elevation, good soil, water convenient, and drainage easy.

Aspect.—It is generally believed that the aspect should be southern, others recommend an east and west aspect. I think that much depends on the locality; but I believe that a southern aspect will be found most generally suitable.

Construction, Dimensions and Arrangement.—In arranging the ground-plan for private stables there are many points to be considered. The space may be limited, and the number of horses to be accommodated large. Again, we have the preconceived ideas of master, builder, and servant to meet. The master and servant will probably be of one opinion; the horses must be kept close for warmth, as few doors, windows, and ventilators as possible to prevent draught, the hay-loft above the stables to keep out the cold, underground drains, etc. The builder will have his ideas of decoration subservient to comfort and utility. If a man spends his money on a stable he is at perfect liberty to erect it on the most approved insanitary method possible; all we can do, if asked for advice, is to endeavour to overcome prejudice and ignorance, urge ventilation, cubic space, and superficial area; and if the plans of the proposed stable are submitted for inspection, to point out those parts which offend against sanitary science. The most common error committed is placing too many horses under one roof, with deficient ventilation and cubic space.

The position of a stable must depend upon the number of horses it is to contain, and the space at command. Never build it in a square if it can be avoided (see p. 247); if possible have a single row of horses between opposite doors and windows instead of a double one; and avoid the evil of putting a number of horses under a broad building, as such cannot be well ventilated.

It would be impossible to give the dimensions for all forms of stabling; but we can state generally what they should be for an individual horse. Stalls should not be less than 6 feet wide and 10 feet long; boxes, 12 to 14 feet square. If an open roof, the wall should be 12 feet high to the spring of the roof; if a closed roof, 14 feet should be the least height. The width of stable should not be less than 20 feet, that is if only a single row of horses is to be accommodated; if a double row, 30 feet; the double row is not recommended.

Light is as necessary for horses as pure air; this point must be attended to, and a sufficiency of windows provided: one large one in the wall behind every two horses, and one to every horse overhead, will be found ample; where a double row of horses is to be provided for, there should be a window for each animal overhead; one of the main evils in stables of bygone days was the utter darkness which was insisted on as beneficial. In crowded towns and cities reflectors on the windows may be necessary, and prove useful as a means of introducing more light. The windows being a means of ventilation, a full consideration of them will be found under that heading (see p. 91).

The **Inside Walls**, excepting that part immediately over the manger, should be of impervious cement with a polished surface; it may be coloured with a neutral tint, if there is any tendency to glare. That portion of the wall above the manger should be made of coloured encaustic tiles, with the margins between each securely cemented. Sometimes the manger is closed in below with woodwork, to prevent accidents from horses getting their heads fixed under it; at other times the wall is simply boarded the same as the stall. If ground air-bricks are used, they should be placed between the stalls, or a ventilated damp-proof course may be used for the purpose of floor ventilation. If the foundation is damp, double walls, or a damp-proof course as before described (p. 244), should be used. When artificial heating of the building is practised the warming bracket should be under the manger; in all new stables this should be arranged for, and made to communicate with the outside by means of an opening of at least one square foot in area; this could be made to be completely closed when the apparatus is not at work. Air-bricks above may be found necessary; they should be placed in the walls just below the roof, and may be carried completely around the building, or only inserted at intervals. Either of those shown at Figs. 35 and 36 will be found useful. Fig. 35 is more suited for ground ventilation, and Fig. 36 for ventilation under the eaves.

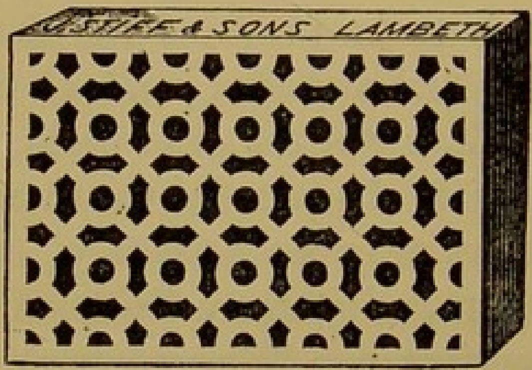


Fig. 35.

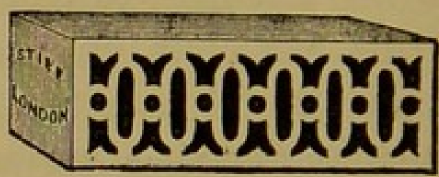


Fig. 36.

Air-bricks.

The **Roof** if flat, or closed in by a loft or rooms above, should be of plaster or cement; the greatest care must be exercised to have it perfectly air-tight, or else ventilation will be interfered with, and the rooms or loft above will become filled with the foul air from the stable. In the roof arrangement must be made to accommodate a foul-air shaft for each horse. If the roof is an open one, ventilation is a simple matter. Open roofs are objected to by most people; one reason is that much space is taken up which might be occupied by a loft or rooms, or it may be that there is no accommodation elsewhere for these places. Again, they are supposed to be very cold and draughty. The open roof used in the army would certainly be too cold for valuable horses, and the chances of down-draught are great; but this is owing to the ridge ventilation being an ordinary louvre; in private stables the ventilating medium in the roof should be a fixed upcast cowl. The outlet in the roof need not exceed 1 to $1\frac{1}{2}$ square feet per head, it being taken for granted that other means of outlet ventilation, such as air-bricks, windows, etc., exist. This area is less than that given on page 103, but my remarks there apply principally to big public stables.

Flooring.—The conditions enumerated in military stables here also hold good; the flooring must be impervious to moisture, not slippery, and easily cleaned. In every case the foundation must be prepared with concrete, with a slight fall towards the drain. In the selection of paving material, large clinkers, vitrified channelled paving-brick adamantine clinkers, etc., are commonly used.

Vitrified paving-brick is of two kinds—Welsh and Staffordshire brick. They are blue-black in colour, and their broken surface should show them to be the same colour throughout. Those reddish towards the centre are of inferior quality. The bricks are made $9'' \times 4\frac{1}{2}'' \times 3''$, and are divided into two or eight squares (see Fig. 37). They are

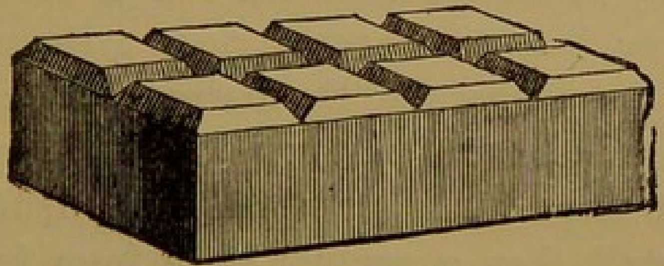


Fig. 37.—Vitrified Paving-brick (St. Pancras Iron Works Company).

quite water-tight; but dirt lodges in the squares, and, in my experience, they are slippery. A Staffordshire brick with one longitudinal groove (Fig. 38) is made by the St. Pancras Iron Works Company, which is readily cleaned, and affords a good foothold; the drainage runs along the brick and not on the joints, which is a great point in its favour. In laying these bricks care has to be observed that the grooves in the brick are kept the least bit higher than the drain into which they lead. The Adamantine Clinker is a good brick; it is usually laid in a herring-bone pattern, and is more suitable for passages than for stalls or boxes, owing to its numerous joints and small size.

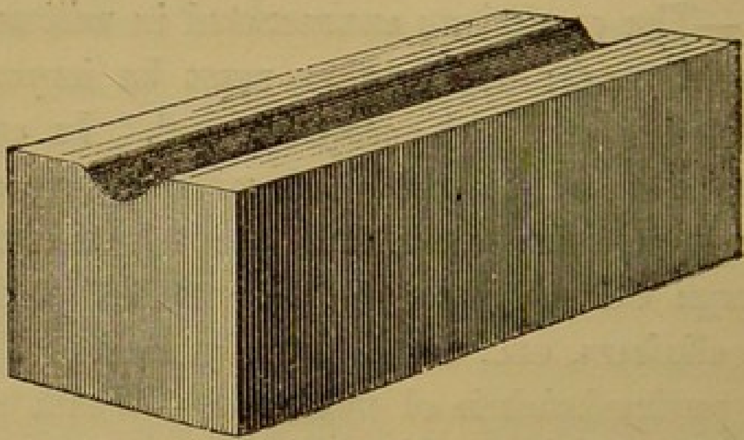


Fig. 38.—Vitrified Paving-brick with One Groove.

The position of the flooring differs greatly; it may have one slope from front to rear, or the sides may incline towards a channel in the centre, or all four sides may incline towards a trap in the centre of the box or stall. There is little to choose between these various systems; they all depend upon the character of the drainage which is adopted. If a trap in the centre of the box or stall is required, then all sides must slope towards it; if the trap is to be outside the box or stall, then a gradual slope from front to rear, with an inclination of the sides towards the centre, will suffice. The chief point to observe is that whatever slope is adopted it should be as slight as possible; the least inclination will carry off water.

Fig. 39 will give an idea of how stable floorings are usually paved. I am not in favour of diagonal grooves, and prefer the arrangement of stall at *b* or *d*. Whatever grooves are provided, the majority should run across the stall, and not all take a straight direction from the manger to the heel-post; non-observance of this is a fruitful cause

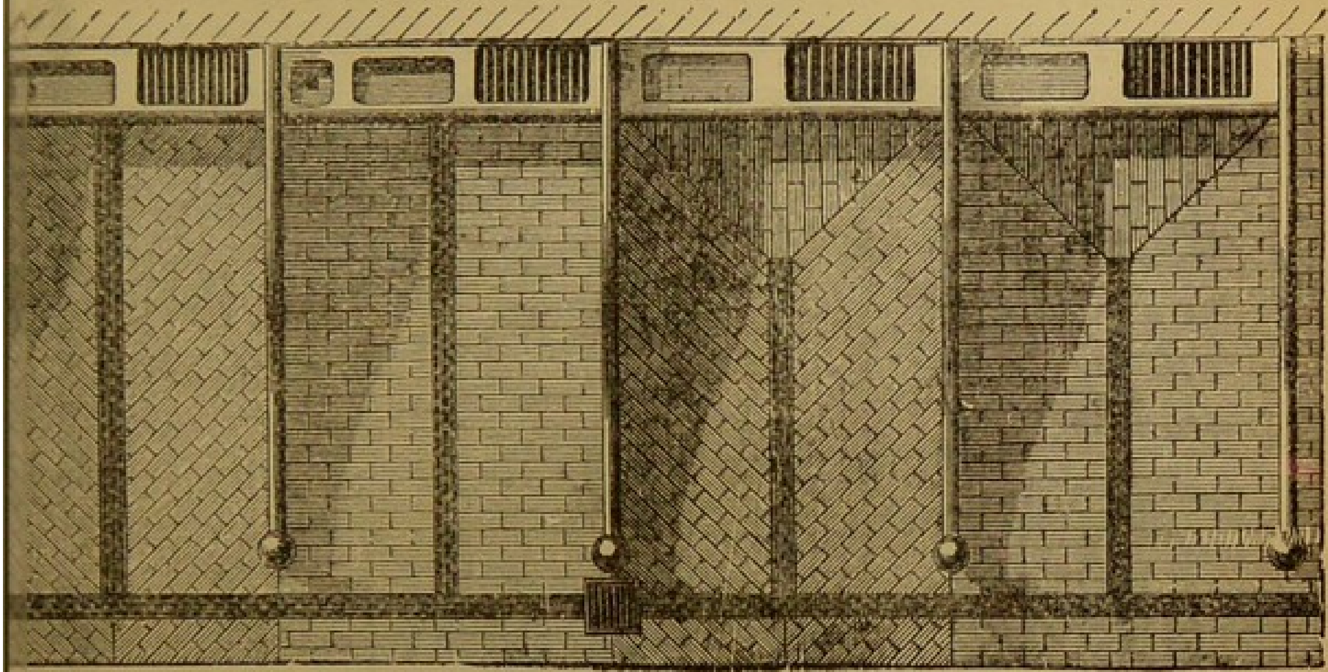


Fig. 39.—Methods of laying Paving-bricks in Stalls ; *b* and *d* are good arrangements (Musgrave).

of slipping up and consequent injury. Fig. 40 shows a good arrangement of paving. Fig. 41 shows a method of arranging the paving of a loose box when underground drains are required.

Asphalt as flooring fails in durability, and also presents

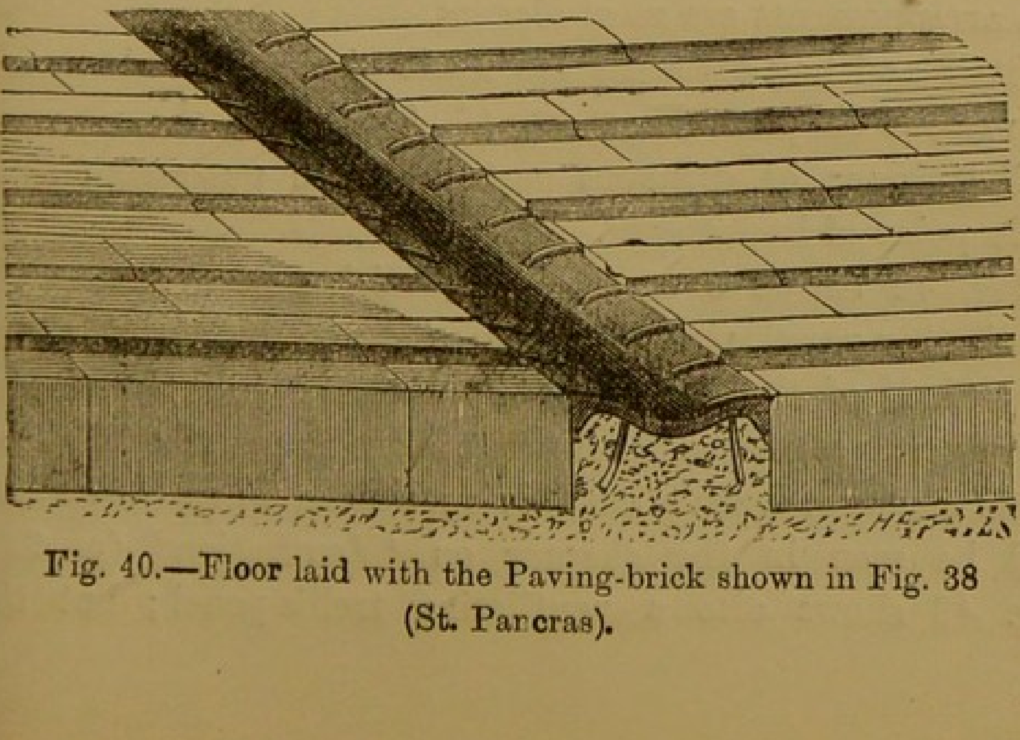


Fig. 40.—Floor laid with the Paving-brick shown in Fig. 38 (St. Pancras).

a slippery surface; it is perfectly impermeable to moisture; in private stables where horses are always kept bedded down it might prove a useful flooring, but it is quite unsuited for military stables.

Fig. 41.—Loose Box Paving (St. Pancras).

Drainage and flooring are usually considered together; we must, however, depart from this course, as owing to its importance a special section will be devoted to the subject of drainage.

Stable-fittings. — Much talent has been exhibited by stable-constructors in the fittings of stables, and some of the arrangements are most elegant.

Stall and box divisions are made of wood and iron, and of various shapes. Figs. 42, 43, 44 and 45 show several stall-divisions of different patterns, each possessing some little point of importance.

Fig. 42 shows a strong stall-division with a so-called ventilating panel, moulded ramp, and ventilating pillar; the lower half of the division is of 2-inch wood. The air for the pillar is conveyed from without by means of a tube; as a sole means of ventilation it is unreliable, for reasons which will be seen in the chapter on 'Ventilation' (p. 94). Fig. 43 shows also a ventilating trellis-panel; but the point of importance is that it contains a bar or barrier which can be drawn across the stable at night, so that in the event of a horse slipping his head-collar he cannot get to worry his stable companions. This bar can be pushed back during the day into the barrier-sheath. Fig. 44 is a stall-division with a solid part at the head to

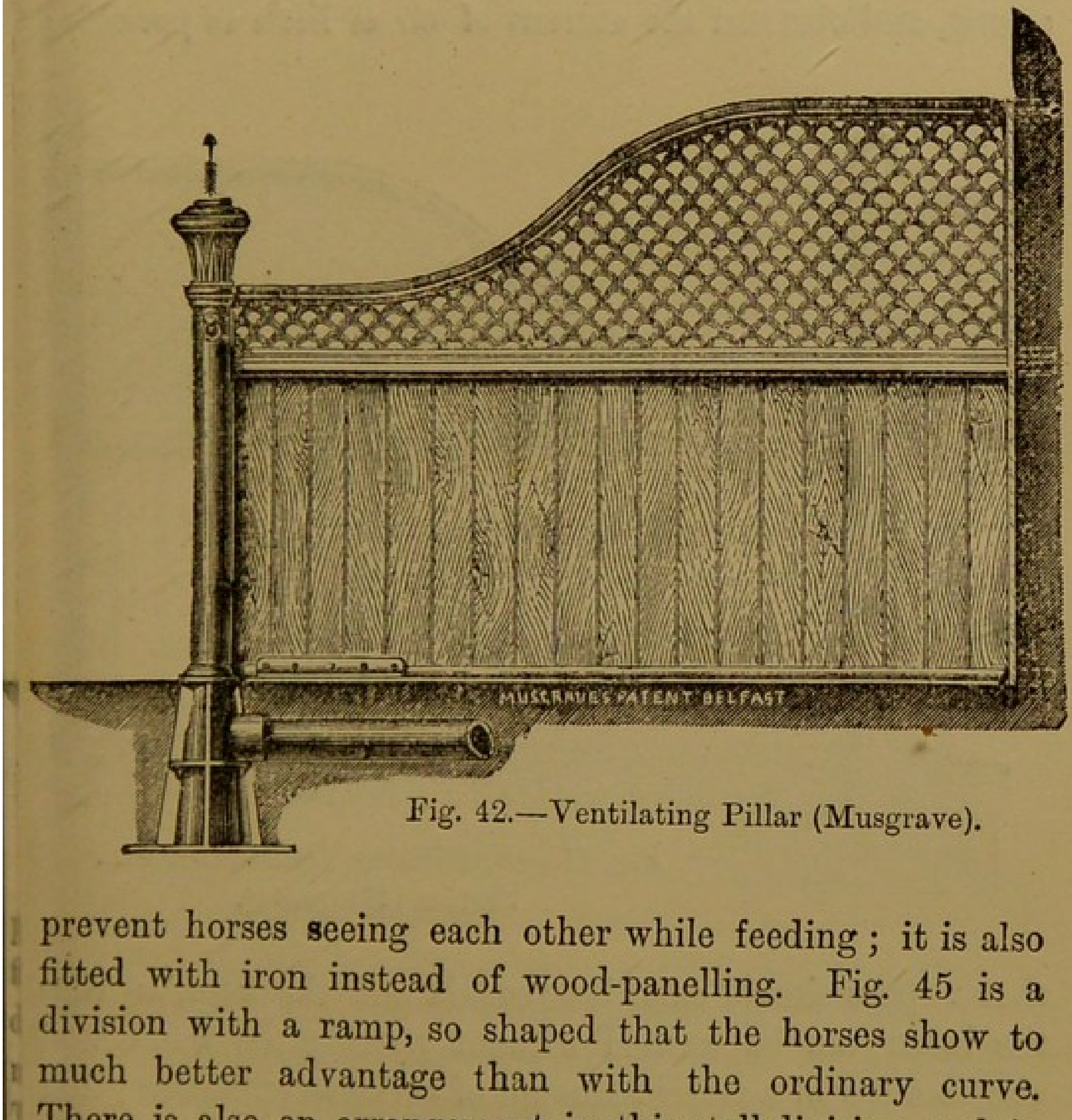


Fig. 42.—Ventilating Pillar (Musgrave).

prevent horses seeing each other while feeding; it is also fitted with iron instead of wood-panelling. Fig. 45 is a division with a ramp, so shaped that the horses show to much better advantage than with the ordinary curve. There is also an arrangement in this stall-division, and in that of Fig. 42, which allows of new boards being readily inserted, and broken ones removed. In some stall-divisions that portion of the wood-panelling which is most exposed to the kick of the horse is placed horizontally, so that the foot may slide along it, and thus the force of the blow be to an extent expended. Some makers turn out particularly handsome stall-divisions designed to harmonize with the style of architecture so extensively carried out at the present time in new buildings.

The requirements of a stall-division are that it should be strong, and obstruct the current of air as little as possible;

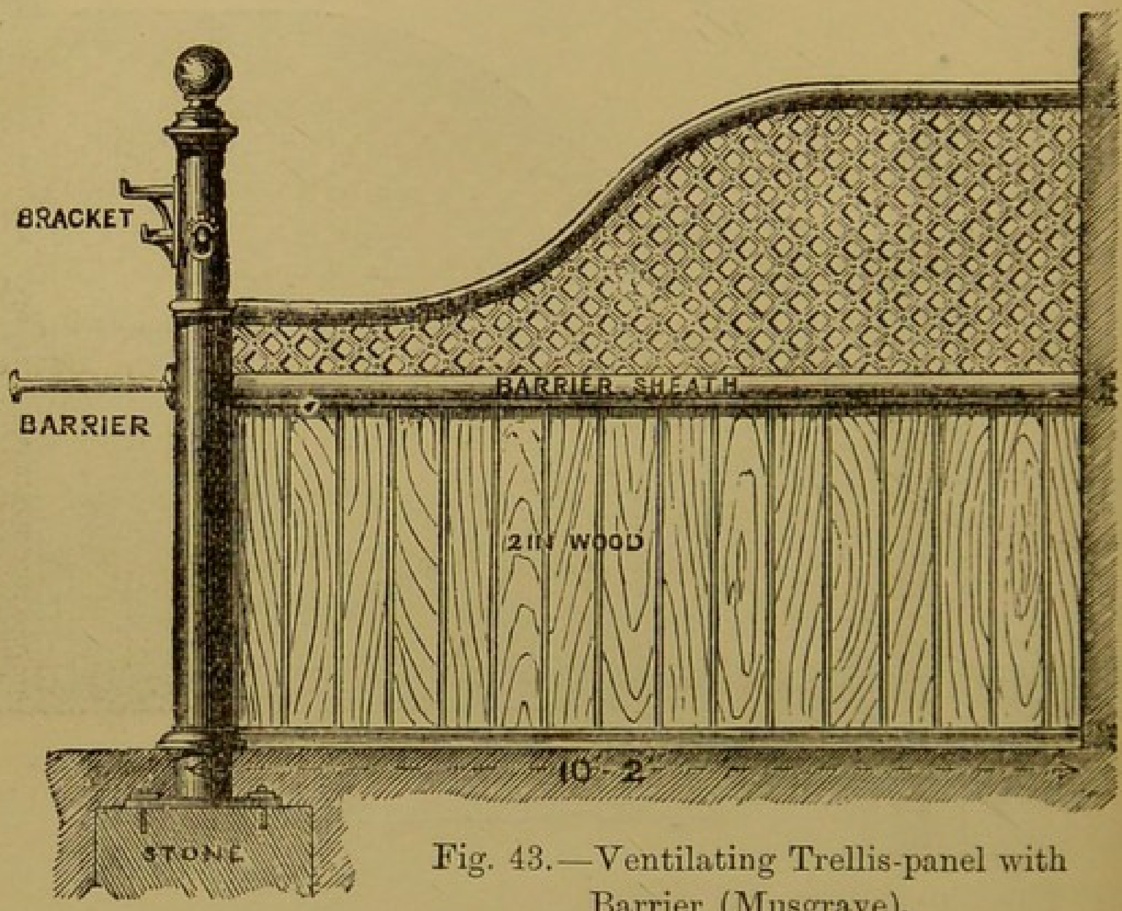


Fig. 43.—Ventilating Trellis-panel with Barrier (Musgrave).

that a space should exist between it and the floor, so that the latter can be washed without wetting the wood, and also to allow of a certain amount of surface-ventilation; that the boards can be readily removed and replaced if broken, and that there should be a solid head to the trellis-work to prevent horses disturbing each other whilst feeding.

Loose-box divisions differ in no important particular from those of stalls; their requirements are much the same. The doors, however, demand attention; they must be so arranged as not to injure a horse passing by or through them; and for this purpose there are many ingenious devices, of which perhaps the sliding-door is the best; if the door is hinged it must be made to fold back flat against

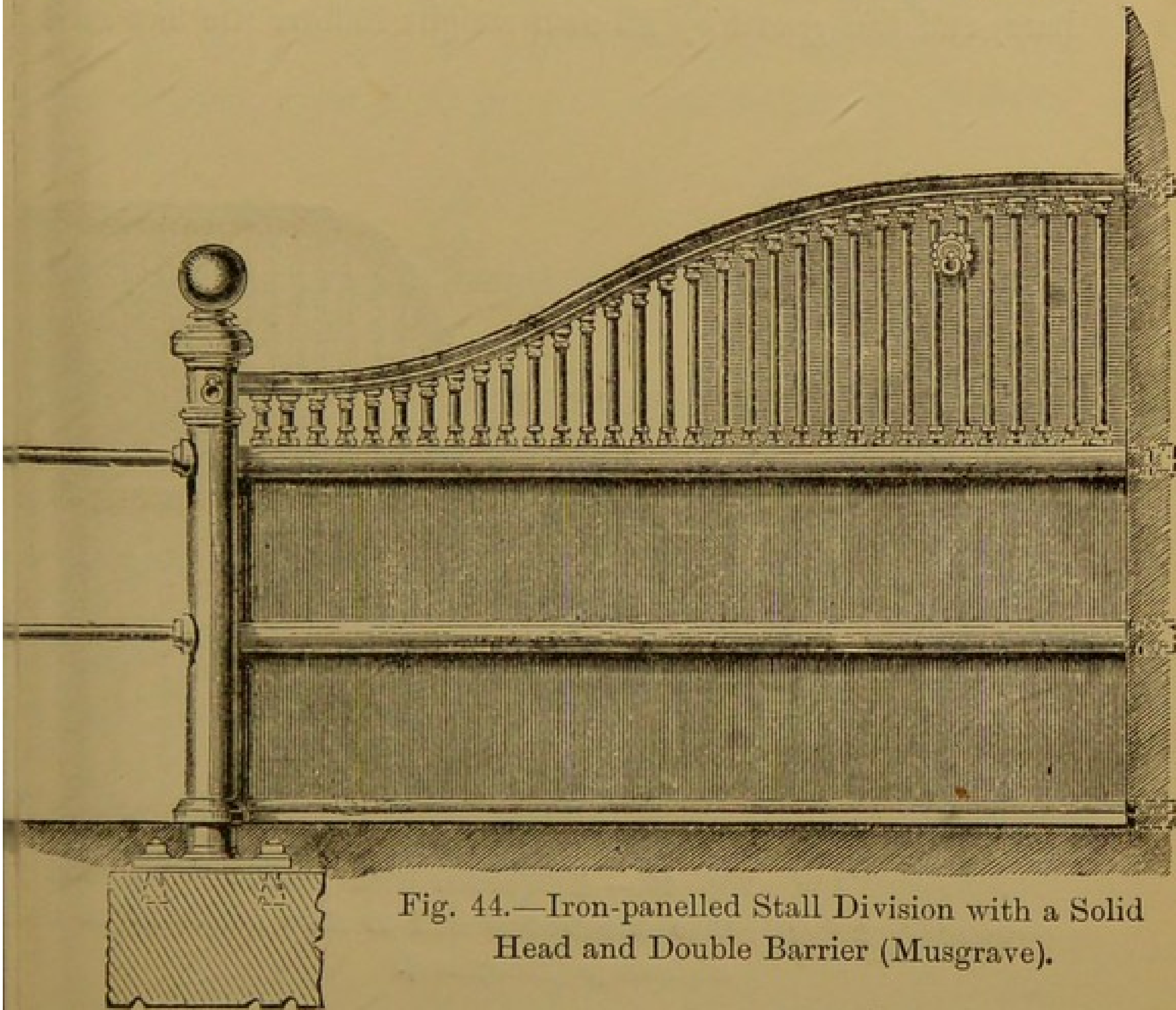


Fig. 44.—Iron-panelled Stall Division with a Solid Head and Double Barrier (Musgrave).

the side of the box, and have no projecting bolts or latches. Fig. 46 shows a strongly made box-division, with harmless latch, and door which folds back flat. No fixed ironwork should exist over the doors, or injury to the head may result.

Mangers and Hay-racks.—The various forms in use are shown in Figs. 47, 49 and 50. Fig. 47 is arranged to have a constant supply of water by the horse; the vessel in which this is placed can be turned over, and the water thus utilized to flush the drain; the hay-rack is on a level with the manger, and has a guard placed over the hay. This latter is a sort of gridiron, which slides up and down on two rods; the horse can pull the hay out between the bars, and the guard by its own weight follows the hay as it

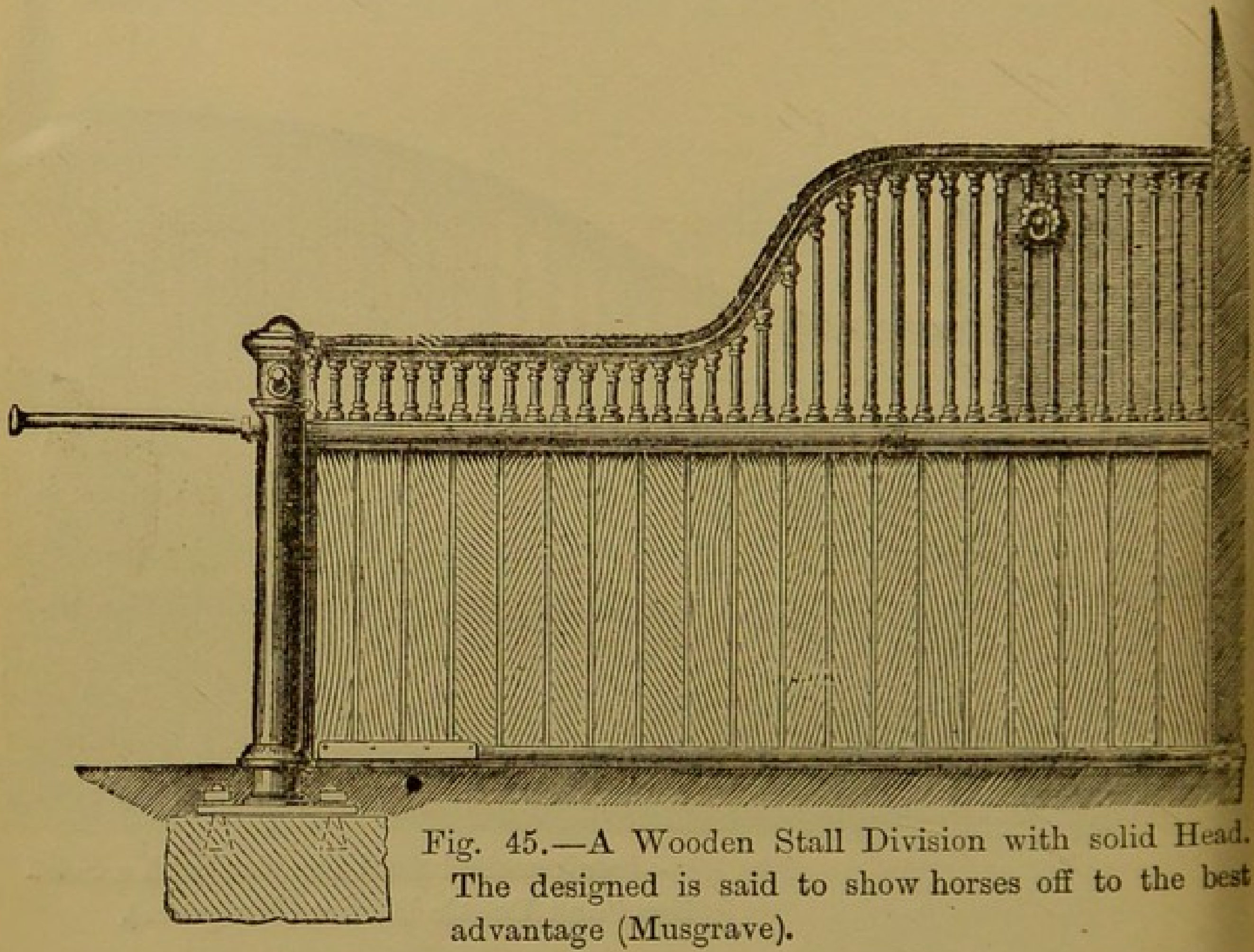


Fig. 45.—A Wooden Stall Division with solid Head. The designed is said to show horses off to the best advantage (Musgrave).

decreases in bulk. The object of this guard, which is seen in section, Fig. 48, is to prevent the horse pulling out more than necessary, and thus avoiding waste. Fig. 49 shows a manger with the rack raised; the bottom of the rack is perforated for the dust and seeds to drop through, which latter are removed by a sliding-door in the seed-box. A very handsome stall is shown at Fig. 50. The fittings are made with the tumbling water-vessel; but the hay-rack is made in the form of a niche in the wall.

These are the principal forms of manger in use; they are made of wrought-iron with smooth rounded edges, sloping away from the horse's knees, placed at a height of about 3 feet 4 inches from the ground; the water is supplied by a valve; the mangers are readily emptied and cleaned, and are sufficiently large to prevent a horse getting his head

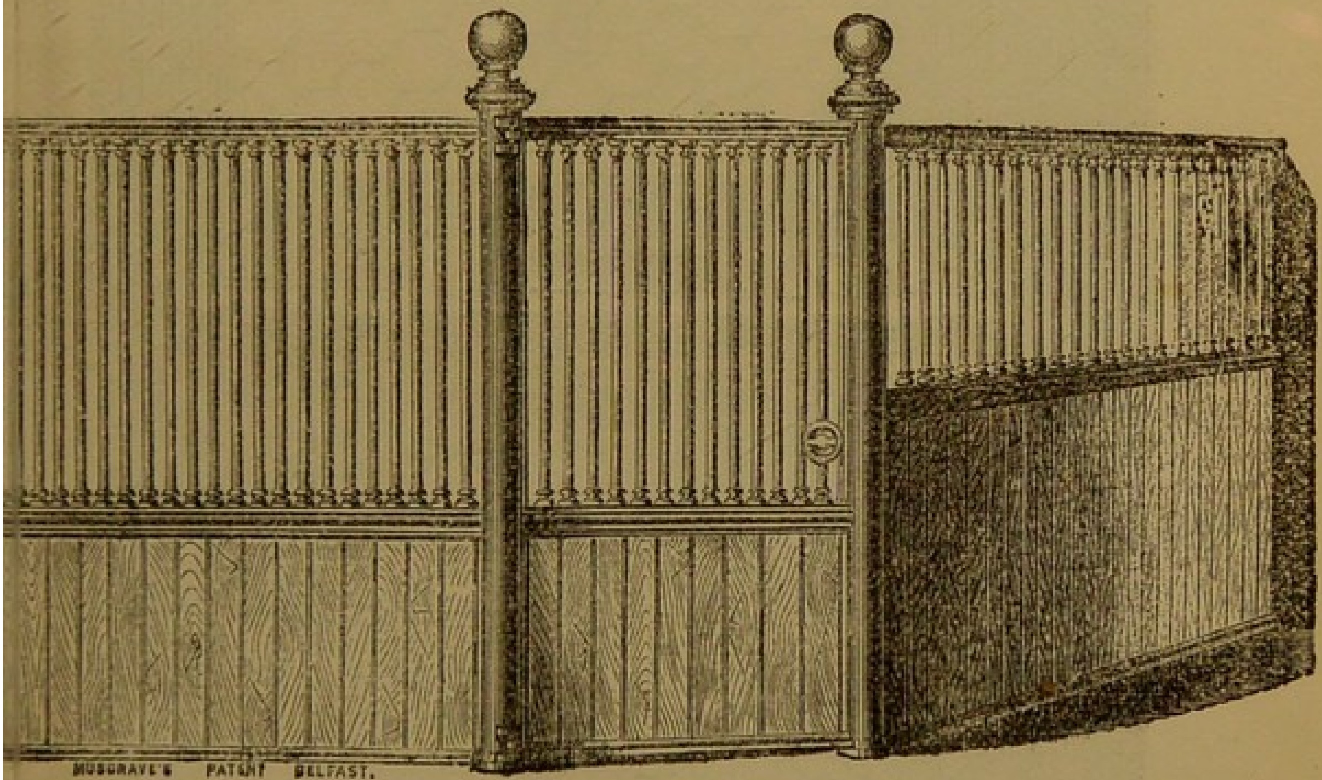


Fig. 46.—Box Division (Musgrave).

fixed in them. The manger-fittings for boxes do not differ materially from those described.

The only point which I consider objectionable in all these mangers is the arrangement for emptying the water-vessel into the stable-drain. Ammoniacal and other gases must come up the pipe emptying into the drain, and the drinking water runs a risk of contamination. The pipe should open *over* the drain, and not directly into it.

Fastenings.—The methods of tying a horse in his stall are not unimportant. The ordinary chain through a ring in the manger is very noisy; if employed, care should be taken that the log used with it weighs heavier than the chain, or else the latter is not pulled back when it becomes slack, and the horse is liable to get his fore-leg over it. Fig. 51 shows a method of preventing all rattling noise; it

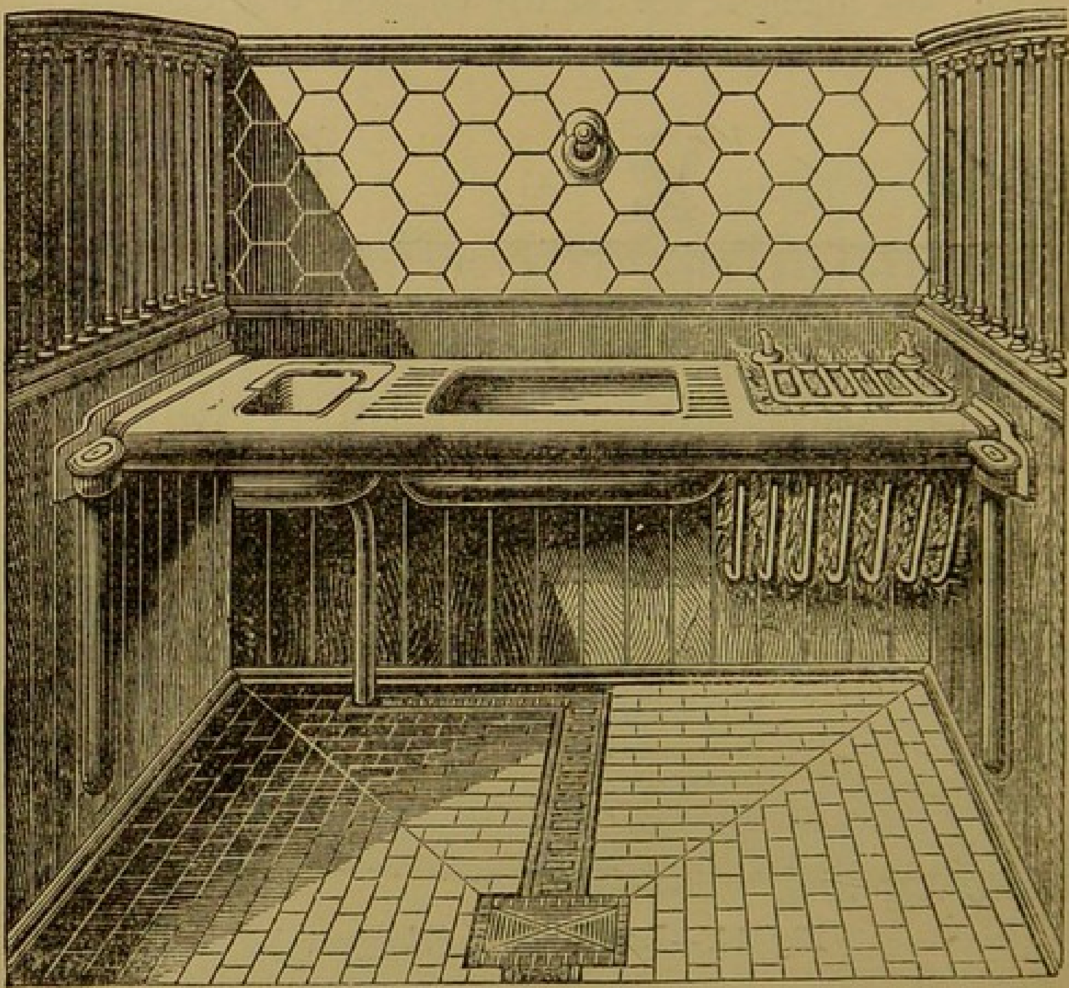


Fig. 47.—Manger with Sliding Hay-guard (Musgrave).

is known as Musgrave's patent tying. The horse is not fastened to the manger; but the chain or halter works through a long slit in the top-plate, which allows it to play as freely as if there were no manger before the horse. The bracket, below the slit, holds back the halter-weight close to the wall. The weight has an India-rubber buffer on the top, which strikes a flat place at the base of the bracket,

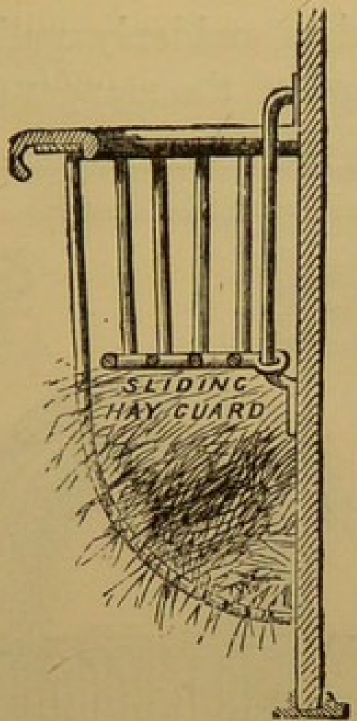


Fig. 48.—Section of Sliding Hay-guard (Musgrave).

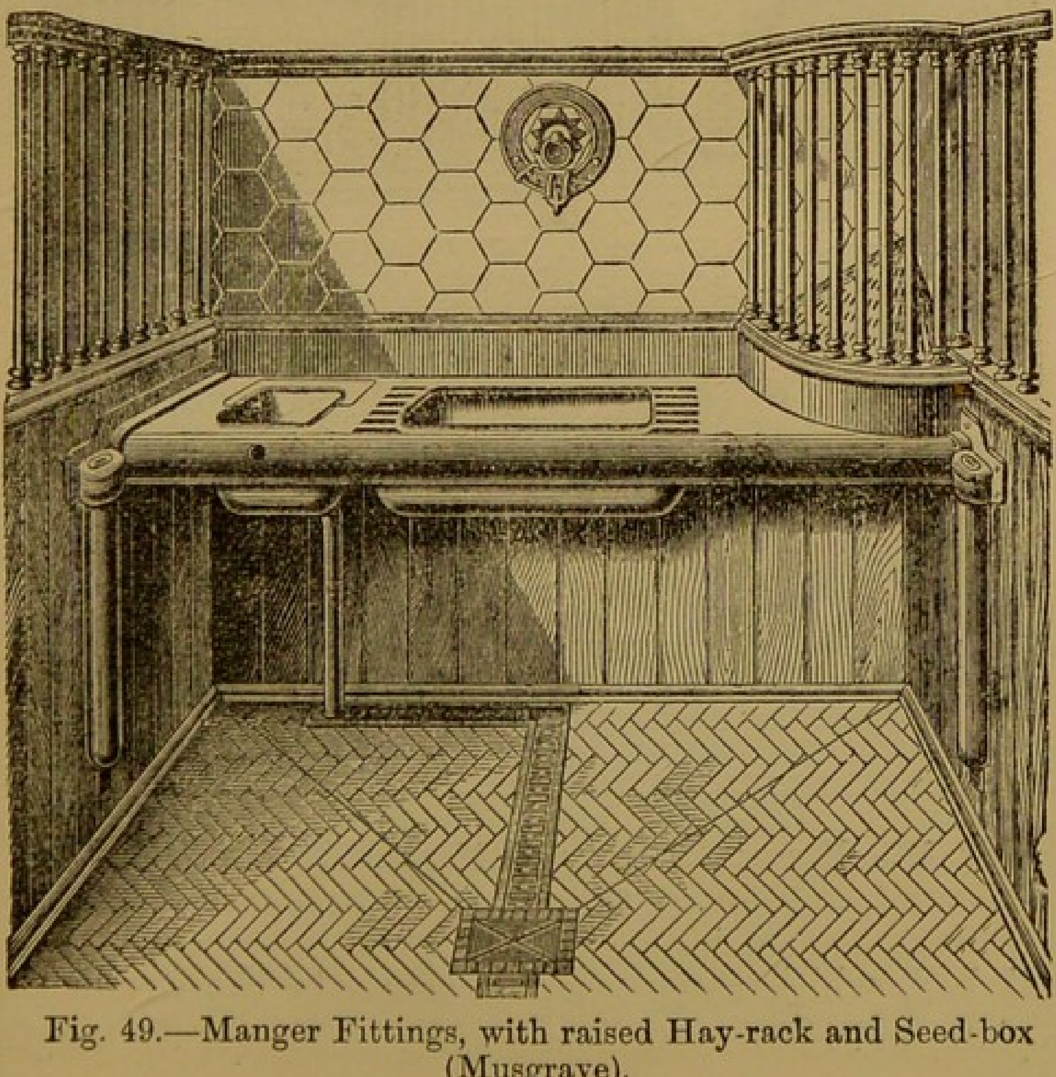


Fig. 49.—Manger Fittings, with raised Hay-rack and Seed-box (Musgrave).

breaks the shock when suddenly pulled up, and prevents noise. The upper end of the manger-chain or halter has a

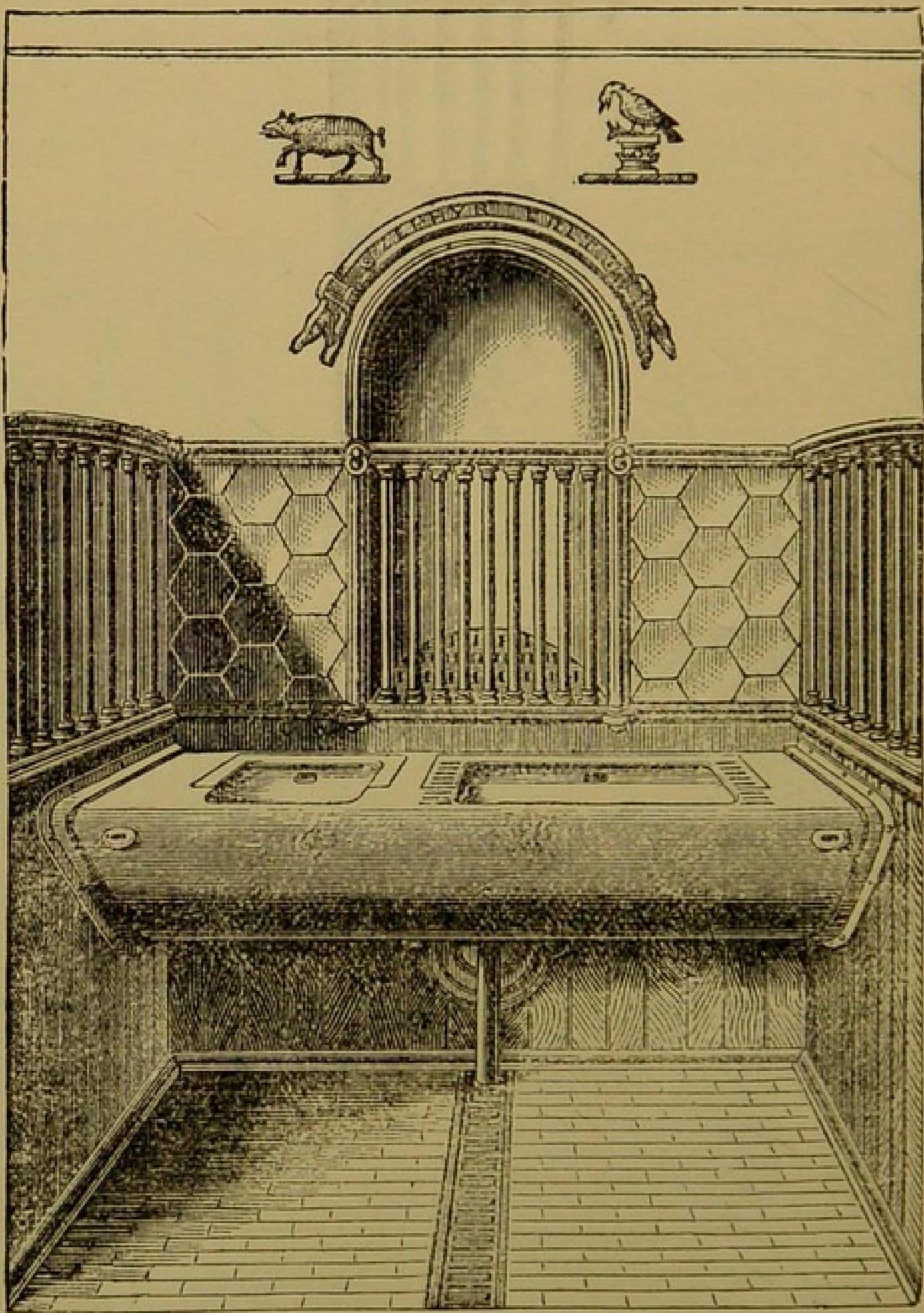


Fig. 50.—Manger Fittings, with Hay-rack let into the Wall (Musgrave).

small ball, which stops when it comes to the slit in the top-plate, and relieves the horse while feeding of the weight

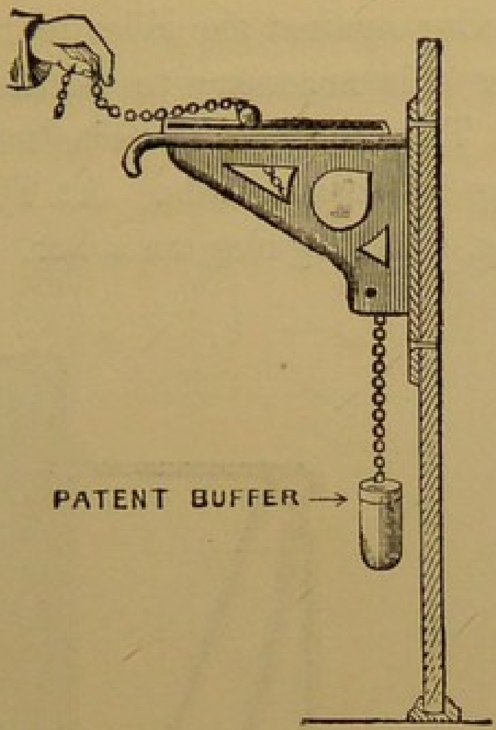


Fig. 51.—Noiseless Fastening (Musgrave).

of the chain, the latter only coming into play when the horse throws up his head.

Fig. 52 shows an arrangement for placing either beneath

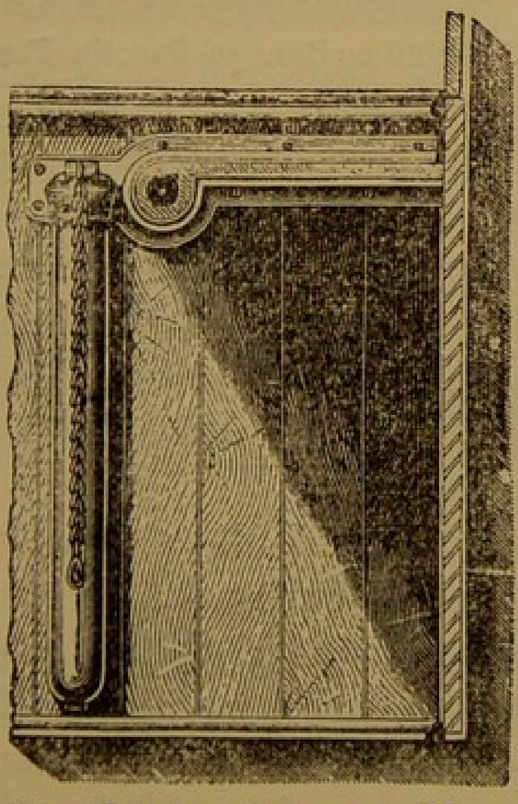


Fig. 52.—Noiseless Fastening (Musgrave).

the manger or fixing against the sides of the stall, depending upon whether it is necessary to tie the horse by one or two fastenings. This method is noiseless. On reference to Fig. 49 it may be seen *in situ.* At Fig. 53 is another form of fastening, a sliding-ring on a bar.

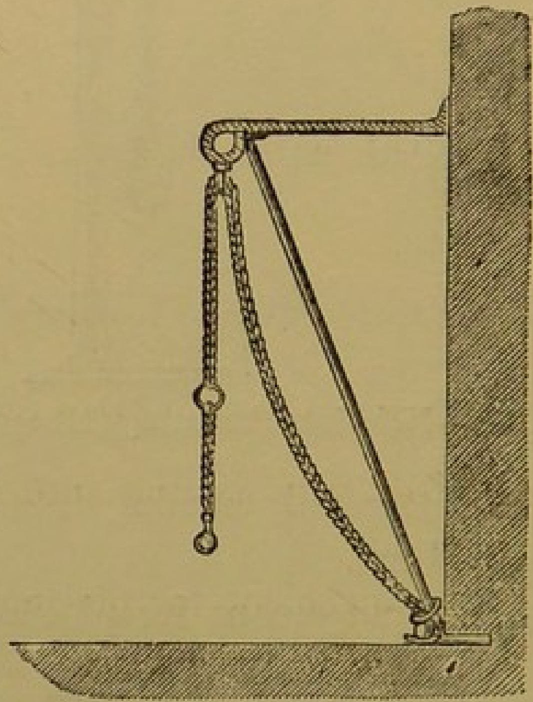


Fig. 53.—Sliding Ring on Bar (St. Pancras).

Doors.—We have previously given the dimensions of stable-doors; none should be less than 4 feet by 8 feet. One of the greatest faults in stable construction is that the doors are made much too narrow and low; these are a frequent source of injury to the horse. Another advantage gained by large doors is the facility with which the air of stables can be renewed.

The latches used for all doors in a stable should be countersunk, with no projections; they should not be furnished with a spring, but be of the bolt class (see Fig. 54); there is no projecting surface to injure a horse, and being no spring, the bolt during the time the door is open is concealed within the latch, and out of harm's way. Messrs.

Musgrave have a latch which presents a flat surface on the inside, and a handle with rounded edges on the outside (see Figs. 56 and 57).

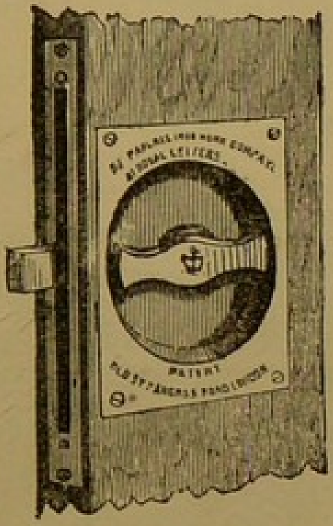


Fig. 54.—Harmless Latch.

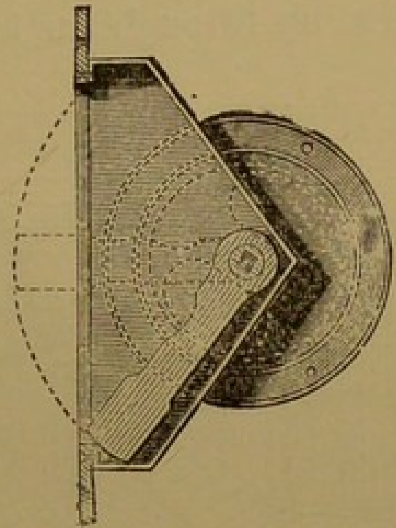


Fig. 55.—Latch seen in Section.

(St. Pancras.)

The position of doors can only be regulated by the size and internal arrangements of the stable.

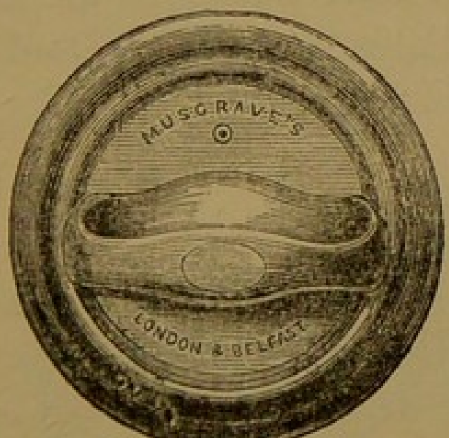


Fig. 56.—Harmless Latch.

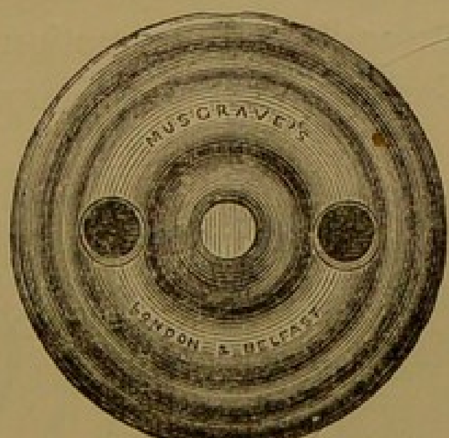


Fig. 57.—Inside View of Fig. 56.

Hay-lofts should not be above the stable, although this is generally recommended as being the most suitable place. The vitiated air finds its way into the loft, and taints the forage; the noise of chaff-cutting and other operations disturbs the horses, and, moreover, a closed roof entirely precludes ridge and interferes considerably with tube ventilation. Should, however, the loft be placed above the stable the chief points to attend to are that the floor is perfectly air-tight, and that the ventilating-shafts which are carried up through the loft are in a similar condition.

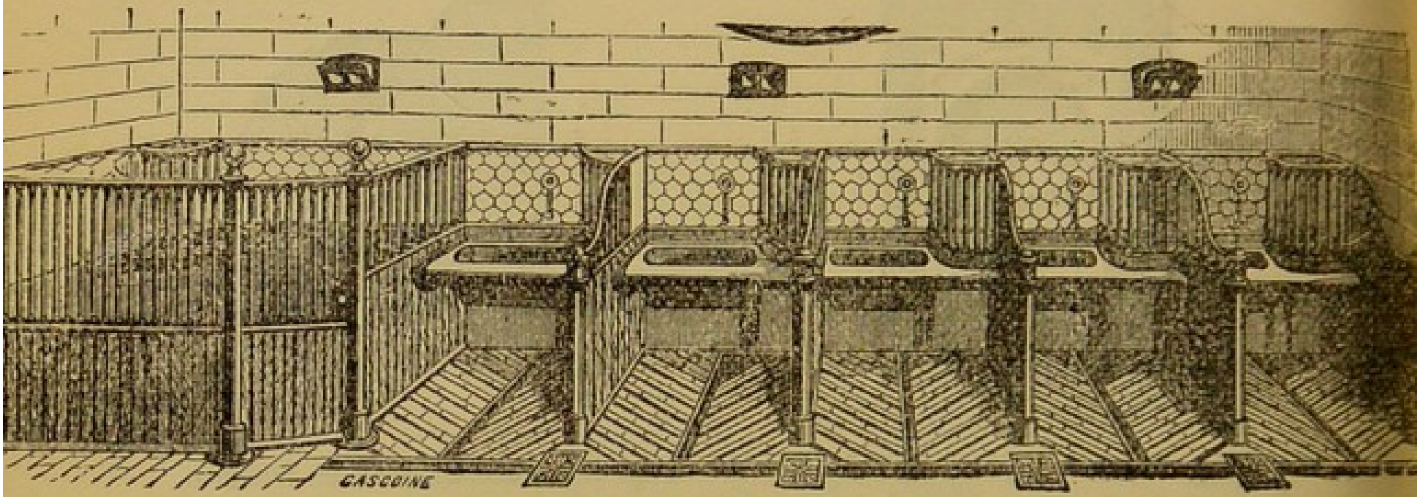


Fig. 58.—(St. Pancras.)

Interior views of the high-class stables we have been describing may be seen at Figs. 58, 59 and 60. They only need surface-drainage, larger and more numerous windows in the walls, and extraction ventilating-tubes in the roof to render them model sanitary dwellings.

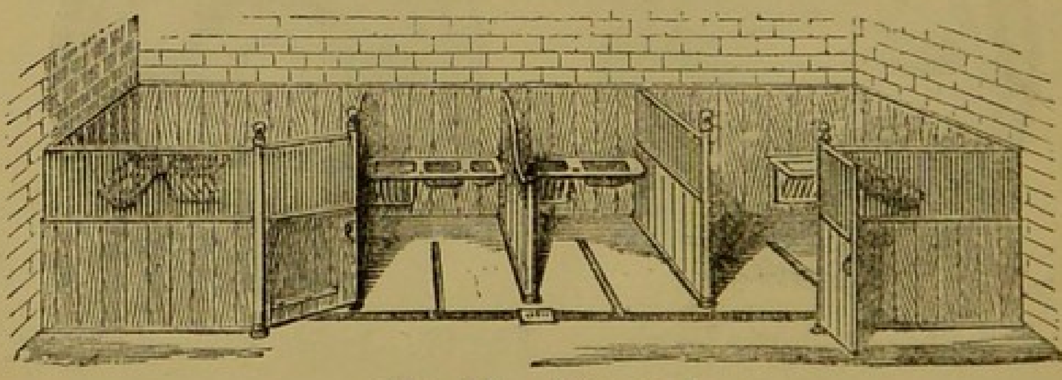


Fig. 59.—(Stevens.)

Middle-class Stables.—The second class of civil stable to be described is that generally used by private individuals in towns and cities; there is usually no choice of site, aspect, or soil; but these may be greatly improved by attention to foregoing rules. The construction and fittings are of plain and substantial material, nothing is sacrificed to appearance; but with them, as all others, paving, lighting, ventilation, and drainage must be paramount considerations. A sufficient cubic space and superficial area must be given; but the question of ventilation and lighting will probably, from surrounding circumstances, be rendered difficult. No

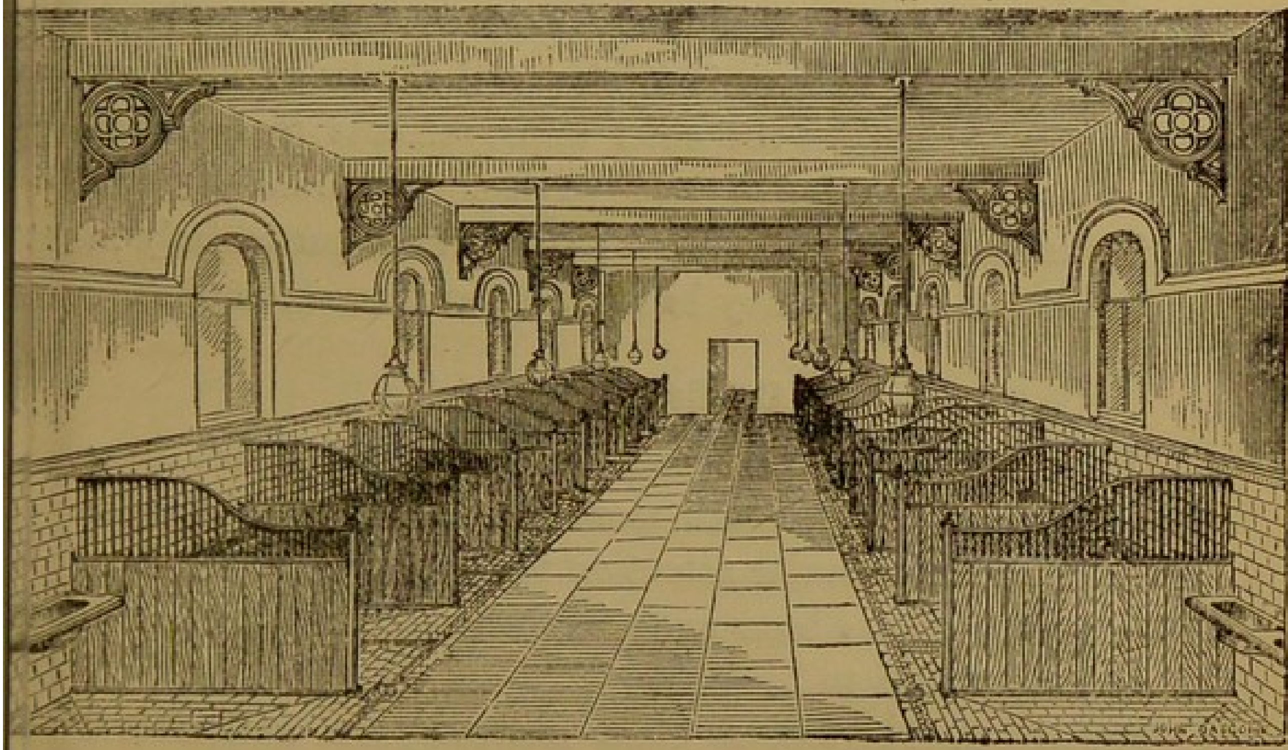


Fig. 60.—(Stevens.)

such difficulty can exist, however, with respect to paving and draining; and these must not be rendered less perfect than in stables of a higher class.

Business Stables.—When we come to our third class we treat of large business stables, such as those occupied by railway, tramway, omnibus companies, building and other contractors, cab-stables, etc. Many of these have to be arranged to accommodate a large number of horses; the fittings must be substantial but inexpensive; the ventilation must be as perfect as possible; overcrowding avoided;

as much light as can be obtained, and the paving and drainage thorough. To meet all these necessities, the type of stable for any large number of business animals must be such as that described for army horses (see pp. 245 to 256).

It must be remembered that when a large number of animals are associated under one roof, that the liability to disease is greatly increased. Two or three horses may not to all appearances suffer from defective ventilation, drainage, or small cubic space; but so sure as this is applied to a large body of animals, so sure is it that evil results will follow. With existing stables the chief improvements to be made are those of ventilation and paving. No difficulty can be felt in remedying the latter; the former, particularly in underground stables, may be most difficult to accomplish.

Cattle Houses.

If the habitations for horses have been neglected, those for cattle have been much more so. The cattle plague of 1865 directed particular attention to this subject, and some improvements have been made in their condition; but much more yet remains to be done.

Mr. J. C. Morton, a great authority on agricultural matters generally, has drawn attention to the insanitary condition of cow-houses, and the various types which are met with. He says,* 'It is either a clean and tidy place—where both the cowmen and their stock are clean, dry, and comfortable; everything in its place; the animals all lying down, being comfortably fed, and the air with no other perceptible smell than that of the chloride, which the careful owner sprinkles once or twice a day along the gutter—*or*, it is a filthy hole.'

I am afraid the majority of cow-houses fall within the latter classification.

* *Journal of the Society of Arts; Veterinarian*, 1868.

According to the Metropolitan regulations, the minimum cubic space per head is fixed at from 600 cubic feet in certain cases to 800 cubic feet in others. The necessity for the introduction of legislation was occasioned through the cattle plague, and later by the intimate connection said to exist between the cow-house and several epidemic diseases in man, such as enteric fever, tubercle, scarlatina, diphtheria, etc.

We do not regard these diseases, excepting tubercle, as being due to the bovine; when outbreaks of enteric, scarlatina, or diphtheria occur, and are traced to a milk supply, they are due to infection of the milk from a human source. This is doubtless the correct view to adopt.

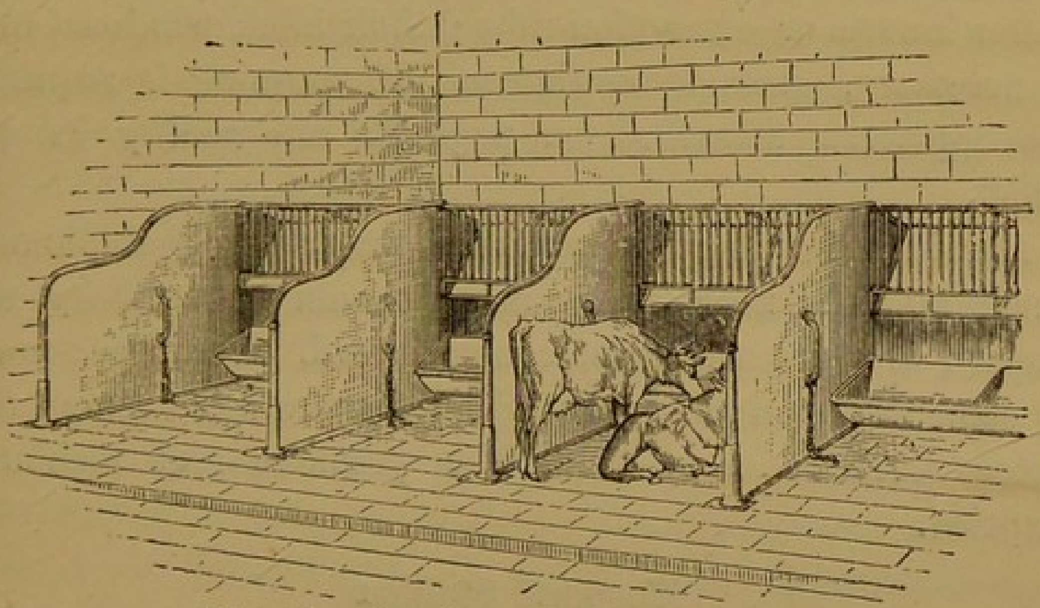


Fig. 61.—Cow-house Fittings (Stevens).

The chief points to be attended to are ample cubic space and superficial area; an impermeable flooring; and most perfect arrangements for drainage, and ventilation.

The cow-house should be 30 feet wide, with a double row of cows facing the outer walls, leaving a space 4 feet wide between the animals and the wall, which is used as a feeding passage, and up and down which runs a truck from the fodder-rooms. In the centre should be a 5-foot passage. The best fittings are of iron, such as are shown at Fig. 61.

The flooring must be laid on cement, and consist of the channelled bricks, such as those previously described, or asphalt, or flagged stones with their joints thoroughly cemented. The stall must have a slight slope to allow of drainage; the drainage should be surface, and run behind each stall to the ends of the building, where it is conducted outside into trapped drains.

The iron cow-house fittings are a wonderful improvement on their predecessors; and not the least advantage of them is the ready manner in which they can be disinfected in the event of an outbreak of disease.

The lighting of the houses is effected by windows and from the roof; their outlet ventilation should be ridge, either louvre or extraction-tube; their inlet, windows and, if necessary, ground ventilators. If warming is required the apparatus described on page 83 can readily be applied.

Absolute cleanliness is required; water supply ample and pure; no wells near the premises should be used for *any purpose*, they are sure to be contaminated. Grain-pits must be cemented, and all receptacles for excreta the same; the latter must be away from the premises and regularly emptied.

Hospital Stables.

The construction of stables for sick horses will differ in no essential particular from those already described in the foregoing pages, with the exception that the stalls should afford a larger area and cubic space, and a certain number of boxes of good cubic capacity should be provided.

The old infirmary stables of our barracks were, for many reasons, better lighted and ventilated than the troop-stable of that period. The explanation is that it was recognised that sick animals required more air; but the most important advantage, which was quite an accidental one, was the absence of men's rooms over the infirmary stables, and so roof-ventilation and increased light were obtained.

The infirmary stables at Woolwich are all boxes, affording ample superficial area and cubic space; there is ground and roof ventilation; the roof is flat, and the ventilation is carried on by means of a shaft. The great fault in these stables is that they form three sides of a square, the fourth part being walled in to more effectually oppose the free circulation of air.

The model plan of infirmary stables and loose boxes, as suggested by the Commission, is to be for eighteen horses. The superficial area per head is 137 square feet, and the cubic space about 1,900 feet. There is only a single row of stalls.

Ventilation is provided for by a louvre carried along the ridge, by a course of ventilating air-brick carried all round the stable at the eaves, and by a course of air-brick along the bottom of the wall opposite the stalls. For lighting and additional ventilation when necessary, each stall has over it a swing-window 2 feet 3 inches high by 2 feet 6 inches wide; there is also a row of windows in the opposite walls. The loose boxes allow 204 square feet of area, the cubic contents being about 2,700 feet. The partitions between the boxes are carried up to the roof. Each box has a louvre in the ridge, a ventilating course of brick under the eaves, an air-brick 9″ × 6″ close to the ground, opposite swing-windows, and a door with a fanlight over it. The doors for the infirmary loose boxes should be made in a top and bottom half, with a noiseless hinge and fastening. They should open outwards, and be provided with a catch. In the model infirmary stable they are made only 3 feet 6 inches wide; they should be at least 1 foot wider than this. The drainage, paving, internal fittings, and litter-sheds of these stables are the same as those previously described in the model troop-stable.

A foot-bath should be made in each infirmary capable of holding four or five horses. The water-supply should be plentiful. A good sling-box should be found, having close to it a tap which can be utilized for the purpose of wound-irrigation. A boiler-house is necessary for the supply of water for fomentation and other purposes, and all dressings which have been removed from wounds, etc., should be destroyed by its fire.

Near the infirmary should be found a paddock where convalescents and others may be turned out. A place with impervious floor should be arranged for the purpose of *post-mortem* examinations; and at least 100 yards of good level road should be convenient for the purpose of examining lame patients.

Stables named lazarettos are provided for cases of contagious disease. Iron-work fittings, cemented walls, and impervious floorings are absolutely necessary if the building be a permanent one; though it would be better, I think, if these places were simply wooden enclosures, which could then be entirely destroyed by fire, and a fresh one used for each case.

In large veterinary infirmaries there should be a place constructed for the disinfection of men attending on animals affected with contagious diseases, with their clothing and stable utensils; also the clothing, saddlery, and appointments of the patient.

Infirmary Stables in India.—These should be like the troop-stable, with the exception that there should be loose boxes; to the stalls it is advisable to have doors of galvanized iron. The cubical contents of a box should not be less than 3,000 feet. The pharmacy must contain all that may be required in the way of instruments and medicines, for one may be a thousand miles away from any medical depôt, and entirely dependent on the infirmary resources.

Rooms are required for the men on duty to live and sleep in. Arrangements must be made for properly lighting the surgery, men's room, and infirmary. A boiler for supplying water for fomentations, etc., with pipes leading into a place that can be made a vapour-bath; a foot-bath to hold six horses; store-rooms for wood and stock medicines; and a paved surface, with a light roof, for holding *post-mortem* examinations in, are essential. These are a few of the principal points which require attention, though there are many minor ones. So much more sickness is met with in India, and that of a peculiar kind, that the veterinary surgeon cannot be too well equipped. How badly these things are managed may be learned from the fact that there is only, under present regulations, one small tin lantern burning country oil allowed for the whole infirmary; this lamp just gives a light and nothing more.

The flooring of the infirmary stables should have scrupulous attention paid to it.

Forges.—The forge is generally situated near the infirmary stables; but I think that with advantage it might be moved further away. Near the infirmary it is convenient for surgical cases, either for casting horses in or heating irons for firing; but the noise of the farrier's shop is not conducive to the comfort of a sick horse, and the products of combustion do not add to the healthiness of the atmosphere.

A good plan of forge was designed by the Barrack and Hospital Improvement Commission, and they strongly recommended its general adoption. The shoeing-shed is 60 feet long, and 17 feet wide. The forges, two in number, each with a double fire, are placed at each end of the shed; they are 30 feet long by 17 feet wide. The height of the whole building to the spring of the roof is 12 feet; total height, 17 feet 6 inches. There is a ridge-ventilator and skylight running the complete length of the roof.

The ventilation and lighting of a forge are points which require attention; the products of combustion must find an outlet; and if the place is not well lighted there is a risk of accident in shoeing. The flooring should conform to the recognised principles, and it is more important than ever that it be not of a slippery nature. There should be sufficient slope for drainage; the latter as usual should be surface, and carried outside the building.

Forges in India should be open on three sides, with a good double-tiled roof and ridge-ventilator. As a rule they are closed in on three sides, and open on the fourth. These forges, in spite of honeycombed walls, are very hot for the men to work in. One part of the forge is used as a shoeing-shed. The latter should face the west; in most other positions the sun strikes the men on the head whilst shoeing, which work is always done in the early morning or first half of the day. There should be a fire to each troop to enable men to get their work done early; the shoeing-shed should hold for a regiment of cavalry about twenty horses.

Method of Examining a Stable.—The army veterinary surgeon is often called upon during his service to examine and report on stables; and it may not be less useful to his civilian colleague to know how this should be scientifically carried out.

1. Determine the nature of the soil on which the building is placed (see 'Soils'), and the depth of the subsoil water. 2. The position which the stable occupies in relation to surrounding parts, whether they be higher or lower, and what arrangements there appear to be for storm-drainage. 3. Determine the position of the stable by the compass, and if more than one block of stabling, the relation which one bears to another; whether, for instance, they are placed *en échelon*, partial or complete; whether the blocks cover each other, or whether they tend to the formation of a

square. 4. The material of construction should next be noted for both walls, roof, doors, etc. 5. The internal fittings with their description should then occupy attention. 6. A careful examination of the flooring, determining the amount of percolation, if any, which may have occurred; the nature of the flooring, and length of time it has been in use should be noted. 7. The building should next be measured, and the superficial area stated, also the superficial area allowed to each horse by its share of the passage. 8. The amount of cubic space allowed to each horse should then be ascertained (see page 104). 9. The description of ventilation, whether by ridge, shaft, windows, etc.; determine the inlets and outlets by means of smoke, burning some damp litter for the purpose; measure the ventilators, and see whether inlets and outlets correspond in size, and whether they correspond to the requirements of the horses (see page 98). 10. The nature of the drainage, and the condition of the traps, if any exist. 11. On entering the stable determine the carbonic acid by the senses (see 'Ventilation,' page 106); and calculate by means of the formula whether the amount of air supplied is sufficient. Note the internal temperature of the stable, and the temperature of the external air; also the degree of humidity.

Transport by Sea.

The dreadful sufferings endured by animals on board ship in years gone by have, under an enlightened system of management, and a complete revolution in ship-building, become, to a considerable extent, a thing of the past. Much, however, yet remains to be done to avoid poisoning animals on board ship with their own excreta, which can only be prevented by a thoroughly efficient method of ventilation.

The transport of animals by sea is connected either with the live-stock trade for the purposes of human food, or with the conveyance of horses, mules, etc., generally for army purposes during warfare. Though for these two distinct purposes there are many points of an essentially important nature in common, yet so special is that connected with the transport of horses, mules, and ponies that we must regard this section as chiefly devoted to their consideration.

Selection of Ship.—On the care which is exercised in the selection and fitting up of a ship will depend the entire safety of the horses; no more important duty, therefore, falls to the Board of Survey than that of making a judicious selection of a vessel for carrying in safety a most valuable living cargo of utterly helpless, and, in times of bad weather, terrified and panic-stricken creatures.

Wooden sailing-vessels are considered by many to be preferable to steamers for animal transport, for the reason that they are cooler, more easily ventilated, and there is less motion. The drawback to them is their slow pace, though, when placed in charge of powerful tugs, this is greatly obviated. Steamers, from their larger number and their rate of speed, will generally be selected. The main points to observe are that they be large and roomy between decks; and not too small, or else the motion is great. A ship for animal transport cannot be too steady, and none less than 1,500 tons should be selected.* A slow ship should be avoided; the greater the speed the more efficient the ventilation, and the shorter the passage. In the tropics the speed of the ship is often the only current of air.

Ships should be examined as to their freedom from smells and rats, for the former will increase the impurity of the atmosphere, and the latter will attack, partly destroy, and taint the forage.

* In calculating requirements the Government allows ten tons per man and horse.

The width of beam should be observed. Narrow boats, especially if high out of water, roll badly; and moreover the space between the rows of horses is reduced; 30 feet beam should be the minimum width. The hatchways would be best 12 feet square, and not less than 10 feet; the height between decks should be 9 feet, and not less than 8 feet. Port-holes and scuttles should be numerous in the ship's side, one to every 6 or 7 feet. Particular attention should be paid to this on the main deck, which, being close to the water, is usually badly off for scuttles; and is moreover the deck which is the most unhealthy, owing to the difficulties of drainage, the bad ventilation, and the crowding which occurs, due to the greater ground space.

The means of ventilation which will be found on vessels is sure to be not only defective in its working, but infinitely too little for the number of animals it has to supply. Attention must be directed as to how existing ventilation can be improved upon, and extra means employed. There is only one way this extra ventilation can be supplied, and that is by means of tubes carried down to each deck, as described on page 112 (see Fig. 25). It must be put before the skipper that a large number of tubes will be required; and it is for him to decide whether he will allow the holes to be cut in his decks or not. Respecting the number of tubes required for ventilation, there is always sure to be some trouble in the matter. My plan riddles a deck, but then it ensures health to a valuable cargo. It is obvious that the number of tubes required will depend upon the number of decks occupied. My belief is that we should never use more than two decks. In calculating the means of ventilation it must not be forgotten to include the large hatchways.

Before troops are embarked it would be as well for the ventilation to be practically tested, to see that the extraction and inlet cowls work satisfactorily, and that the amount of air supplied is sufficient.

The suitability of the ship as to the position of the stalls should next engage attention. As a rule, a row of horses on either side are carried, and for this purpose 30 feet of beam at least are required; but it may so happen that a double row on both port and starboard side must be conveyed; all difficulties are now doubled, whilst the space at command and ventilation is not increased in the same proportion. To carry a double row on both sides, the minimum width of beam must not be less than 45 feet; but such crowding would occur even with this, that no reasonable extra expense should be spared to avoid the risk arising from it by providing extra ships. I regard as reasonable expense half the value of the entire living freight, a sum nearly sufficient to purchase a ship, let alone to hire one.

The **Fittings** for the accommodation of animals require to have expended upon them the best material and workmanship, with the object of obtaining the utmost strength. How constantly we hear of the death of a large number of animals due to the fittings giving way during heavy weather. I am acquainted with a case where eighty horses were killed, or had to be destroyed, from injuries received through the fittings giving way during a gale; these examples might be multiplied. I hold that the giving way of fittings should no more occur than that the bottom of the ship should fall out. If put up as they should be, bolted to the decks at all corners of each stall, and every means supplied for strengthening and supporting them during bad weather, these dreadful accidents would never occur. The strain on fittings during the rolling and pitching of a vessel is easily calculated; the weight of the animals plus the momentum is not a difficult sum: *each stall* should be so fixed as to stand a strain of 3 tons of dead weight in any direction; moreover, during bad weather it should be arranged that stays could be fixed in between the rear of the stalls and the ship's side, and also stays reaching across the ship from the starboard to the port stalls; by this means, in addition to their own bolting, the stalls on both sides of the vessel would afford mutual support, and we should be spared the shocking sight of a large body of animals being suddenly precipitated to one side of the vessel, through their fittings giving way, and as suddenly thrown back again, their lives being literally battered out of them.

Veterinary Lieut.-Colonel F. Duck, whose experience in animal transport by sea entitles his opinion to great respect, says that he does not consider that a separate stall for each horse is necessary, and that he is certain that they are quite unnecessary for mules. What he proposes is to have pens or boxes for two or four horses; the animals would then move about more freely, and the circulation through their limbs and feet be thus improved. In fine weather one or two may be removed from the box, thus allowing the others to lie down and rest. If we adopt a separate stall for each horse we must allow a width of 2 feet between the side-bars, and the length of the stall should be 6 feet 6 inches to 6 feet 9 inches. For larger horses 5 per cent. of the stalls are made bigger. V.-Colonel Duck advises separate stalls to be obtained for kicking or vicious animals; and these might be made where there is the greatest motion—viz., at the extremities of the vessel. There should always be found 5 per cent. of spare stalls for hospital and other purposes; those for the hospital should be where there is the least motion, but not near the engines. We have previously spoken of the uprights or stanchions forming the stall, and the necessity for these being of sound workmanship and strongly bolted to the decks, the side-bars should also be of great strength, and so made as to readily remove when it is considered necessary to convert some stalls into a loose box, or for other reasons. If these side-bars are weak they give way when the vessel is pitching, and telescoping occurs. The rear-bar or haunch-piece should be hollowed out, and placed lower down than is at present the case, so that the animal may lean back and rest in it. It is a point of importance to observe that with mules the front or chest-bar be fitted lower down than it is for horses. Veterinary-Colonel Duck has told me of a case where the non-observance of this precaution resulted in nearly every mule having at the end of the voyage a long gash across the throat.

No padding of any kind is required by the bars; if there, it gets saturated with sweat and dirt, and only chafes the animal.

Slings are not absolutely necessary; in bad weather they are a positive evil, for a horse if lying in them simply swings about, and is bruised all over. In fine weather, particularly with delicate horses, they may afford a means of rest which the animal will not take any other way. Slings, moreover, heat the body, become very dirty and hard, and the animal, trusting to them, takes the weight off his feet, and so disturbs the circulation in these parts, which we know is so much assisted by the movements of the body; thus we have a predisposing cause of laminitis. V.-Col. Duck says that a strong argument used in their favour is that they prevent horses falling in their stalls and getting under the rear-bar, a position from which they are extricated only with difficulty; but he believes, and has moreover practical experience to bear him out, that cinders or coir-matting put down will prevent this falling about; and when it does occur, as it will do in bad weather, it is probably generally due to prostration from sea-sickness. A proportion of slings should be found on board for use in suitable cases.

The **Flooring** of the stall is a platform laid on battens on the deck; the platform on which the horse stands has battens screwed on to it in order to give a foothold; the planks composing the platform should be left about an inch apart to allow the urine to readily run through on to the deck, which is situated an inch or two below, and the space between the planks also affords a foothold when the vessel is pitching. The battens on which the platform rests must be so arranged as to allow urine to run through them, and out behind the stall. All edges in the fittings, uprights, bars, foot-battens, etc., must be rounded. Mangers should be of galvanized iron, and hung upon the breast-bar.

Embarkation.—Horses should not be embarked in high condition, but should for two or three days previously be placed on a laxative diet and exercised. Moreover they should be embarked on empty stomachs; particularly should this be the case where slings are used for embarking purposes. Regarding the shoes, all should be carefully examined, feet shortened where necessary, nails replaced, etc., it being an understood thing that the shoes remain on the whole voyage. Experience shows this to be the best method, otherwise the soles get bruised from knocking about in bad weather, and the feet break away. The careful inspection of every animal before embarking is one of the veterinary surgeon's most important duties. Glanders is, of course, the chief disease looked for; if detected, there is only one course to pursue—the infected troop or troops must be isolated, and the regiment on no account allowed to move or embark.

The process of embarkation is either by means of boxes hoisted up by a crane and lowered on to the deck, or by means of slings. The former is without risk, and the most comfortable method; the latter is uncomfortable, in some degree risky, but takes a shorter time. The slings should be rapidly but carefully adjusted, the breast-rope fastened *first*, and then the breeching-rope, which *must be drawn tightly* and well secured. The animal should be rapidly run up, lowered carefully on to the horse deck, a little bedding being placed for him to land on, and received by some good determined men to prevent him plunging on first feeling his feet.

It is not a part of the veterinary surgeon's duty, but it is a point of importance, to observe that only a complete unit or units should be embarked. It is no use sending the horses and men in one ship, and their saddles and medicines in another.

It is recommended that after embarking the vessel should stand off for some hours to allow matters to settle down, and the horses to get accustomed to their new position. The proposition is a wise one, and should always be carried out where practicable.

The **Feeding** to be adopted on board is to be non-stimulating; 3 or 4 lbs. of oats, the same quantity of bran, and 10 lbs. hay daily will be quite sufficient for the first week or so; later the corn ration may be increased to 5 lbs. daily, with a similar quantity of bran, and during the last week of the voyage the animals may be placed on ordinary diet. In temperate climates they should be watered as usual, but in the tropics it should be given four times a day. Horses do not care for condensed water, but if mixed with natural water the objection is removed.

Grooming should be carried out systematically; for the first few days little will be done, but after a time wisping the body and hand-rubbing the legs should be carefully carried out. By leaving spare stalls at intervals grooming can be performed, for as an animal is done, he is shifted into the spare stall, and the next one gone on with.

Particular attention must be paid to the cleanliness of the stalls; they must be swept out, the manure in the passage behind collected in baskets and thrown overboard, the decks flushed with water to get rid of the urine, and disinfectants used if necessary.*

In the tropics stables should be held in the morning; after this as few men should be below as possible, for they only add to the impurity of the air space and increase the temperature. A few good men as a stable guard for sweeping up, etc., should be provided. In badly ventilated ships the air below is so foul that the men can only remain in the horse decks for short periods at a time. Can we wonder at horses dying when they have to live in an atmosphere of this sort for four or five weeks?

Exercise can frequently be carried out on coir matting during fine weather; it is a most excellent practice which should never be neglected.

The **Ventilation** must be constantly examined to see that it is working well. If Boyle's tubes are used, no difficulty will be experienced in this direction; but inspections should be made to see that the tubes are not obstructed. If windsails are the only means of inlet, we must have as many rigged as can be obtained; every attention must be paid to the trimming, and special men should be told off for this purpose. Where ports and scuttles can be opened arrangements should be made to catch the air. In wooden ships planks on the upper deck may be removed to allow of more air in the tropics. Punkahs have been used to keep the air moving while passing through the tropics, and

* With every care the fittings become very foul; at the termination of a voyage they are occasionally given as a bonus to the captain. V.-Colonel Duck has told me of a case where the fittings, when removed from a vessel in the Bombay Dock, created such a dreadful smell that the captain was ordered to remove them at once.

arrangements for producing a current of air by means of a wheel have been tried; the latter could be worked on a large scale connected with the engines, the air being driven into the decks by means of a Desagulier's wheel.

Attempts have been made to keep the air pure by means of cloths soaked in some disinfectant being hung up; spraying the atmosphere with an ordinary garden syringe should be found useful.

Lime is sometimes thrown in the stalls to absorb the ammonia arising from the urine; this practice should not be permitted, as it destroys the feet.

Chloride of zinc or carbolic acid should be the disinfectants used, if any are required. The best disinfectant, however, for the decks of a horse ship are scrupulous cleanliness and plenty of fresh air.

The bilge should be disinfected with carbolic acid, and pumped out daily.

The proper drainage of the stalls is essential; the false bottom of the stall ensures the urine running through to the deck, but from here it must be conveyed away. On the upper deck this is easily managed by scuppers opening over the ship's side, but the main deck is difficult to drain owing to its proximity to the water. If it can be managed, scuppers should be used; but if not, the urine must be conveyed by pipes into the bilge, and from here pumped out every day. This arrangement does not appear a very sanitary one, but it is the only practicable one in most cases. Tanks arranged in the hold for the reception of urine, disinfected and pumped out daily, would appear to be the most sanitary method of disposal. The same system of drainage will apply to the lower deck.

Horses are often carried on deck, but by some this is not considered advisable excepting good weather is anticipated. The exposure on deck is greater, and the motion more felt;

but the great objection to the plan is that in heavy weather the horses may be washed away.

Animal transports, particularly for horses, should not be exposed to rough weather if it can be avoided. The shelter of a port should be obtained if possible; or if in mid-ocean, the ship should lay-to rather than drive ahead. Casualties may occur from rolling even when a ship is at anchor, as in the South African ports. V.-Col. Duck informs me that in one night about a dozen horses were lost in a transport off Durban from this cause. The casualties ceased as soon as steam was got up, and the ship put head on to the sea.

A great deal of nonsense is written with regard to the amount of medicine which should be laid in for a voyage. In a most excellent work on Military Transport, there is a scale laid down for 100 horses, and some of the items are truly astonishing; for example, 12 lbs. of nitre for 100 animals for an ordinary voyage! There is a singular belief in the necessity for vinegar and nitre for horses on board a ship; these are no more required than they are for animals ashore, and the use of nitre should be strictly prohibited, excepting when ordered by the veterinary surgeon.

The diseases to which horses at sea are liable are chest affections, particularly pneumonia, due to breathing foul air, and the heated body being exposed to draught from the windsail; derangements of the bowels, from want of exercise; laminitis, from standing long in one position; congestion of the brain, or 'ship staggers,' a singular affection due to some reflex effect conveyed to the brain through inability to vomit; and in the tropics, heat apoplexy.

The only affection which requires any consideration is the congestion of the brain; the symptoms are very alarming, and the animal dangerously violent. V.-Colonel Duck says that the only thing to do is to get the patient out of the stall, bring him to the hatchway, apply cold water to the head, have a couple of men to steady and soothe him, and the good effect of this treatment is astonishing. The more violent the symptoms, the greater the necessity for taking the horse out of the stall.

The mortality on ship transports is very high; it can only be reduced by the adoption of a rational system of ventilation, and the introduction of fittings which will not give way during bad weather. The loss of animals by transit during the Zulu War amounted to 2·77 per cent.—in one case 39 horses died in one vessel; during the China War the losses (between India and Hong Kong) were 3 per cent. The losses of the Indian contingent which went to Egypt in 1882 was nearly 1 per cent., of which one regiment lost 42 horses. Many years ago Mr. Mellows, V.S. 1st Dragoon Guards, published the losses of this regiment in going from Cork to Quebec, and in coming home again.* In the outward voyage 11·6 per cent. of the horses died, and on the homeward voyage 4·8 per cent., *including three suffocated by closing the ventilators.* These were the sailing-ship days.

At the end of a long voyage horses are soft and not in a fit state for work. Military exigencies, such as occurred in the Egyptian Campaign of 1882, may necessitate horses coming direct off board a ship and doing a thirty or forty mile march, but such a proceeding can only be attended with great sickness and mortality. Exhaustion and laminitis are the two diseases which occur under these circumstances. Percivall tells us† that 'In the expedition to Corunna, the late Mr. Castley had an excellent opportunity of observing the effects of great exertion immediately after continual standing. That beautiful brigade of cavalry, consisting of the 7th, 10th and 15th Hussars, landed at Corunna about the 20th November, 1808. They had been on ship-board, owing to contrary winds, upwards of three weeks. A

* *Veterinary Record*, April, 1848. † 'Hippopathology,' vol. iv.

few days after disembarking they marched up the country, by squadrons, in daily succession, occasioning, thereby, the last squadron to be later in its march by nine days than the first. Mr. Castley himself marched a day after the last squadron, and found at Betanzos, the first stage, twenty horses left behind with fever in the feet, the greater part of them belonging to the squadron that marched first from Corunna. And such continued to be the case, more or less, all along the line of march. Still, the first suffered much more than those that marched last; a circumstance inducing Mr. Castley to believe that the *immediate* exertion the horses were put to, after having stood upon their feet so long on board ship, had much to do in causing the disease.'

During the Boer War a battery of artillery made, in three days, a fifty-mile march shortly after landing; thirty horses were left on the road, of which number eleven died.

After landing, regular exercise and feeding should be observed; the exercise may gradually be increased in amount, but from ten to fourteen days should certainly elapse before horses should be put to severe work after a long voyage.

Respecting the **Transit of Cattle and Sheep by Sea,** the principles regarding ventilation, cleanliness and security of fittings are the same. The animals are usually carried in pens which, according to regulation, should not exceed 9 by 15 feet, the floor of the pens to be battened for foothold. Between November and April freshly-shorn sheep are not allowed to be carried on the deck of a vessel.

The cleansing and disinfection of vessels could best be carried out by means of a steam jet in connection with the boilers, and afterwards fumigations with sulphurous acid or chlorine, and then lime-washed: the latter method is the one laid down by Act of Parliament.

The importance of legislating for the transport of animals may be gathered from the fact that no less than 1,700,000 are brought annually to this country for food. Of these quite 1,250,000 come some considerable distance by sea. There are between 11,000 and 12,000 horses imported yearly, and about half that number exported. This represents a very large sea traffic which requires vessels to be specially constructed for the trade. These vessels should conform to the principles we have laid down.

CHAPTER VI

REMOVAL OF EXCRETA.

THE efficient carrying off of the discharges from the kidneys and bowels are essentials in stable drainage. This question, which is such an important one to the human hygienist, and no less important to ourselves, is much simplified by the fact that the solid excreta of animals is not conveyed by underground drains into sewers, but is removed to manure-pits to be ultimately disposed of for fertilizing purposes. We have, therefore, only to arrange for the conveyance from the building of the urine containing portions of suspended fæces.

Nothing can be more simple than the rules for the arrangement of proper drainage; but unfortunately the carrying out of them is not always a matter of such simplicity. When considering the subject of air, we pointed out that amongst other causes tending to produce impurity of stable air were the emanations from the discharges of the bowels and kidneys. Our object is, therefore, to carry off these from the stable as rapidly as possible, remembering that the longer they lie the greater the danger.

The removal of the solid excreta by hand, and its conveyance away from the building, is simple and effective if regularly performed; if, however, allowed to lie, it rapidly ferments, giving out organic vapours and carbonic acid gas, and assisting materially to render the air impure. This change is all the more rapid if the mass becomes wetted with urine; the latter secretion soon undergoes change, the urea breaking up into carbonate of ammonia, and if allowed to percolate through, or come in contact with the fæces, it dissolves out of them much of the colouring and perhaps nitrogenous matter, and consequently presents a larger amount of organic substance to undergo putrefactive change.

The amount of solid and fluid excreta produced by a horse in twenty-four hours will vary according to size, work, season, and the amount of food given. Hard-worked horses whose skins are constantly acting will produce less urine than animals doing slow or moderate work; still we can obtain approximately the quantities of both produced.

Colin calculates that a horse secretes 3 lbs. 7 oz. of urine and 38 lbs. of fæces in twenty-four hours. From experiments made by Professor Varnell at the Royal Veterinary College, the amount of excreta passed daily was found to be—fæces, 49 lbs.; urine, 20 lbs. Recent observations on the horse show that the average amount of fæces is between 25 and 30 lbs. per diem, and the urine rather more than one gallon. A cow excretes about 60 lbs. of fæces and 18 lbs. of urine in the twenty-four hours.

We are all aware of the difference in the consistence of the fæces of the various domesticated animals; this is due to the difference in their feeding, their digestive powers, and the amount of water the fæces contain. The latter has an important hygienic aspect, for the more watery the excrement the larger the amount passed into drains, and the more rapid the process of decomposition; on the other hand, the drier it is the more easily is it removed, and the less liability is there to putrefactive changes. There is about 77 per cent. of water in the fæces of the horse, 82 per cent. in the ox, and 56 per cent. in the sheep.

We have one important point to note, and it is this, that although the horse secretes about 30 lbs. of solid and $1\frac{1}{4}$ gallons of liquid matter in twenty-four hours, yet the whole of this is not deposited in the stable. I should say that quite half the fæces are left in the streets; and, on the other hand, at least three-fourths of the urine are deposited in the stable. That this is so will occur to the mind of every person connected with the management of horses. We are all aware of the dislike manifested by horses for urinating in the streets, on account of the splashing which occurs to their legs. Moreover, as the horse can only urinate at rest, it follows that the opportunity for getting rid of the secretion whilst out of the stable is not always afforded him; and so it happens that the very excreta which contributes the greatest amount of impurity to the air of stables is almost wholly deposited in them. It is for the collection and removal of this fluid that drainage is adopted.

Drains may be divided into stable-drains or pipes, and sewer-pipes. The former comprise any drain used *within* the building, and the latter the pipe which conveys it to the sewer. It is necessary to have this division for purposes of description.

Stable drains may be partly surface and partly by pipes, or wholly surface; in other words, the excreta may be removed by means of channels underground, or channels on the surface of the ground. There can be no difference of opinion as to which of these is the most sanitary proceeding; *carry nothing underground which can be conveyed by the surface* should be our maxim. Unfortunately this is not always agreed to, for the reason that open channels in a stable are considered unsightly and spoil the appearance of the place.

The most common condition met with is a combination of these methods; surface drainage by means of open channellings from stalls and boxes, into underground drains which run the length of the building.

Surface drains are made of various material; they may simply be the spaces left between the ordinary paving or cobble stone, cemented to prevent percolation, and with sufficient fall in the ground to bring about drainage; or they may be made of vitrified brick specially prepared for stable-flooring, many excellent specimens of which are in the market. (For an account of these, and the necessary conditions for a stable-floor, see the article 'Flooring,' page 269.)

An open channel or surface drain constructed of stone, vitrified brick-work, or iron, may run the length of the stable, receiving the drainage from stalls and boxes at right angles. There is little choice of material; the vitrified brick is very good; its smooth surface offers no obstruction, and it is durable; it is this which is used in the new pattern Government stables. The only points to be attended to are that the joints are quite impermeable to moisture, and that sufficient fall is given for the urine to run off. The width of this open channel must entirely depend upon the number of animals from which it receives excreta; 8 to 12 inches wide should be fully enough for a large stable; as to depth, it should be as shallow as consistent with keeping the contents together; the depth should be about one third or fourth of the width. The direction taken by this surface-drain must depend entirely upon the length of the stable; with a number of stalls or boxes on one or both sides of the building, the drain running the length of the stable at the rear of the stalls, with a fall to both ends, and receiving the drainage from the stalls at right angles, will be found the most convenient arrangement. The surface-drain is then carried outside the building, and empties itself into the sewer-pipe over a trapped grating at least 12 feet away. We have described the stall or box-drain emptying itself into the stable surface-drain at right angles; this is hardly correct; a right-angled junction is not the most favourable, for if fluid is descending with any velocity it is liable, particularly in a very shallow drain, to run over the side; the junction is best made as a curve, joining the stable-drain in the direction of its fall, thus facilitating the flow.

Such is the simplest and most sanitary arrangement for stable-drains; unfortunately there is a prejudice against them in high-class buildings, but their advantages are obvious. They can be inspected from end to end, can be thoroughly flushed and cleansed; no pent-up gases can form; perfect dilution of the products of decomposition occurs; a block is impossible, and there is an entire absence of traps or gullies in the stable, and consequently no connection with the sewer. A plan of this system of surface-drainage may be seen in Fig. 34, page 251.

We occasionally see these surface-drains emptying their contents into traps in the stable placed at certain intervals throughout their length. This feature impairs their value, as it introduces an underground drain into the building.

Fig. 62 shows an iron surface-drain roughed to give a foothold. It is made by the St. Pancras Iron-work Company at the suggestion of the late Professor Spooner. Another form of surface-drain in iron, affording a good foothold, is made by Musgrave and Co.

Covered surface-drains are made by the above firms, the covers being in short lengths of perforated iron easily lifted up; by raising one or more sections the drains are readily swept out. Fig. 63 shows another pattern by the St. Pancras Company; the cover is in long lengths; the figure also shows a section of this drain. The same firm have introduced another covered drain; it is 6 inches wide, and being shallow will allow a horse to tread in it without injury, should the top be removed. The movable cover is made of wrought-iron, which cannot be broken, the surface being well roughed to prevent slipping and the holes for the escape of liquid are shaped so as to exclude short straws. This

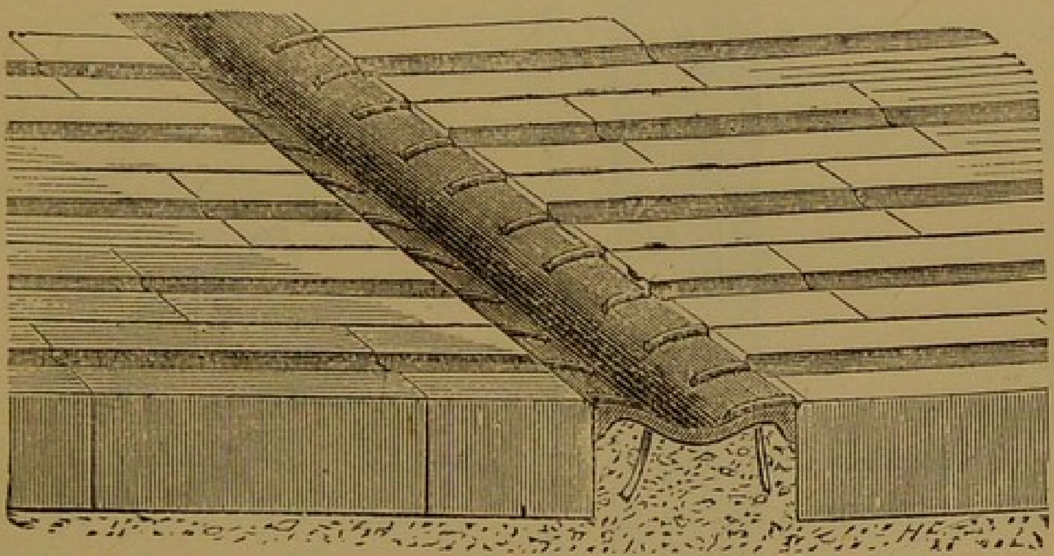


Fig. 62.—Iron Surface-drain (St. Pancras).

gutter may be made with sloping bottom in such a manner that the slight fall usually required may be entirely done away with, and the stall laid perfectly level from head to heel.

I have no practical experience of these covered surface-drains. The ordinary ones in use are always a source of trouble through getting filled with litter and manure, and unless regularly cleared out they become a source of nuisance. The iron surface-drains are vastly superior.

Fig. 39, page 271, shows two plans for arranging covered surface-drains in stalls. The two stalls on the left of the figure receive the waste water from the manger, which I

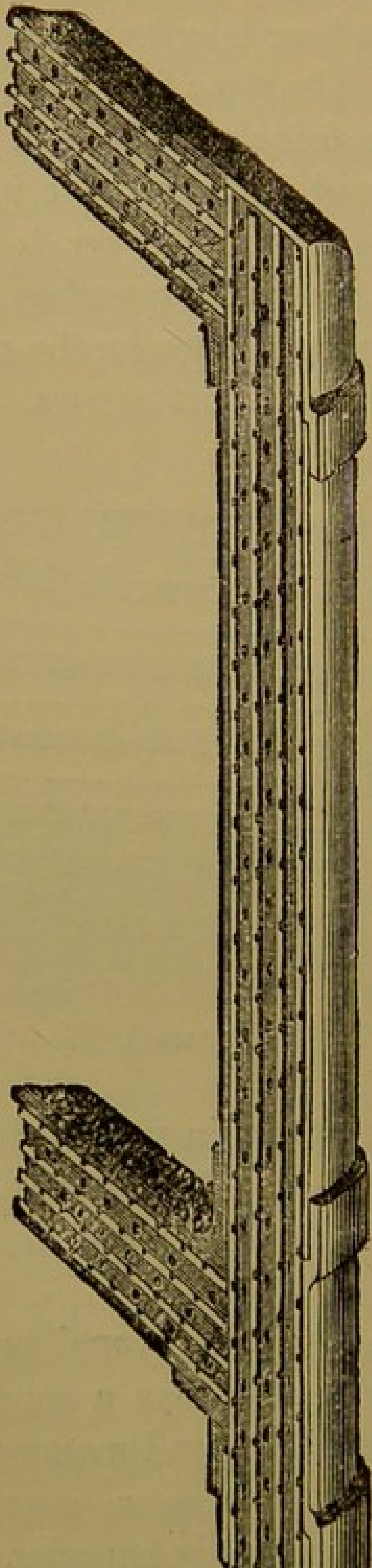
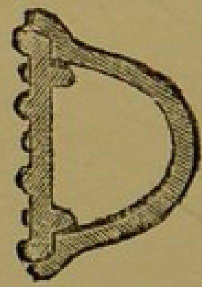


Fig. 63.—Covered Surface-drain with Movable Cover.



Section of Fig. 63.

have before said is objectionable, unless the pipe opens *over* and not into the drain.

Underground or Subsoil drains in a stable are to be condemned; still, as people will insist on having them, we must consider their best mode of construction in order to prevent them becoming a nuisance. These subsoil *stable-pipes* or drains sometimes commence in the box or stall; at other times they commence outside it, receiving the urine by means of a surface-drain, covered or uncovered. There can be no doubt that of the two this latter mode is the best, as a trap in every box or stall is a great evil. Wherever traps are found they must be furnished with a water-seal which is not likely to get out of order; the pipes leading from the traps are made of earthenware, or more correctly stoneware; the form of pipe which should be used is that known as an access-pipe; the joints must be perfectly water-tight, the bed on which they are laid should be of brickwork or concrete to prevent any settling, and as soon as they have arrived outside the building they should be ventilated, as will be presently described. The course these subsoil stable-drains should take must be determined by the nature of the ground and the size of the stable. The principle should be to get them outside by the most direct route, and have half a dozen short ones rather than one long one.

Fig. 64 shows a method of arranging subsoil drainage in boxes. The trap in the centre is objectionable, but if required Figs. 41 or 64 show the least insanitary method of arrangement.

The *sewer-pipes*, or drains, are those which commence outside the building and convey the contents of the stable-drain or pipe to the sewer. Where surface-drainage is established the gutter opens into the sewer-pipe over a trapped grating; but where subsoil stable-drains are used a different method has to be established. If our stable-drain was directly continued into the sewer-drain, then the inside of the stable is, excepting for the one stable-trap (which is often not a trap), in direct connection with the inside of the sewer, and if the presence of gas in the sewer is sufficient to force the water-seal in the trap, then sewer air is poured into the building. Traps cannot be depended upon; they are, as pointed out by Eassie, only auxiliaries to good drainage; and what we require, therefore, is to place the

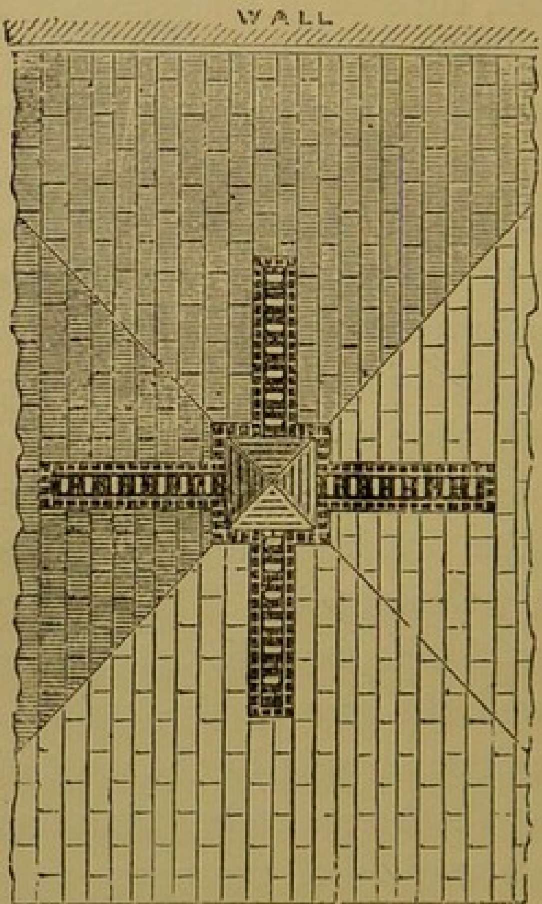


Fig. 64.—Subsoil drainage of Box or Stall with a Trap in the centre (Musgrave).

stable in such a position that even if the trapping should fail, yet the sewer air cannot enter the building.

This is accomplished by what is known as disconnection, viz., the stable-pipe does not open directly into the sewer-pipe, but only by means of some contrivance, which of itself is freely open to the outside air. We will consider these methods presently.

Sewer-pipes (the pipes leading from *outside* the stable to the sewer) are of earthenware. They are made of pipe or fire clay, or a mixture of these; they are salt or glass glazed, are oval or round in shape, and vary in size from 2 to 36 inches in diameter. They may be made so as to afford ready access in case of stoppage, and such should always be used. These access-pipes are made with a lid at various intervals throughout their length, which can readily be removed and the drain examined. Several patterns of access-pipe are in the market, of which Jennings's, Stiff's, and Doulton's are best known. All pipes leading to the sewer should be laid in a bed of clay, and their joints made perfectly water-tight. If the ground is newly made, there

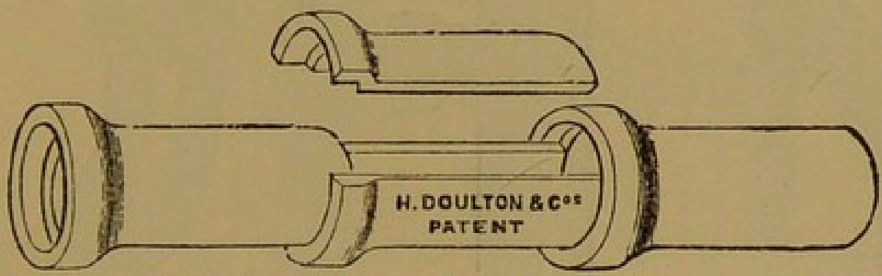


Fig. 65.—Access-pipe, 'Opercular' (Doulton).

s a chance of the pipes breaking when it commences to settle down. In these cases the pipes should rest on brick-work.

All subsoil pipes, whether for use inside or outside the stable, should not exceed from 6 to 8 inches in diameter; their most favourable declination is from $2\frac{3}{4}$ to 3 inches in every 10 feet, and they should be laid in a straight line. When one pipe joins or empties into another, the junction should be none other than a curved one or like the junction seen in Fig. 66; a right-angled junction not only impedes the flow, but favours the deposit of solid matter in the pipe; T or L shaped pipes must never be used.

A pipe must always open into one rather larger than itself. Where the sewer-drain opens into the sewer a flap-trap may be affixed, if considered necessary, to prevent the reflux of gases when the sewer is full.

The **Ventilation of Sewer-drains** and their disconnection from stable-drains has now to be considered. The importance of this cannot be over-estimated. The object, as previously explained, is to prevent the reflux of gas from the sewer into the stable. The introduction of sewer air is brought about by pressure within the sewer-drains or sewers of pent-up gases, which overcome the hydraulic seal which exists in the stable-trap. To prevent this occurring, we disconnect the stable-drain from the sewer-drain at their

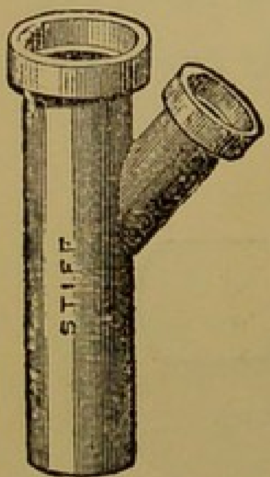


Fig. 66.—Single Junction.

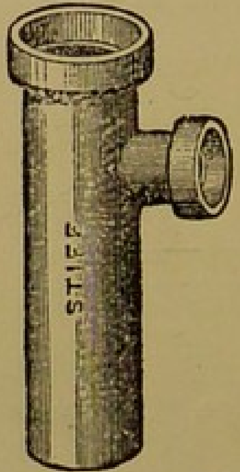


Fig. 67.—Single Junction (right angled).

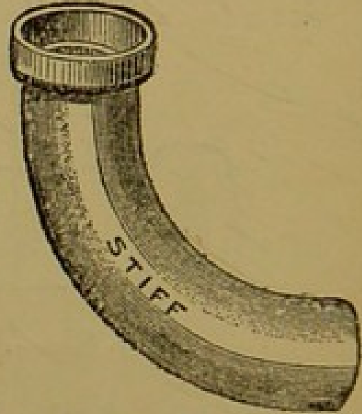


Fig. 68.—A Bend.

junction (which is, of course, outside the building), so that if there is any tendency to reflux of sewer-gas, it cannot force its way into the stable-drain and so enter the building, but escapes by means of a ventilator into the open air. This is the golden rule—where pipes exist in buildings they must be ventilated where they join the drain which is going to convey their contents into the sewer; if this is not done the interior of the stable is in direct communication with the interior of the sewer.

The most simple form of disconnection and ventilation is shown in Fig. 69, where A is the wall; B, the stable-drain;

C, a syphon-trap containing water which acts as a seal against the gases; D, the pipe leading to the sewer; and E, the ventilating opening communicating with the syphon. If the sewer air passes back through D, it will not force the water-seal at the syphon C, but escapes into the open air by means of the ventilating pipe E; this latter must be carried to the top of the building, and if necessary provided with a conical cap. All ventilating pipes should be straight; if

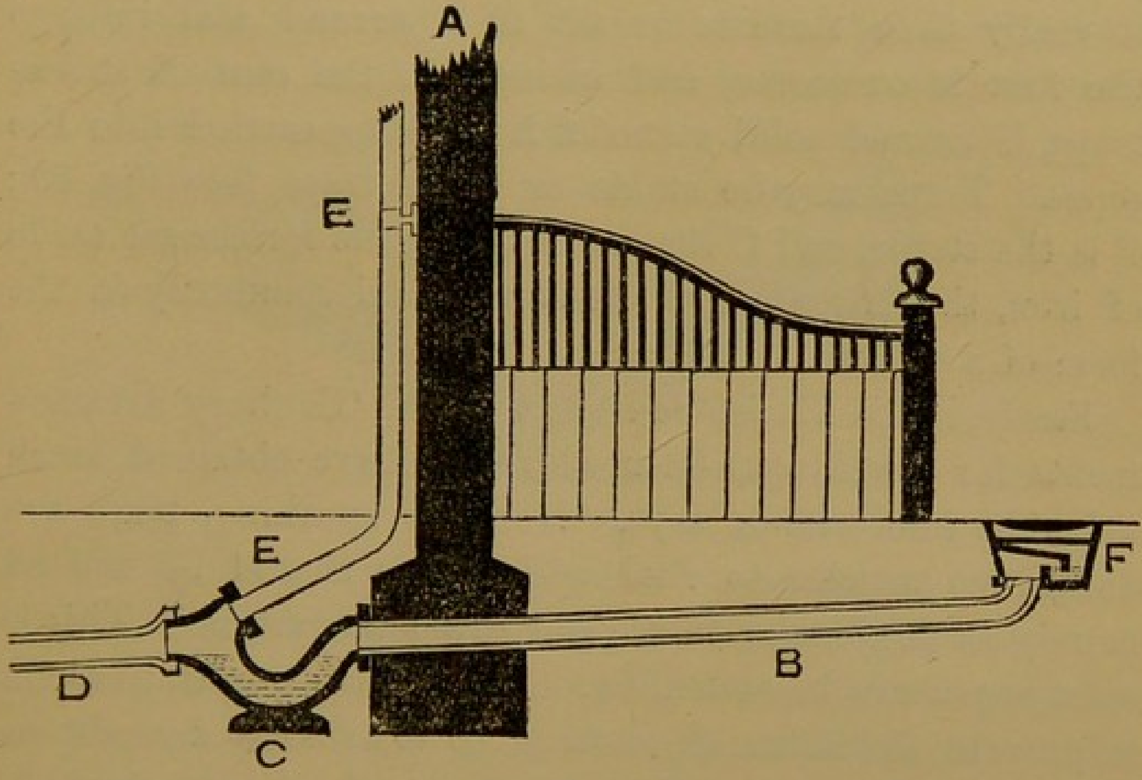


Fig. 69.—Disconnection and Ventilation of Drains.

bends are necessary, curved ones should be used; a ventilating tube *must equal in size the pipe it ventilates.*

This is the rationale of the whole process of the ventilation of drains; many different plans are adopted, but the principle in all these is the same—an air-opening outside the building, where the sewer gases may escape should they be forced up.

The veterinary hygienist will not be called upon to legislate for sewers. These are all constructed on well-known principles, and are under the charge of properly qualified persons.

Traps.—A trap is placed wherever the air of a building communicates with the inside air of a pipe. The object of a trap is to prevent, by means of the water which it contains, the sewer air from passing into the stable. If, however, the sewer-pipe is ventilated in the manner we have described above, it is obvious that the process of trapping in the stable is, to a very great extent, dispensed with; it really then remains to act as a second seal in case the first is overcome, and to save, in the case of stable-traps, litter and solid material from being carried into the pipes. Traps may be stable or sewer traps (see Fig. 69; F is the stable, and C the sewer trap); the former are made of iron, the latter are of stoneware, and commonly in the form of a syphon.

Eassie, in his admirable little work on 'Sanitary Arrangements for Dwellings,' from which we have obtained much valuable information, says, 'Honestly speaking, traps are dangerous articles to deal with; they should be treated merely as auxiliaries to a good drainage system.' This is most important to remember. To depend upon traps alone to prevent the influx of sewer air is to trust to a condition which is liable at any time to get out of order, and which will certainly fail when most required.

There are four reasons why a water-seal alone cannot be depended upon without ventilating the pipe:

1. The pressure of the gas forcing the foul air through the water.
2. By a vacuum being caused by emptying the pipes suddenly, and so drawing off the water by suction from the trap; or if two syphons are placed close together and unventilated, the one may run the other dry.

3. By evaporation of water below the tongue of the trap.
4. By the water absorbing the sewer gas at one side, and giving it off at the other.

To guard against these consequences ventilating pipes must be introduced, as before described, to carry off the gas from sewers or drains to some place where it may be discharged with safety.

The following are the various traps in use:

The *syphon-trap* (see Fig. 70) is a curved tube containing sufficient water to prevent the foul air being forced back.

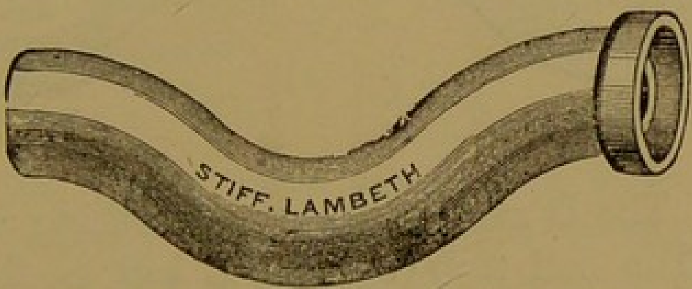


Fig. 70.—A Simple Syphon.

If the curve is deep enough, the water always present in it, and if well laid and properly flushed, this syphon is a very efficient trap. It should be noted that the water in a syphon may be sucked out of it by the syphon action of another farther on, or by the syphon being so small that when run full the water is all drawn off by the pipe it is supplying. Should this condition occur, there is no longer a trap formed, and the sewer air can pass backwards. To prevent one syphon sucking another empty, a ventilator or air space must always be placed between two syphons. A very efficient form of syphon is one recommended by Eassie, with a ventilating tube running up from the centre of the curve. This tube can be carried up to the top of the building.

Fig. 71 shows a syphon, and the dotted lines indicate where ventilating tubes may be inserted. Fig. 72 is another syphon with an opening which can be used for inspection purposes and kept closed with a cap, or a pipe may be inserted for the purpose of ventilation.

A mid-feather trap is a bad one; the D trap, the dip trap, and bell trap are notorious as the "domestic air

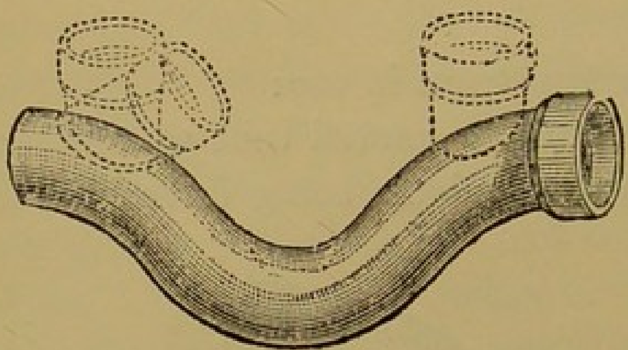


Fig. 71.

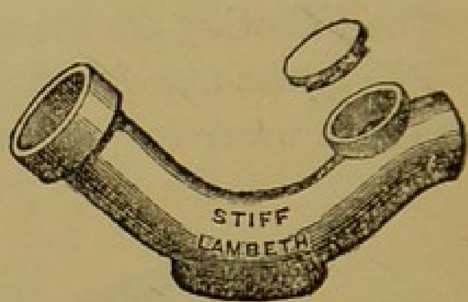


Fig. 72.

poisoners." The D and dip traps are nothing better than cesspools. The bell trap (Fig. 73) is bad, as the trapping arrangement is so readily removed, and the inside of the stable is then in direct connection with the inside of the sewer. The mid-feather is a difficult trap to clean out.

Bell traps should never be used in a stable, for the reason

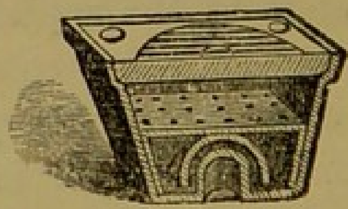


Fig. 73.—The Bell Trap.

that they are under the control of the groom, and are more often left untrapped than trapped. The only trap that should be used is one possessing a water-seal which cannot be interfered with. It is essential that stable traps should have some arrangement for arresting portions of litter carried into them, and prevent them being carried into the pipes. Fig. 74 shows a good trap, worked on the syphon principle, with a fixed tongue which cannot be

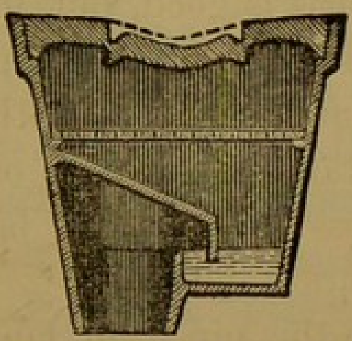
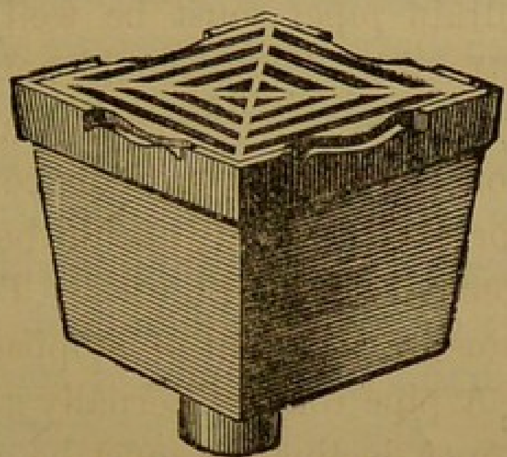


Fig. 74.—Section of a Stable Trap with a Fixed Syphon (St. Pancras).



The Exterior of Fig. 74 (St. Pancras).

interfered with. Foul water should never exist in a trap; the latter should be flushed out daily, for which purpose a tap and hose should be found in all stables.

Traps are required for all sinks or gulleys in the yard

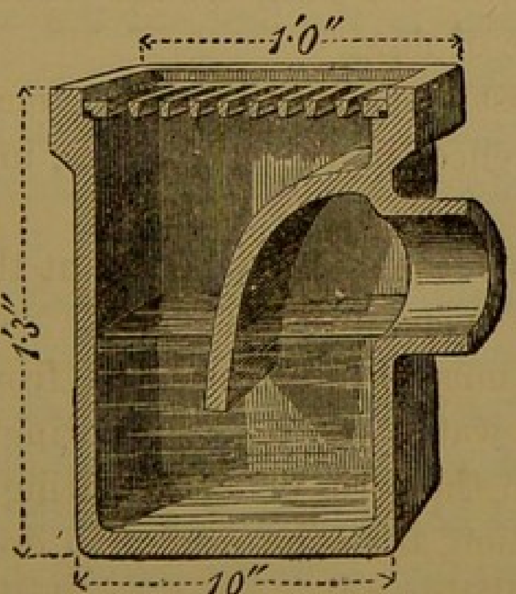


Fig. 75.—A Trapped Gully (Stiff).

which communicate with the sewer; a good one is shown at Fig. 75; it is deep enough to prevent solid material being carried into the sewers, but it should be regularly cleaned out, especially after rain.

Rules for drainage may thus be summarized:

The drain pipes must be well and truly laid, and perfectly straight. They should not rest on the collar, or the joint will eventually give; a firm clay basis is good, but in loose soil to prevent subsidence they should be laid on brickwork. The joints should be well luted, but not with clay; cement should be used. To facilitate examination of the drains in the event of stoppage, access pipes should be used. A pipe rough internally soon "furs" and clogs.

A proper declination must be given to the pipes; if laid level the contents stagnate; if too much slope the liquid contents run off, and leave the solids behind them; the fall should be 3 inches in every 10 feet. The contents of a pipe should be in constant motion.

Drain pipes must not be too large—6 inches is a most suitable size; if larger the flow is not facilitated.

The junction should never be at right angles; an oblique or curved junction is the best, as the sewage must be delivered in the line of flow.

A large pipe must not empty into a small one; in a large pipe the difference should be 3 inches, in a small one 2 inches.

A flap trap should, if possible, be fixed at the end of the sewer pipe where it opens into the sewer.

The stable pipe must be disconnected from the sewer pipe by means of a water-seal and ventilating tube; these may be combined in the form of a ventilating syphon, or a complete disconnection, as in the case of an open water-trap and grating. Ventilating tubes must be straight, have no right angles, should equal in size the pipe they ventilate, and open out above the roof of the stable; water pipes from the house-top should never be used as ventilating pipes.

Traps are merely accessories to a good drainage system.

The best stable trap is the fixed syphon; the worst is the bell trap. The essentials of a good trap are that it should be so arranged that the trapping cannot be interfered with, that means exist to arrest solid material, and that it contains a good water-seal. Traps must be daily flushed out.

Lastly, never have subsoil drainage in a stable if it is possible to have surface.

Manure Pits.

The chief points to note about these receptacles for the solid excreta are that they be kept far enough away from the stable to prevent contaminating the air, and that they be perfectly impermeable to moisture. My experiments on the air of manure pits showed that they should not be situated nearer than 13 yards to any stable. To secure impermeability to the flooring of the pit, it should be constructed of well-cemented stone on a good concrete foundation. Not only should the pit be impermeable to moisture, but the ground surrounding it should be well paved to prevent soakage. The greatest care should be taken that no manure pits are constructed close to wells or other water-supply; nor should they be near houses.

Manure pits should be emptied once a week; it is hardly necessary to refer to the absurd idea of the supposed *healthiness* of the emanations from them. No decomposing organic matter is healthy, and there is a belief gaining ground that human diphtheria and typhoid fever may have their origin in manure heaps.

Where cess-pits are used they should be constructed of a perfectly impermeable material; they should be regularly emptied, and the greatest care taken that they are properly ventilated by means of a tube of good diameter surmounted by a fixed exhaust cowl. They should be situated as far from the stable as circumstances will permit, at least 100 yards.

CHAPTER VII.

SOILS.

We are very deficient in exact information as to the part played by soils in the production of disease. There can be no doubt that in many cases their influence is very great, particularly in some diseases to which man is liable; regarding, however, diseases of the lower animals, our information on this point is very inexact. I know of but one affection where I have felt strongly inclined to believe that telluric phenomena have influenced its production, and this disease is anthrax. We need scarcely say, however, that glanders-farcy, tuberculosis, and other diseases have been mentioned in connection with a filthy soil; but in these cases so many other insanitary conditions exist in combination, that it would be difficult to define the part played by the polluted soil.

In the following chapter we have condensed the information collected by human hygienists on the subject of soils from their sanitary aspect, and have particularly dwelt on those points which appear to us to be of most importance, either from their direct veterinary bearing, or as laying the foundation for future observation in regard to the part played by soils in the production of disease amongst the lower animals.

The geologist views all soils as rock, irrespective of their physical properties. Whatever may be their composition or texture, soils, geologically speaking, are mainly of two sorts: *soils of disintegration*, arising from the waste and decay of the immediately underlying rocks, and *soils of transport* whose ingredients have been brought some distance, and have no connection with the underlying formation. Under this latter head are comprehended all drift and alluvial material. There are also soils of organic origin, such as peat, and vegetable mould or *humus*, which are to a great extent of animal origin or elaboration (Page).*

The most common forms of soils met with are, in the order given by Parkes, the granitic, metamorphic and trap rocks, clay slates, limestone and magnesium limestone rocks, chalks, sandstones, gravels, sands, clays, marls, alluvial soils and cultivated soils; all these consist of organic and inorganic matter, intermingled with air and water. The most important of these constituents are, as far as our present knowledge is concerned, air and water.

Air in the Soil.—The depth of air in the soil is unknown; all soils, even the hardest rocks, contain an appreciable amount. The more porous the soil the larger the amount of air contained; this will vary, depending on the soil, from 20 per cent. to 40 per cent. A familiar example of soil containing air is given when the ground is turned up in agricultural or other operations; it always occupies a greater bulk than it did before; Parkes puts it at from two to ten times its own volume. The air in the soil contains oxygen, nitrogen, carbonic acid, ammonia, nitric acid, carburetted and sulphuretted hydrogen; these latter being, in all probability, derived from the decomposition of organic matter. Besides these, the soil air contains a considerable amount of moisture. The oxygen in the soil is much smaller, and the carbonic acid very much greater, than that found in the air. This is particularly important with regard to the CO_2, for it is stated that the CO_2 in the

* 'Economic Geology.'

air is derived from that found in the soil, the pressure within forcing it out. The deepest strata of soil contain the most CO_2; Pettenkoffer's experiments gave at a depth of 5 feet 1·58, and at 13 feet 18·38 of CO_2 per 1,000 volumes.

The movement of soil air is important; it is a process constantly occurring more or less freely, depending on the porosity and dryness of the soil. The actual motive power is due to the rise and fall in the ground water, and the difference in temperature between the superficial and deep strata; other causes are named, such as barometric pressure, force of the wind, etc., but these are perhaps exceptional. A building, owing to its higher temperature, acts as a suction pump to the soil on which it stands; by this means gases are drawn into stables, both from below and laterally, derived from the impure soil on which they stand. The most important of these gases is carbonic acid, but with it must be mixed compounds of hydrogen and ammonia derived from the soakage of urine and fæces into the soil.

We see from this the necessity of having an impermeable flooring for all buildings designed for the accommodation of animals, remembering that the pollution of the floor is very great, and that soakage into soils from a pervious floor is something considerable. Not only should the actual material for the flooring be impervious, but a layer of concrete should be beneath the whole building with the object of keeping out the damp, and preventing the soil air being drawn upwards. It is in Indian stable management that our greatest difficulty is felt in this direction; the floors being all earth rapidly absorb the sewage, and give out again the products of decomposition with the soil air.

Water in the Soil is of two kinds, moisture or dampness, and ground-water. Moisture is found wherever air exists in the soil; ground-water, on the other hand, is a stratum of water filling up all the pores of the earth and excluding the air. The boundary between the moisture and ground-water is termed the water level; it consists of both air and water. The moisture may only reach 2 or 3 feet below the surface before it joins the ground-water; on the other hand, it may be as much as 15 and 17 feet deep. The ground-water may be high, viz., about 5 feet from the surface; or low, being as far down as 15 feet; or in some cases much lower. Between these heights it may vary considerably, and often very rapidly. Fluctuating heights of ground-water are very dangerous to health; a persistently high ground-water is dangerous, whilst a low ground-water is healthy.

The more compact the soil, the less moisture will it contain; still, according to Parkes, the hardest granite and marbles will hold no less than from ·4 to 4 per cent. of water, or about a pint in a cubic yard. Loose sand may hold 2 gallons of water in a cubic foot; chalk, 13 to 17 per cent.; clay, 20 to 27 per cent.; sandy loam, 33 to 36 per cent.; humus, 40 to 60 per cent. Moisture in the soil is produced by rain, by the power the soil has of attracting moisture from the air, and by the fall of, and capillary attraction from, the ground-water.

The Ground or Subsoil Water may be at a great depth from the surface; from 15 to 17 feet is a common and safe height. This mass of water is in continual movement up and down, or horizontally; the direction of movement is towards the sea or nearest river; its rate of movement varies, owing to obstructions it may encounter, such as impermeable strata, roots of trees, etc.; observations which have been made have shown it to vary from 7 or 8 feet to 15 feet daily. The variations in the level of the ground-water, such as are brought about by rainfall, obstruction at the outlet, or during its passage through the soil, are of the most importance from an hygienic point of view.

Excessive moisture in the soil is unhealthy owing to the organic matter which is carried into the air by evaporation, this organic matter having undergone decomposition in the presence of heat, air, and moisture. Damp places are proverbially unhealthy; phthisis in man and glanders-farcy in the horse are attributed to this cause, and diseases of the air-passages are probably more common than on dry formations. The healthiness of a soil is in inverse proportion to the amount of water it contains. The effects of a damp soil on health are stated in the 'Sanitary Report for 1852' as follows:

1. Excessive moisture, even on lands not evidently wet, is a cause of fogs and dampness.

2. Dampness serves as a medium of conveyance for any decomposing matter that may be evolved, and adds to the injurious effect of such matter in the air; in other words, the excess of moisture may be said to increase or aggravate excess of impurities in the atmosphere.

3. The evaporation of the surplus moisture lowers temperature, produces chills, and creates or aggravates the sudden and injurious changes of temperature by which health is injured.

A large amount of evidence has been collected to prove the connection between typhoid fever in man and the rise and fall of the ground-water. When the ground-water has fallen rapidly, particularly after an unusual rise, then cases of typhoid are most prevalent, and the lowest level of the ground-water corresponds with the largest number of typhoid cases. For some time past I have considered that there was a distinct connection between the rise in the level of the ground-water and the production of anthrax amongst horses in India. It was the result of many observations that anthrax was most frequent during wet weather. V.-Col. Duck, from his South African experience, has observed the same thing. It is a matter of common observation that anthrax and rain are associated. In man cholera, enteritis, and intermittent fevers follow the rise in the level of the ground-water.

On the authority of Koch the soil is the chief habitat of micro-organisms. He shows that surface soils and moulds are extraordinarily rich in bacterial germs, but that as we go deeper the micro-organisms diminish rapidly. At a depth of 3 feet 3 inches they seem entirely absent.

In the case of animals dying from anthrax no spores were found in bodies buried more than 3 feet 3 inches deep, for the reason that at that depth the temperature for the development of spores is not high enough, and there is an absence of a free supply of oxygen. According to this theory it should be perfectly safe to adopt deep burial in the case of anthracoid bodies.

Marshes are produced where the subsoil water is at the level of the ground. Such places are flat, but not flooded, the vegetation abundant and rank, the drainage indifferent. Marshy districts are notoriously unhealthy; malaria is produced in such places, excepting those with peaty soils, or those regularly flooded by the sea. In some parts of the Continent and England marshes are prolific sources of anthrax, and we know that sheep placed on marshes are subject to attacks of fluke disease.

Drainage of the soil is the only method of proceeding where the moisture is great or the ground-water high. Such drainage is common in agricultural works; deep drainage of 4 feet being considered best. Open drains are not generally used excepting as a temporary measure in drying the body of the soil. Pipes are laid down at a depth and distance apart regulated by the sanitary engineer; such drainage removes the water from the soil, rendering it dry, and well aërated.

The case of the horses in two of the royal stables at Munich, described by Pettenkofer, shows in a very striking manner the grand effects of subsoil drainage. In both stables there was the same stable management, and the same class of horse, and yet in one of them a fever was present which did not occur to those horses in the other stable. The fever was not communicable. The difference in the healthiness of the two places was the difference in the level of the ground-water. In the unhealthy stable it was only $2\frac{1}{2}$ feet from the surface, in the healthy 5 to 6 feet. Draining the former stable, and reducing the level of the water to 6 feet, rendered the stable perfectly healthy.

The height of the ground-water of any place is readily determined by observing the height of the water in the neighbouring wells. In observing the rise and fall Parkes gives certain precautions to be adopted, lest local conditions of wells, and proximity of rivers, be taken as representing a rise and fall in the subsoil water. Observations are recommended to be made at least once a fortnight, and over a considerable district.

Vegetation performs important functions with regard to the soil. It rids it of organic matter by assimilating it as food. In all soils, except the hottest and driest, animal refuse in the soil is acted upon by minute living particles, which constitute a ferment. It is called the process of nitrification, or the nitrifying ferment, for under its influence organic matter passes into nitrates, nitrites, ammonia, and fatty hydrocarbons, which are readily absorbed by growing vegetation. It was found by observation at Liverpool that cinder refuse and animal and vegetable *débris* took three years before it completely disappeared in the soil.

In hot countries vegetation protects the ground from the effects of the sun's rays, and evaporation being thus prevented the soil is kept cooler, whilst the evaporation from the vegetation is so great as to greatly lower the temperature of the air. Schleiden estimates the quantity of water evaporated from a woodland tract to be ten times the amount precipitated on its area.* The Eucalyptus globulus is said to absorb and evaporate twelve times the rainfall. The roots of all trees absorb and evaporate large amounts of moisture, and thus the temperature of the air is lowered. In cold countries the vegetation protects the soil, and thus prevents the abstraction of its heat. Trees check the movement of air; they may thus be either beneficial, as in an exposed position, or they may be hurtful from the stagnation which results; so impassable is the barrier afforded by trees that they may be protective against malarious miasma. The removal of trees requires great discretion, not only on account of this protection to the soil and cooling of the air, but from the fact of their drying the soil by the absorption of moisture, and facilitating the sub-soil drainage which flows through the channels formed by their roots. Brushwood has the character of being unhealthy, and should be removed from ground surrounding buildings; herbage, on the other hand, is healthy.

Soils possess different powers of absorbing heat, depending on their colour, composition, and texture. Sandy soils are the hottest, clays and humus the coldest. There are two distinct heat-waves in the earth, the one a daily, the other an annual wave. The daily wave is produced by the absorption of the sun's rays, which are slowly conducted downwards; during the night this ceases, and an upward wave results. This daily wave is not perceptible 4 feet below the surface. The annual wave of heat, due to the

* 'Hygiene and Public Health,' Buck.

summer heat and winter cold, may be detected, according to Professor Forbes, at a depth of from 50 to 90 feet from the surface. One of the effects of soil drainage is to raise the temperature of the ground.

The reflection of light from soils depends upon their colour. All who have been in India are aware of the intense reflection of light from a bare sandy surface. The horse suffers less from this 'glare' than man does, due to the large black bodies attached to the pupillary opening absorbing to a great extent these bright rays. Still, it is worthy of consideration how much of the cataract existing amongst horses in India is due to the intensity of sunlight producing nutritive changes in the lens. The Asiatic horse suffers more from this than does the Australian, and in the old days when the Asiatic did all the work in India, cataract was one of the most common causes of rejection for the service.*

Composition of Soils.

Soils consist of organic and inorganic material; of the former the most important is the vegetable matter which exists on the surface or substance of the earth. Vegetable matter exists in the earth, according to Parkes, in three forms, viz., deposits, vegetable *débris*, and incrustations; other organic matter is found in the earth, the result of human and animal excreta; it is fortunate that this is rapidly appropriated by plants, for whose use it is converted into compounds of ammonia, etc. It is not, however, in every soil that this conversion goes on; in gravels and porous soils oxidation of animal refuse is rapid, and destruction thereby effected; in soils retentive of moisture such rapid destruction does not take place, and the result is poisoning

* I have this on the authority of V.-Colonel Shaw, Madras Army, who for many years held the appointment of veterinary surgeon to the Madras Remount Depôt.

of the water which passes through it. Ten to 45 per cent. of organic matter is found in marshes; this organic matter is made up of certain acids which require renewed chemical investigation. Vegetable matter decomposes very slowly; heat aids it and renders the soil alkaline from ammonia; cold retards it, and renders the soil acid (Parkes). Regarding the reaction of the soil, a wet soil is slightly acid; if very acid it is a bad sign, particularly for vegetation. If the soil be rendered alkaline by the addition of ammonia, or by the decomposition of substances producing ammonia, it then becomes fertile.

The mineral matters of the earth are, as may be imagined, very numerous, and the most common of them are well known to all. 'The principal ingredients of soils are sand, clay, carbonate of calcium and humus; as each of these preponderate, the soil is said to be sandy, clayey, calcareous, or peaty.'*

The following table, compiled from Parkes, will give all the leading points connected with the chief soils:

* 'The Chemistry of the Farm,' R. Warrington, F.C.S.

Names of Soils.	Site.	Slope.	Permeability to Water.	Emanations into Air.	Drinking Water.	Remarks.
The Granitic, Metamorphic, and Trap Rocks (when unweathered)	Healthy	Great	Slight	None	Few impurities	When these rocks are disintegrating, they are supposed to be malarious.
Clay Slate	,,	Usually great	,,	,,	,,	Water often scarce.
Limestone and Magnesian Limestone Rocks	,,	Considerable	Moderate	,,	Hard, sparkling, and clear	Of the limestones hard oolite is the best, and magnesian the worst.
Chalk	,,	Moderate	Great	Slight	Hard, but good	If the chalk is mixed with clay it becomes damp and cold.
Sandstones	,,	,,	Variable but usually considerable	,,	Sometimes impure	Sandstones mixed with clay are damp.
Gravels	,,	Slight	Great	,,	Pure	Deep gravels are healthy except when placed below the general surface, when water rises through them.
Sands (healthy)	,,	,,	Arrested by subsoil	,,	,,	Healthy sands contain no organic matter, and are of great depth.
Sands (unhealthy)	Unhealthy	,,	,,	Considerable	Impure	Unhealthy sands are composed of an underlying stratum of clay, laterite, and vegetable sediment. The subsoil water is high, and water rises through from higher levels. Sands containing soluble mineral matter are unhealthy.
Clay, Marls, and Marshes	,,	,,	Slight	Considerable	,,	

Alluvial soils are those produced by the disintegration of other rocks. They consist largely of vegetable matter, the whole being brought down by river floods, and deposited as the water subsided. These soils are rich in organic matter, give out emanations to the air, and poison the drinking water; water neither subsides nor runs off; marshes are common. *Alluvial soils with dense marls and clays are the most unhealthy sites.* The greater part of the Indian peninsula consists of this formation.

Made soils are those consisting of cinders and rubbish which have been used for filling up inequalities in the ground. Such sites are open to great objections owing to the amount of organic matter, much of it in a state of decomposition, which has been deposited. Stables built on such a foundation must for some time, until nature's own efforts of purifying the soil have been completed, remain unhealthy owing to the amount of organic matter drawn into and mixed with the air in the stable.

Selecting Locality for Buildings or Camps.

The question may arise, especially in civil life, as to the most suitable site for stables. In the army, suitability of position is subordinate to military considerations, but even here our opinion may be taken on one or more points. Respecting the formation of camps, the army veterinary surgeon may often be called upon to make the most judicious selection available, especially in those camps which will form the hospitals and remount depôts in all future operations in the field. He has, however, only second selection, as the most healthy position for the men must of necessity come before that for the horses.

The principal points to be considered in selecting localities are those relating to the meteorological conditions, conformation of the ground, composition of the soil, and physical conditions.

Meteorological Conditions.—The weather for all seasons should be carefully ascertained; the rainfall, direction of prevailing winds, temperature, prevalence of fogs, etc., should be noted.

Conformation of the Ground.—The height above the sea, position and slope of surrounding hills, the chief watersheds, direction and position of rivers, depth of valleys, etc., should be observed. Elevated lands out of which there is drainage, and into which there is none, should, if possible, be obtained; a free circulation of air is thereby also ensured, an important condition in a military camp. Narrow valleys are unhealthy; the air there, particularly in the tropics, is stagnant. In wet weather they are damp, not only from the drainage into them, but from the pressure of the water in the higher level of the hills forcing the soil water to the surface. Plains close to the hills should be avoided for the same reason.

Composition of the Soil and Physical Conditions.—A determination of this is important in deciding, not only the question of drainage, but the presence or otherwise of organic matter. A good deep gravel is the most desirable; clay, alluvium, and sands with a clayey substratum, are objectionable. The height of the ground-water should be ascertained, and its yearly fluctuations obtained if possible. Dryness of the soil is absolutely necessary. The character of the surrounding vegetation should be observed, and the water-supply, its sufficiency, absence from contamination, etc., especially attended to. Damp soils may be to a great extent improved by drainage; and if this is required, the position and direction of it should be noted.

It is obvious that many of these points cannot be carried into effect under certain exigencies of military service, still, the rules hold good, and we should endeavour to work as near to them as possible if we are to ensure a judicious selection. On the other hand, with regard to the selection of localities for building purposes, particularly in civil life, most of these points are under our control, and should receive most careful attention.

If called upon to advise what steps should be adopted to improve the healthiness of a position which has infringed the laws of sanitary science, we should bear in mind the four simple rules formulated by Parkes :

1. Drain subsoil and lower the level of the ground-water.

2. Pave under houses so as to prevent the air from rising from the ground.

3. Pave or cover with short grass all ground near buildings in malarious districts.

4. Keep the soil from the penetration of impurities of all kinds by proper arrangements for carrying away rain, surface, and house water and house impurities.

Chemical Examination of the Soil.

The only point we will name here is the examination to determine the amount of air and moisture in the soil. This requires no chemical apparatus, and can be readily performed. The determination of organic matter and gases in the soil of stables would be a most interesting and important inquiry, but would require more time and apparatus than is at the disposal of the general practitioner.

Determination of Water.—Weight a known quantity of the soil, spread it out on a sheet of paper, and dry it in a warm room (or in the sun in the tropics) for four, twelve or twenty-four hours; weigh it every few hours until it ceases to lose weight. The loss roughly represents the amount of moisture, from which the percentage can be easily calculated. The same experiment may be useful in determining, from the rapidity or otherwise of the drying, whether the soil is especially retentive of moisture, and whether drainage is likely to be required.

The **Determination of Air** in the soil may be roughly made as follows. Take any flat-bottomed bottle and divide it carefully into 150 parts, pasting a piece of paper on the outside to mark the divisions. Introduce into it 50 parts of the earth which has previously been dried at the boiling-point of water, press it lightly into its place so as to represent its natural condition, and pour upon it 100 parts of water; shake it to expel the air, and allow it to stand for some time; read off the number of parts remaining, and the difference between the 150 parts originally existing, and the number of parts remaining, will represent the amount of air expelled; from this the percentage of air can be calculated.

Example.—Fifty parts of earth and 100 parts of water equal 150 parts; after standing some time only 148 parts remained; the difference of 2 represents the amount of air in 50 parts of the soil, or 4 per cent.

CHAPTER VIII.

DISINFECTION.

By the term disinfection we understand the destruction of organic matter and disease-poisons.

Disinfectants, antiseptics and deodorizers have been somewhat confused. A disinfectant is a destroyer of germs, an antiseptic an agent which prevents the growth and production of germs, and a deodorizer one which has the power of acting chemically on ill-smelling gases, and destroying their odour. An agent may be both a disinfectant, an antiseptic, and a deodorizer; but a deodorizer may be neither a disinfectant nor an antiseptic.

It is the process of disinfection which principally concerns us in hygiene. We have many diseases of the lower animals, notably glanders-farcy, pleuro-pneumonia, strangles, influenza, variola, cattle-plague, foot-and-mouth disease, anthrax, etc., the poisons of which possess the power of multiplication, and are more or less resistant to the process which generally destroys organic matter. In order then to prevent any further multiplication of these poisons, we endeavour to bring about their destruction; the agents used are chemical or physical; the former is most extensively practised, the latter is the most effectual; but the difficulties of applying it cause the chemical process to hold the most important place.

The agents used as disinfectants are the mineral and organic acids, such as nitric, hydrochloric, acetic, sulphurous, sulphuric, and carbolic acids; preparations of chlorine, iodine, bromine, mercury, zinc, iron, copper, lead, alum, lime, potash, soda, etc. These are the principal disinfectants, and singly or combined form the largest number of the various preparations used as such.

It has been laid down by Parkes that, in order to apply the process of disinfection in a scientific manner, we should know, 1st, the nature of the contagium or disease-producing agent; 2nd, the means by which this is spread; 3rd, the effect produced on it by the action of the disinfectants used for its destruction.

In the present light of our knowledge we must regard the contagia as consisting of particles of living matter; this will hold good whether the disease in question be glanders or scabies. It is unnecessary here to enter into the subject of disease germs, and the arguments in favour of or against their specific power. They are undoubted, and exist in all diseases capable of producing their like by inoculation, and though the poisons of rabies and some other diseases have not yet actually been seen, it must be held that they are as undoubted as the poisons of anthrax or tuberculosis.

The means by which disease poisons are spread, are through direct contact with the diseased fluids of sick animals; by water or food soiled by their body fluids; by air containing particles given off from their skins and lungs, or carried up by the process of evaporation from the infected ground on which they stand; by contact between healthy animals and men who have been attending on the affected ones; by the sale and conveyance about the country of hides, horns, flesh, offal, bones, tallow, excrement, etc., of affected animals; by the superficial burial of carcases, and the bringing to the surface through animal agency of the particulate poisons of the dead; and through placing healthy animals in sheds, stables, railway waggons, ships, etc., which have been occupied by diseased ones. Such are the principal modes by which specific diseases are conveyed, of which we have had many practical examples in this country, the cattle plague being the most notorious.

The sanitary measures which have, therefore, to be enforced to prevent the spread of disease are obvious. The public declaration of the infected area; the drawing of a sanitary cordon around it for a distance which must be governed by the infectious nature of the poison; the absolute cessation of communication between the infected area and the outside world, and the immediate destruction of affected, and in many cases of non-affected, animals—are the first measures to place in force. The difficulties of a thorough carrying out of these principles may be readily appreciated; they can only be enforced by a veterinary sanitary police powerfully supported by the law.

The above measures can, if properly applied, be absolutely certain of limiting the disease to the infected area; in this we have enormous advantages over the human hygienist, who is allowed much less control over public liberty, and moreover cannot carry out that golden principle of limiting the spread of a contagious disease by the immediate destruction of the diseased patient.

We have now to consider the disinfection of the infected area, and first as to the diseased patient. We know that with most of the specific diseases special parts are affected from which the poison is discharged from the system; thus the diarrhœa of cattle-plague, the nasal discharge in glanders and influenza, the desquamation in variola, the subcutaneous serum in anthrax, the saliva in foot-and-mouth disease, the aërial particles in pleuro-pneumonia and tuberculosis, etc., are all means by which the water, air, food, soil and buildings are infected, and capable of reproducing the disease unless disinfected.

It is clear that the discharges from the body should be destroyed by fire, the fæces and litter burned, the soil on which the patient has stood disinfected by litter being burned on it, and the ground to the depth of 6 or 12 inches dug up and buried with the carcases; if a paved flooring, it should be disinfected by burning, and any cracks caused by this should be afterwards filled up with cement; all food presented to the patients, or which has been kept under the same roof with them, should be destroyed by fire; all buckets, water-troughs and other drinking vessels destroyed, or if made of metal heated strongly; grooming materials, brushes, cloths, etc., should be burned; the clothing should either be burned or boiled for several hours; mangers, bails, and walls should be burned by passing over them blazing straw or other material which will give out a good flame; this process I regard as most essential—I have practised it repeatedly in dealing with anthrax. It is readily performed; with care there is not the slightest danger of fire in brick buildings, and I consider it the very best, most simple, and least expensive means of disinfection. If the manger fittings are of iron, they must be strongly heated; if wood, they should be slightly charred; and the walls must be thoroughly burned. In buildings provided with gas this complete and simple method of disinfection could be done with an arrangement like a singeing machine, with most excellent results. After thoroughly burning the parts should be scraped, and the scrapings buried with the animals; wood and iron work, walls and floor, should then be treated with boiling water containing at least 20 per cent. of crude carbolic acid. Drains should be flushed out with strong solutions of carbolic acid, and the doors, windows, etc., not forgotten to be dressed with the same material. The place is now ready for aërial disinfection; for this purpose every crevice, ventilator, window, drain, door, etc., should be closed, and the whole place submitted to a thorough fumigation with chlorine or sulphurous acid gas.

There is little to choose between these agents; both are excellent if thoroughly applied. For sulphurous acid to be effectual it should be present in the proportion of at least $3\frac{1}{2}$ per cent of the cubic space. One pound of sulphur will yield $11\frac{3}{4}$ cubic feet of sulphurous acid gas; therefore, for every thousand cubic feet of air-space in the building 50 oz. of sulphur must be burned. The vessel containing the sulphur, mixed with a little spirits of wine, must be placed in each stall, and the whole building rapidly closed and left undisturbed for at least twenty-four hours; if at the end of that time it is still full of gas, allow it to remain so for a day or two longer. Ironwork and woodwork may now be painted, walls lime-washed, and the process of disinfection is completed. For effectual disinfection it is absolutely essential that no detail be omitted; the most complete disinfection of the stable would be useless if the buckets and brushes are not subjected to the same treatment.

It is evident that the extent to which disinfection has to be carried must depend upon the character of the disease we are endeavouring to eradicate. Glanders and cattle plague would certainly require to be dealt with on the above lines; but when we come to such diseases as influenza, or scabies, our methods of disinfection may undergo modification to the extent considered necessary by the peculiar nature of the disease; for instance, the thorough disinfection of bails, posts, mangers, clothing, and grooming appliances would be more especially attended to in scabies, whereas aërial disinfection would chiefly occupy our attention in cases of influenza.

Our measures would not be complete unless the persons in attendance on the sick animals are disinfected. Their clothing should be boiled or baked, preferably the latter, and their bodies thoroughly washed, particularly the hands, which should be perfectly disinfected; attention should be paid to the nails of these persons; they should be cut short and thoroughly cleaned.

The disinfection of hides, flesh, horns, hoofs, bones, tallow, etc., is recommended. I consider that when we are dealing with diseases where these may convey the poison, nothing less than their entire destruction by fire or chemical processes should be carried out. The flesh is an important economic consideration. I cannot, however, conceive that the flesh of diseased animals can be fit for human consumption.

During the progress of an epizootic, dogs and other small animals should be prevented entering the infected area, and if found should be destroyed.

Harness or saddlery worn by affected animals should be thoroughly disinfected; ironwork should be passed through the fire, or boiled, and such disinfectants as strong carbolic solution, or bichloride of mercury, used for the leather-work. There is often great difficulty in obtaining permission to thoroughly disinfect leather-work; it is poor economy after cremating the body, fumigating and disinfecting the stable, boiling the attendants' clothes, and passing iron-work through the fire, to then content ourselves by simply *washing* leather-work. It is true that the disinfectants used will rot the leather, but the leather portions of one set of saddlery or harness are cheaper than a troop of horses. The lining of saddles and stuffing, also numnahs when worn, would be best destroyed; particular attention should be paid to these articles in cases of scabies.

Railway waggons are best disinfected by a jet of super-heated steam, such as any Company should have the means at hand to apply. The ordinary lime and carbolic acid whitewashing is, it is feared, often too hastily and imperfectly performed. When steam cannot be applied, boiling water containing 20 per cent. carbolic acid should be freely applied. Cattle and horse ships should be disinfected in a similar manner, and afterwards aërial disinfection practised by means of sulphurous acid gas or chlorine.

Heat as a disinfectant, if properly applied, is the most reliable; there is probably no disease which will withstand an hour's exposure to a dry heat of 220° F., or to boiling water or steam of 212° F.

Dry heat penetrates very slowly into fabrics, whereas moist heat finds its way in rapidly. Ovens have been constructed for the purpose of baking clothing and other articles in contact with diseased bodies. The difficulty hitherto has been to ensure the raising of the temperature equally throughout; the use of disinfecting ovens, heated by gas, seems to have accomplished this. In boiling substances the addition of carbolic acid or other disinfectant in the proportion of 1 to 20 is recommended.

Carbolic Acid as a disinfectant has for some years occupied a high place. In its action it coagulates albuminous substances. Stress must be laid on the important fact that 'no virulent liquid can be considered disinfected by carbolic acid unless it contains at least 2 per cent. by weight of the pure acid' (Baxter); in smaller proportions than this the fluid is preserved, and not disinfected, and the organisms instead of being destroyed, are, as it has been expressed, simply 'pickled.' Carbolic acid must not be used in conjunction with chlorine. The acid has no effect on sulphuretted hydrogen. A solution for disinfection should contain from 5 per cent. to 20 per cent. of the acid.

Sulphurous Acid Gas, or its solution in water, is a very powerful disinfectant. According to Baxter it is the most powerful volatile disinfectant known. In its action it combines with ammonia and destroys sulphuretted hydrogen. It should not be used in the presence of chlorine or permanganate of potash, as they destroy each other. In using the solution as a liquid disinfectant, the fluid or substance to be disinfected should be rendered strongly acid. For aërial disinfection 50 oz. sulphur should be burned for every 1,000 cubic feet of space; the action should be allowed to continue for at least twenty-four hours. The gas is prepared by burning sulphur in pans either by the introduction of a little spirits of wine, or live coal. For further remarks on this agent see p. 342.

Chlorine.—This popular disinfectant acts by uniting with hydrogen and setting free the oxygen. It is the most valuable deodorizer known, but unsafe as a disinfectant unless used in large quantities. It is prepared in several ways; the simplest is the addition of hydrochloric acid to black oxide of manganese, 4 parts by weight of acid to 1 of the manganese; heat is applied, and the chlorine of the hydrochloric acid is readily given off. One pound of the black oxide will liberate $8\frac{1}{4}$ cubic feet of chlorine. Another method of preparation is by acting on 4 parts of common salt, and 1 part black oxide of manganese, with 2 parts of sulphuric acid and 2 of water, and heating gently. It may also be prepared by acting on chloride of lime with hydrochloric or sulphuric acids.

Bromine, Iodine, and Permanganate of Potash, though good disinfectants, are much too expensive for ordinary purposes; it requires a large amount of the permanganate to thoroughly disinfect.

From experiments made in Berlin, it was found that $3\frac{1}{2}$ ozs. of bromine could disinfect a space of 918 cubic feet against the most inveterate forms of infection, for removing which sulphurous acid had proved unsuccessful; for simple deodorization one-third of an ounce of bromine hung up high was found sufficient for a space of 7,000 cubic feet.

The **Mineral Acids** are good disinfectants, but there are objections to their use owing to their caustic nature. Dilute hydrochloric acid 1 to 20 may be used, but there are other agents which best take its place.

Several **Salts of Metals** are used as disinfectants, of which the chloride of zinc is the most common. It is, however, unreliable for disinfecting specific poisons. Caustic lime is freely used as lime-wash, but its disinfecting action is open to doubt; it should always be mixed with a powerful disinfectant, such as carbolic acid; as a covering for carcases when placed in a pit for burial, it is useful, after being slaked, in hastening destruction.

Bichloride of Mercury is the most powerful antiseptic at present known; even in very dilute solution, 1 in 1,000 or even in 2,000, it is absolutely destructive to bacterial life. Its extremely poisonous nature will, however, limit its application to special cases where it can be employed under proper professional supervision.

Burial.—The disposal of the dead bodies of animals dying from infectious diseases may here be considered.

The process of burial in quicklime, the hides being slashed to render them useless, is the universal method of disposal. It is evident that it presents very many disadvantages, and is far from being without danger.

The soil and water poisoning which occurs through burial is a point of great importance; wells have been known to yield water having a distinct taste of butyric acid, when animals have been buried in their vicinity; but even of more importance than this are the chances of the malady being propagated through burial. Pasteur's experiments in producing anthrax in healthy animals through being grazed over the graves of victims of this disease are still fresh in our memory. It has been shown by Koch that deep burial of anthracoid bodies was perfectly safe through limiting the supply of oxygen, and thus preventing the development of the spores of this bacillus. If, therefore, burial be adopted, only deep burial should be permitted; the animals should be laid in the pit on their backs, and side to side; the elbows and stifle-joints should be cut through, which will allow the limbs to fall; there should be at least six feet of earth between the surface of the ground and the upper part of the body; to make sure of this, a pit of nine feet in depth should be dug, and the labour this entails can only be appreciated by those who have had to carry out this method of interment; as a rule the work is done hastily, and the pit is seldom sufficiently deep. If twenty animals had to be buried, the pit would have to be $60 \times 9 \times 9$ feet; the amount of labour this represents is very considerable.

The process of **Cremation** is the true hygienic method of disposal; it is expensive and tedious, but has the merit of being absolutely safe. Having had during outbreaks of anthrax to burn a very large number of animals, I found, after trying several methods, that the following one was expeditious, and very simple:

I use a trench dug in the form of a ✚, about $\frac{3}{4}$ foot deep in the centre, and gradually becoming shallower as it reaches the surface of the soil; it is 7 feet long each way, by $\frac{3}{4}$ foot wide, and the earth taken out of the trench is thrown in the right angles formed by it; on this earth the wood is placed; if two pieces of stout iron can be obtained to rest the wood on, so much the better. A layer of big wood comes first, then the trunk, which has had all the limbs and viscera removed; next more wood, and on this are placed the limbs covered by wood, and lastly the viscera, also well covered with wood. The pile is then set fire to, and the body of a horse can in this way be readily consumed in five or six hours. The object of the cross-shaped trench is to ensure a draught whichever way the wind is blowing. The ashes are thrown into the trench and the place filled in. I have cremated about 100 animals, and the method described I find superior to any other.

If the body be placed whole on the fire it will take about twelve hours to consume.

CHAPTER IX.

LABOUR.

THE writer on human hygiene has to devote attention to the subject of exercise, its beneficial effects when taken in moderation, the harm likely to arise from neglecting it, and the effects on the system generally of healthful exercise.

The veterinary hygienist cannot speak of his subject as exercise, but as labour; it is the practical outcome which the investor expects for his purchase-money and the expense of keep and attendance, no matter whether the horse in question be for racing, draught, charger, hack or hunter. Labour, then, being the universal result of the employment of horses, it is not to be wondered at that in many cases people have been led to regard living flesh and blood as so much machinery, which only requires to be placed in motion to continue indefinitely at work.

It is the improper application of labour which helps to fill our hospitals for horses; animals are taxed beyond their strength, are worked for hours together, or placed under such artificial conditions that they are unfit, or soon become so, for very ordinary work. Examples of this are not required; they are met in every class of horse with which we have to deal.

It is rarely necessary for us to have to consider whether horses are receiving sufficient work to keep them in health; it is only the wealthy who can afford to keep animals in comparative idleness. Our consideration with the majority of employers of animal labour, is whether more is not being obtained from the horse than he is capable of giving without permanently suffering as a result

Thousands of horses are killed through overwork, or through expecting from them work for which their conformation or physical condition unsuits them.

Although the labour performed by horses varies widely in its nature, yet we observe one common and uniform result, which is, that it tells on the legs. It does not, as in man, tell on the heart and big vessels by inducing organic lesions in them, but it affects the supports of the body, which in man are rarely diseased. I have been led to wonder why this should be so; why should not the athlete develop a spavin instead of an aneurism? The difference undoubtedly lies in the position in which the two animals apply their force. It is easier to drag than to lift; dragging tells on the limbs, lifting on the vessels.

It is not to be supposed that violent exertion has no ill effect on the bloodvessels of the horse. I am a believer in aortic compression as one cause of 'roaring'; moreover, we know that aortic aneurisms have been found in horses, though such cases are rare. The evil effects, then, of excessive work we look for not in the chest, but in the general condition and limbs.

I have often been struck by the fact that horses will work till they drop and die from sheer exhaustion. Such cases are common in the hunting-field, and in military service. It can only be the discipline and moral control exercised over the horse by man, which prevents it pulling up and refusing to go any further on the first feeling of exhaustion.

The physiological effect of labour shows itself on the lungs, heart, muscles, digestive and urinary system, and skin.

The chief point of importance regarding the lungs is the elimination of carbonic acid in large quantities, and an increase in the amount of air taken in.

Elsewhere ('Veterinary Physiology') I have described the amount of air which horses expire at work, the carbonic acid given off, and the oxygen absorbed at different paces. The formatiou of carbonic acid occurs in the muscles. During muscular contraction large quantities of it are produced, and are carried off by the veins, to be got rid of by pulmonary oxidation. If anything interferes with this oxidation the carbonic acid rapidly accumulates in the system, and muscular exertion is no longer possible. This is the explanation of the so-called pulmonary apoplexy observed in horses exposed to severe exertion.

It is quite evident that if this amount of CO_2 is being got rid of during labour, working animals should have a free supply of carbon to make good the loss; and conversely, that during rest or when lying idle the carbon in the food must be reduced in amount, or it will accumulate in the system. With this increase in the amount of CO_2 we have an increased demand for pure air; hence the necessity for perfect ventilation when animals are working under cover, as in a military riding school. We all know the condition in which many 'rides' leave the school; the dripping skin and general want of tone manifested by the horses are due entirely to the defective ventilation of the schools, the heated air being saturated with moisture, and containing large quantities of carbonic acid.

The effect of work on the lungs should be observed, and attention paid to the breathing as recorded by the flanks. Irregularity of movement, jerking expirations, and the length of time it takes for the respirations to settle down, are all valuable guides as to the effect of work on the system. Spasm of the diaphragm has often been known to result from excessive work.

The effect of exercise on the heart and bloodvessels is to increase the flow of blood through them. Damage to their structure rarely results, as we have before explained;

still, cases of ruptured heart and bloodvessel from actual labour have been known to occur in the horse.

The most common result affecting the circulatory system is dilatation of the aorta and pulmonary vessels, the former resulting in compression of the left recurrent nerve, and consequent 'roaring.' The distress resulting from severe exertion, as in the hunting-field, arises from the accumulation of carbonic acid in the lungs, and the engorgement of the heart and bloodvessels; that deep sigh, in which, as Stewart expresses it, the rider feels his legs thrown apart by the expansion of the horse's chest, is produced by the engorgement of the heart, and is an infallible sign that danger is approaching.

The result of work on the muscles is to cause them to become firmer, closer in texture, and the fatty portions to be removed. We know there is a general feeling of firmness and tone conveyed in handling a horse in training; the muscles stand out, their divisions clearly marked, superfluous fat disappears, and the tendons and ligaments are firm, clean and tense.

The chemical changes occurring in muscles during work are very interesting. Helmholtz states that during work there is an increase in their temperature, which up to a certain point is proportional to the work performed. The muscles become acid from the presence of lactic acid (being alkaline during rest); there is a diminished proportion of oxygen, and an increased amount of carbonic acid in them. During rest a certain amount of oxygen is stored up in the muscles, which has been shown by Pettenkoffer to be due to the action of the nitrogenous food consumed; hence the necessity for nitrogenous material during labour. The actual motive power is produced by the oxidation of the fats and carbo-hydrate matter of the food, assisted, perhaps, to an extent by the nitrogenous material.

Muscular exhaustion is produced by the accumulation in the system of lactic and carbonic acids, the latter being due to the insufficient amount of oxygen supplied. During rest these acids are removed, the muscles become alkaline, and a store of oxygen is laid in for future work.

The effect of moderate work on the digestive organs is to increase the appetite, and empty the posterior bowels. Severe and exhausting work has the opposite effect; it destroys the appetite for a certain time, sometimes for hours. Digestion experiments tend to show that horses do not digest more during labour than during idleness.

Less urine is secreted during exercise than when the horse is standing idle; the amount of decrease is not very much, the cause of it is the increased elimination of water by the skin and air-passages. With regard to the constituents, more inorganic matter is excreted during rest than during work, and we know that during idleness benzoic acid is formed, and that when horses are worked hippuric acid takes its place. Great attention has been paid in man to the amount of nitrogen excreted during rest and idleness, the nitrogen being represented by the urea, uric acid, creatin, creatinine, etc. In the horse the nitrogen is represented by the urea, hippuric acid, creatin and creatinine. As hippuric acid contains nitrogen, and benzoic acid does not, we cannot safely compare the total nitrogens of rest and idleness; if, however, we compare the ureas, we find that on the whole there is a slight increase in the amount excreted during work over that excreted during rest, but the amount is unimportant.

The effect of work on the skin is to increase the discharge of watery and fatty material. By this process the animal temperature is regulated. The process of sweating horses in training has now almost disappeared; it was considered a useful method of getting rid of superfluous fat and fluid from the system, and was rarely omitted; its abuse brought it into disrepute. When judiciously practised it appears to me to be a very rational method of preparing horses for fast work, and, in the form of a vapour-bath, is calculated to save their legs considerably.

Any article on training, whether for the turf, road, or field, would, even were I competent to write upon it, hardly fall within the scope of this work. We may, however, briefly note the guiding rules which science and experience dictate as being necessary to observe in bringing animals into work. The training of a horse will depend upon the character of the work he is to undergo. Training for the turf is a gift which but few men possess. It requires a lifelong experience, and a thorough knowledge of the subject. To train successfully the trainer has to gauge carefully the power and strength of each animal under his care, to regulate the work to suit his constitution, and to know exactly when the animal has given him the maximum amount of power he is capable of yielding. He must recognise the least sign of failing, whether in wind or limb, and pay a care to feeding and general stable management which practically amounts to living with his charge. Such exacting conditions as these are only fulfilled by a few talented men whose knowledge, in many cases empirical, is nevertheless sound and practical.

Training horses for the field and road, more especially the latter, is generally entrusted to men whose chief qualification is that they possess a strong seat and plenty of nerve. Many of them are good, and turn out well-broken and steady horses; very many of them are bad, and ruin horses through ignorance, which a good and careful man could with patience bring round. Firmness, patience, good hands, and a good seat, are what these men require; a combination of qualities rarely met with, but when existing they are a blessing to the horse, and a source of considerable income to the possessor.

Training horses for the army is quite another system; discipline and steadiness have to be enforced; strange sights and noises have equally to be disregarded by the horse, and the greatest attention must be paid to his bitting to enable the soldier, in riding with one hand, to have the animal under control. He must also be so thoroughly drilled that he readily apprehends what his rider requires.

Military training is of the utmost importance; horses are made or ruined by it. They may come out sound, useful animals, with flexible and strengthened joints, good mouths, and implicitly obedient; or they may return ruined in their temper and disposition, and the seeds of incurable lameness laid. The whole thing depends upon the course of instruction which is given, and the care, patience, and humanity which is exercised.

No matter what the training is for, we must not expect too much at one time from the horse. He must have time for his muscles to develop, his chest to expand, the superfluous internal fat which is surrounding his heart and vessels to be removed, and for his tendons and ligaments to develop and strengthen. During this period he must be well fed and groomed, and that comprehensive subject good stable management enforced.

Experience shows that the best muscle-developer is smart walking exercise. According to the requirements of the training, faster paces may gradually be substituted, but only by degrees, and for short periods at a time. Galloping is the only means by which a horse obtains his 'wind,' or powers of staying. It is evident that his gallops must be regulated carefully, so that nothing like distress is produced.

The length of time occupied in training must vary according to requirements; a horse may be made fit for the hunting-field in three months; hacks and harness horses may be fit for their special work in two months, but a horse being trained for military purposes may take longer than either. Speaking of horses between four and five years old, joining the service utterly unbroken and unbacked, no less period than four months should be devoted to their training; delicate animals may even require longer than this. Hastening horses through their military training is a sure and fruitful source of many lamenesses, some of which are incurable.

In concluding these brief remarks on training, we may profit by what Parkes says with regard to the theory of the subject: 'What the trainer accomplishes is in essence the following: a concordant action is established between the heart and bloodvessels, so that the strong action of the heart during exercise is met by a more perfect dilatation of the vessels, and there is no blockage of the flow of blood; in the lungs the blood not only passes more freely, but the amount of oxygen is increased, and the gradual improvement in breathing-power is well seen when horses are watched during training. This reciprocal action of heart and bloodvessels is the most important point in training; the nutrition of nerves and muscular fibres improves from the constant action, and the abundant supply of food; the tissue-changes are more active, and elimination, especially of carbon, increases.'

The Amount of Labour which should be Enforced.

A consideration of this subject must lead us briefly to inquire into some elementary mechanical principles, the mathematical laws governing the production of force, and the amount of power exerted by horses during labour.

The centre of gravity is roughly the central part of the body or mass; this point is determined by reference to the weight of the body in three directions, and the point of intersection of the three planes is the centre of gravity. Every body must have a base, and a line let fall through the centre of gravity should fall within the base, or else the body is unstable; this line is called the vertical. In Fig. 76, illustrating a loaded cart, if the centre of gravity be at G, the body would be stable, for the vertical would

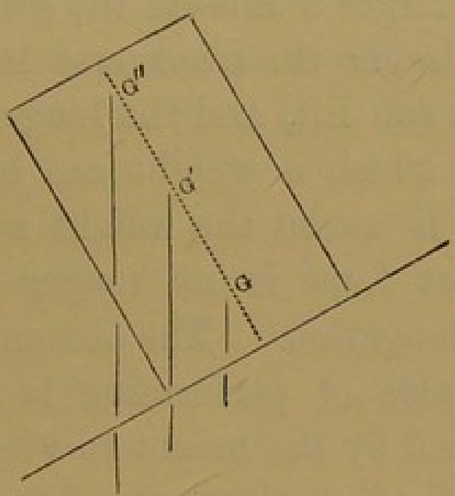


Fig. 76.

fall within the base; at G′ it would be unstable, for the vertical would fall at the edge of the base, and very little would suffice to upset it; at G″ the cart would certainly fall. The practical outcome of this law is obvious—keep the centre of gravity in loaded vehicles low. The centre of gravity of the horse's body is almost opposite to the 8th or 9th rib, at the centre of the chest. The line of direction of his weight must fall within the base formed by his four feet; if he is unequally loaded by having a greater weight on one side than the other, then the centre of gravity is altered, and equilibrium destroyed. In descending a hill the centre of gravity is thrown forwards, the result being that the horse has to hang back to allow it to fall within the base; in ascending a hill the centre of gravity is thrown backwards, the horse has then to keep his body forwards in order that it may lie within the base.

Almost all the levers of the body are of the third order, viz., the force is applied between the fulcrum and the weight; this is the most wasteful of levers, but it makes up in velocity what it loses in force.

Muscles correspond to the general law that the work performed by bodies is proportionate to their bulk or weight. The larger a muscle the greater the effort it can produce; the larger the transverse section of a muscle the greater load it can lift, and the longer a muscle the greater the height to which a weight can be lifted. By *absolute muscular force* is meant the weight which a muscle exercising its greatest force is no longer able to lift without undergoing elongation. The amount of work which a muscle is capable of performing is equal to the weight lifted, multiplied by the height to which it is raised.

The amount of work a muscle or set of muscles is capable of performing is expressed in a definite manner; it is spoken of as so many foot-pounds or foot-tons. A weight of 1 lb. lifted 1 foot high, is called 1 foot-pound. A horse at work exercises a certain effort which we endeavour to estimate for the whole period of labour, and express it as being equal to so many foot-pounds or foot-tons raised. In other words, if the horse could have exercised in one moment all the force he exercised during the whole period of labour, it would have sufficed to have lifted so many pounds or tons 1 foot high. If a weight of 1 lb. is lifted to a height of 12 feet, it is clear that the force exerted would have been sufficient to have raised a weight of 12 lbs. to a height of 1 foot; or if a weight of 2 lbs. is lifted 12 feet, the same power would have lifted a weight of 1 lb. 24 feet.

In order then to express the work performed, it is spoken of as pounds or tons lifted 1 foot high. The principal work we are called upon to express is not executed by the process of lifting, but by the process of pulling; it is not vertical but horizontal work; we therefore speak of animal power as so many foot pounds or tons of horizontal transport, viz., so many pounds or tons conveyed 1 foot.

It is an exceedingly difficult matter to estimate the amount of work a horse performs, for the reason that the conditions of his labour are so constantly changing. He may be at the walk, trot, canter or gallop; he may be on level road, or going across country. If in harness the draught rarely remains the same for many minutes together, owing to the inequality of the road—he may be exerting a force of 40 lbs. one moment, and 160 lbs. the next; in other words, the pace at which the work is performed, the resistance of the ground, and, if in draught, the friction between the wheel and axle, all exercise an enormous influence on the amount of work done, which renders calculations only approximate.

The daily work performed by a horse has, at different times, received attention at the hands of scientific investigators. Watt, Rankine, Smeaton, Tredgold, Brunel, and others, have more or less carefully considered the matter. The latter has dealt with the subject of draught very thoroughly, the article being published in Youatt's work on 'The Horse.' We are indebted to it for a deal of useful matter, some of which is embodied in this chapter.

Mechanical daily work is the product of three quantities: 1st, the effort; 2nd, the velocity; 3rd, the number of units of time per day during which the work is continued (Rankine).

The effort exerted in traction can be measured by means of a spring. If the weight is so great that the horse can scarcely put it in motion, such a load is the *limit of his power.* When the weight has to be carried instead of drawn, we have no means of absolutely measuring the effort exerted to move it. Dr. Haughton determined, from the calculations of M.M. Weber, that the force exerted by a man walking at the rate of 3 miles per hour on a level surface was equivalent to lifting one-twentieth part of the weight of the body, so that the force exercised by a man weighing 150 lbs. in simply moving his body along at 3 miles per hour, is equal to $7\frac{1}{2}$ lbs. at each step.

The effort exerted during saddle-work can only be based on these calculations; it will vary with each velocity: it may be the one-twentieth part of the entire weight of horse or rider, or as much as half the weight. We must not forget that the weight of the animal forms no inconsiderable portion of its load.

The greatest distance a horse can go for several days in succession without enduring fatigue, has been defined as the *limit of his velocity*, between which and the limit of his power there must be a proportion affording the maximum effect, and the most advantageous for his power. The effective work is said to be at a maximum when the animal is so loaded, that with its whole force in action its velocity amounts to one-third of the greatest velocity it is capable of exerting unloaded; and the force of traction corresponding to this velocity is half the limit of his power. The following table will make this clear:

Duration of labour in hours.	1	2	3	4	5	6	7	8
Maximum velocity unloaded in miles per hour	$14\frac{3}{4}$	$10\frac{1}{2}$	$8\frac{1}{2}$	$7\frac{1}{3}$	$6\frac{2}{3}$	6	$5\frac{1}{2}$	$5\frac{1}{4}$

If in six hours a horse can go 6 miles per hour unloaded, and the limit of his power be 250 lbs., his effective work for this period would be best obtained by working him at one-third of 6, or 2 miles per hour, and exercising a force of half 250 lbs., or 125 lbs. The above table was framed by Tredgold; I presume the figures were arrived at from direct experiment.

There is a velocity in man at which the maximum amount of work can be obtained with the minimum amount of expenditure. It is found that 3 miles per hour can be performed for 179 foot-tons per mile, whilst 1 mile per hour requires 237, and 2 miles per hour 208 foot-tons per mile; in other words, it requires a greater expenditure of energy to walk 1 and 2 miles per hour, than it does to walk 3. Three miles per hour is therefore accepted as the rate of useful work for a man.

The energy exercised during work will vary with the velocity. It is evident that more force is expended in moving along at 10 miles an hour, than is expended moving at 6. The energy expended is not, however, in proportion to the velocity. It requires more than double the strength to move at 10 than it does to move at 5 miles an hour. With engines it has been ascertained that the energy expended varies nearly as the cube of the velocity; the same is true of the animal body. Thus, if the energy expended at 4 miles per hour be represented by the cube of 4, viz. 64, the energy expended at 5 miles per hour would be represented by 125, or nearly double as great for only 1 mile per hour more. This illustrates the law of the enormous increase of energy required for high velocities. The higher the velocity at which a body moves, the greater resistance it experiences; this resistance is as the square of the velocity, whilst the force to be employed to overcome this will vary as the cube of the velocity.

The following table will illustrate these points :

Velocity in miles per hour	3	4	5	6	7	8	9	10	11	12	13
Resistance experienced	9	16	25	36	49	64	81	100	121	144	169
Force required to overcome resistance ...	27	64	125	216	343	512	729	1000	1331	1728	2197

This table shows us the great increase in expenditure for high velocities, and by referring to Tredgold's table we will observe the great decrease in speed by the duration of labour.

Horse-power has been fixed by experiment at a weight of 150 lbs. lifted 220 feet high every minute. The experiment was made by Watt, who attached a horse to a weight of 150 lbs. passing over a pulley ; he found he could raise it 220 feet per minute. This is called horse-power, and is applied in this manner to engines ; it is equal to 33,000 lbs. raised 1 foot high per minute, or, in other words, 33,000 foot-pounds ($150 \times 220 = 33,000$). This standard of comparison when applied to animal power is much too high ; a horse can do 33,000 foot-pounds per minute for $3\frac{1}{2}$ hours, but for continuous work of eight hours would not be able to perform this quantity.

It is difficult to obtain an approximate value of the force exerted during the whole period of labour. The utmost force a man can exert is 70 lbs., but 30 lbs. is the force he can exercise with the greatest advantage, and he can exert it for ten hours with a velocity of $2\frac{1}{2}$ feet per second. A strong London dray-horse has, from actual experiment, been found to exert a force of 360 lbs. for a short time ; but at the rate of $2\frac{1}{2}$ miles per hour for eight hours, he can only exert a mechanical effect of 250 lbs. An ordinary horse could not exercise a greater force than 150 lbs. for the same time, and it is even stated to be as low as 112 lbs. It is usually considered that a horse can exert six or seven times the strength of a man. Assuming that the average force exerted is 125 lbs., and that if a horse works for six hours per day at 3 miles per hour, he produces his maximum effect, which we will call 1,000, we will find that by increasing the velocity we have to reduce the force of traction, and this reduces the useful effect; thus:

Six hours' labour at	3 miles per hour, he exercises a force of traction of	125 lbs.	and produces useful work	= 1000
	4 ,, ,,	83 ,,	,,	= 888
	$4\frac{1}{2}$,, ,,	$62\frac{1}{2}$,,	,,	= 750
	5 ,, ,,	$41\frac{2}{3}$,,	,,	= 555

(Brunel.)

For higher velocities both the useful work performed, and the force of traction exerted, are considerably reduced. We are clearly shown, in fact, the decrease in speed by the duration of labour, and the decrease in useful effect by the increase in velocity.

Much of what has been stated has reference more particularly to draught, but the same applies to saddle-work. The force which a horse has to exert to carry a weight of 250 lbs. on his back will vary with the velocity with which he has to carry it. To estimate this force we then apply the results which were obtained for man by the Rev. Professor Haughton from the Webers' calculations. At 3 miles per hour on level ground one-twentieth of the weight carried is the force which moves it along; one-twentieth is therefore spoken of as the co-efficient of resistance. The co-efficient will vary with the velocity, as the following table shows:

Velocity in miles per hour.	Co-efficient of resistance.	Velocity in miles per hour.	Co-efficient of resistance.
3 ...	$\frac{1}{20{\cdot}59}$	5 ...	$\frac{1}{14{\cdot}10}$
4 ...	$\frac{1}{16{\cdot}74}$	6 ...	$\frac{1}{12{\cdot}18}$

Velocity in miles per hour.		Co-efficient of resistance.	Velocity in miles per hour.		Co-efficient of resistance.
7	...	$\frac{1}{10 \cdot 72}$	13	...	$\frac{1}{6 \cdot 26}$
8	...	$\frac{1}{9 \cdot 60}$	14	...	$\frac{1}{5 \cdot 86}$
9	...	$\frac{1}{8 \cdot 68}$	15	...	$\frac{1}{5 \cdot 5}$
10	...	$\frac{1}{7 \cdot 52}$	16	...	$\frac{1}{5 \cdot 18}$
11	...	$\frac{1}{7 \cdot 27}$	20	...	$\frac{1}{4 \cdot 21}$
12	...	$\frac{1}{6 \cdot 73}$	40	...	$\frac{1}{2}$

Through the kindness of the late Prof. de Chaumont, who furnished me with the necessary data, I have been enabled to calculate the co-efficient of resistance for the higher velocities.

Let us clearly understand the value of the co-efficients of resistance; and we will take as an example the case of a dragoon in marching order, man and kit complete weighing 250 lbs.: what force has the horse to exert to carry him at the following velocities?

Miles an hour.		Co-efficient.			To carry the weight, the horse, roughly speaking, has to exercise a force equal to
5	...	$\frac{1}{14}$	...	...	18 lbs.
6	...	$\frac{1}{12}$	...	...	21 „
7	...	$\frac{1}{10 \cdot 7}$	...	...	23·3 „
8	...	$\frac{1}{9 \cdot 6}$	...	...	26 „
9	...	$\frac{1}{8 \cdot 6}$	...	...	29 „
10	...	$\frac{1}{7 \cdot 9}$	...	...	31·6 „

I have shown that the most useful weight a horse can carry, lies between one-fifth and one-sixth of its body weight.

It is evident that in addition to carrying the weight of the man the horse has to propel his own weight, so that if we wanted to know the exact amount of force he exercises, say at 5 miles an hour, his own body-weight being 1,000 lbs., the amount would be:

To carry the man the horse exercises a force of					18 lbs.
,, itself	,,	,,	,,		72 ,,
				Total ...	90 lbs.

Every foot of ground over which the horse passes to perform 5 miles an hour on level ground, costs him 90 lbs. of muscular force.

In jumping, or ascending a hill, the horse has to lift his whole weight, and the weight carried, through the height jumped or climbed.

In the case of carriages we have a source of resistance arising from the friction between the wheel and the axle, and between the wheel and the road.

Friction may be made a serious source of resistance, such, for example, as is experienced in passing through heavy soil.

The amount of friction in a wheel when well-oiled metal surfaces are in contact, will depend upon the proportion between the diameters of the wheel and axle, and the pressure exerted; if the pressure is doubled the friction is doubled; the greater the diameter of the wheel the less the friction. Depending on the state of the roads the friction will vary from $\frac{1}{60}$ to $\frac{1}{8}$ the weight of the load.

Suppose the diameter between the wheel and the axle is as 24 : 1, and the friction at the axle is $\frac{1}{5}$ of the load, which we will suppose is 2 tons, then $\frac{1}{5}$ of $\frac{1}{24} = \frac{1}{120}$, and $4{,}480 \div 120 = 37{\cdot}3$ lbs. which is the force necessary to move the load along.

Morin's formula for calculating friction is as follows:

$$F=\frac{Q}{r}\left\{a+b\,(v-3{\cdot}28)\right\};$$

where Q = the gross load,
r = the radius of the wheels in *inches*,
v = the velocity in feet per second,

and $a+b$ two constants, whose values are:

	a	b
For good broken stone road ...	·4 to ·55 ...	·024 to ·026
For paved roads ...	·27 ...	·0684
For Paris pavement ...	·39 ...	·03

On gravelly roads the resistance is about double, and on sandy and gravelly roads five times the resistance on good broken stone roads.

The friction on sandy and gravelly soil is $\frac{1}{7}$; gravel road, $\frac{1}{14}$; broken stone road, $\frac{1}{33}$ to $\frac{1}{50}$; and pavement, $\frac{1}{66}$ of the gross load.

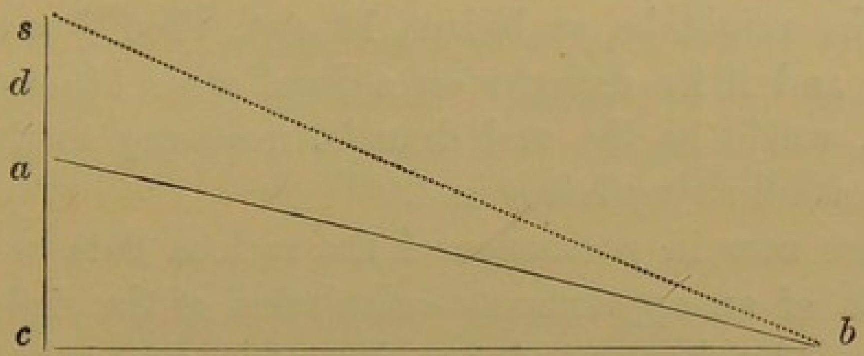
Bevan made some experiments with a light four-wheeled cart, weighing with its load 1,000 lbs., which was drawn over different sorts of road:

	Force of traction necessary to move carriage.
Turnpike road, hard and dry	... $30\frac{1}{2}$ lbs.
" dirty... ...	... 39 "
Hard compact loam	... 53 "
Ordinary road	... 106 "
Newly gravelled road ...	... 143 "
Loose sandy road	... 204 "

The following table, by Hurst, shows the effect of slope on traction. Assuming that 1 ton can be drawn with a unit of labour at the rate of 3 miles an hour:

When the slope is	1 in	80,	take	1 mile as	$1\frac{1}{4}$
"	"	40	"	"	$1\frac{1}{2}$
"	"	27	"	"	2
"	"	16·5	"	"	$2\frac{1}{4}$
"	"	13·5	"	"	$2\frac{1}{2}$
"	"	11·7	"	"	$2\frac{3}{4}$
"	"	10	"	"	3

Templeton, in his 'Millwright and Engineer's Companion,' gives the following practical illustration of a method of calculating the force required to pull a carriage.



'When *a b* lies flat on *c b*, a carriage placed upon *a b* will be at rest; but by raising *a b* leisurely, the carriage will, at a certain height, set off by itself, and run down the plane. Then are we in possession of a triangle that solves what force is necessary to drag any load of any kind on a road or level ground; for the hypothenuse *a b* represents the weight of the carriage, and the perpendicular *a c* what portion of that weight is necessary to draw the carriage on level ground; thus:

Suppose the carriage	12 cwt.
The line *a b*	24 feet.
Height *c a*	3 „

'The declivity, then, is as 3 to 24, or $\frac{1}{8}$. In this case it will be found that $\frac{1}{8}$ of the weight of the carriage would drag it on such a road or level ground, namely, $1\frac{1}{2}$ cwt.; but if the road were very deep and rough, it might require to be raised perhaps as high as *d* or *s*, before the carriage would set off. Now, if *c s* were half the length of *s b*, then it would require one-half the weight of the carriage to drag it on level ground, or, in the above case, 6 cwt.

'This rule is universal, and has been proved by carriages at large, on roads of every description.

'In estimating the draught up hill, the draught on the level must be added to it. Suppose the hill rises 1 foot in 4, then $\frac{1}{4}$ part of the weight must be added to the draught on level ground.

'If the weight be, as before, 12 cwt., then $\frac{1}{4}$ would be 3 cwt.; and if its draught on a level were $1\frac{1}{2}$ cwt., then $4\frac{1}{2}$ cwt. would be the real draught necessary to draw 12 cwt. up a hill rising 1 foot in 4.'

We are now in possession of the various data necessary to admit of an approximate calculation of the daily work performed by horses. Approximate it can only be, as can be readily appreciated by what we have previously said in describing the effect of velocity, resistance, friction, the nature of the ground worked over, and the exact duration and velocity at which the work is performed; if all this information is obtainable, the calculations would be exact; as it is, we can only endeavour to get as near the truth as possible.

The formula for calculating into foot-tons or foot-pounds the daily work of a horse is as follows:

$$\frac{(W + W^1) \times D}{F \times 2240};$$

where W is the weight of the horse.
W^1 the weight carried.
D the distance travelled in feet.
F the co-efficient of resistance.
2240 the number of pounds in a ton.

The result is the number of tons raised 1 foot. The following example will give an idea of how the calculations are made. A horse weighing 800 lbs., and carrying a man and accoutrements weighing 280 lbs., makes a march of 15 miles at 5 miles per hour; what is the work equal to?

$$\frac{800 + 280 \times 79200}{14 \times 2240} = 2705{\cdot}4 \text{ foot-tons, or } 6060096 \text{ foot-pounds.}$$

When we come to estimate the force expended by horses in draught, another element comes into the calculation, viz., the force of traction expended. Dr. de Chaumont informs me that the formula should be :

$$\frac{(W+W^1)\times D}{F\times 2240}+\frac{T\times D}{2240}$$

The first part of the formula remains as before ; in the second half :

T = the force of traction.
D = the distance travelled in feet.
2240 = the number of pounds in a ton.

The following will give an example of this method of calculating : What is the work performed by a harness-horse weighing with harness 1,000 lbs., travelling a distance of 21 miles at 7 miles per hour, and dragging a carriage weighing 6 cwt. ?

Supposing the road to be a good one, the draught of 6 cwt. would be about 16 lbs. :

$$\frac{1000\times 110880}{11\times 2240}+\frac{16\times 110880}{2240}=5157 \text{ foot-tons.}$$

By using the following table, which was kindly calculated for me by Professor de Chaumont, all trouble is saved in estimating the work done by saddle-horses, as for each velocity the foot-tons of work per mile are stated. It is calculated for a horse weighing 1,000 lbs. ; where a greater or less weight than this is required a simple rule of three will give the answer, or multiply the number of foot-tons by $\frac{W}{1000}$, where W is the new weight.

WORK DONE BY A HORSE PER MILE AT DIFFERENT VELOCITIES. WEIGHT OF HORSE, 1,000 POUNDS.

Velocity in miles per hour.	Work done in foot-tons per mile.	Velocity in miles per hour.	Work done in foot-tons per mile.
1	62	21	590
2	88	22	616
3	115	23	643
4	141	24	669
5	167	25	695
6	194	26	722
7	220	27	748
8	247	28	775
9	273	29	801
10	299	30	827
11	326	31	854
12	352	32	880
13	379	33	907
14	405	34	933
15	431	35	959
16	458	36	986
17	484	37	1012
18	511	38	1039
19	537	39	1065
20	563	40	1091

The length of time during which work should be enforced has been stated at from six to eight hours daily. It is evident that depending on the velocity with which the work is performed must the duration of labour be based; our best method is therefore to consider what should be the number of foot-tons of work performed per diem. From a careful consideration of facts, I should fix 3,000 foot-tons daily as the normal work of a horse; 4,000 foot-tons per diem would be a hard day's work, and one which could not be performed continuously; and 5,000 foot-tons could only be performed twice a week.

I have made the following calculations of work performed; the results are, of course, only approximate:

	Foot-tons.
A sharp 'run' of 6 miles, with 10 miles home	5500
Flying Childers, 3 miles 6 furlongs 93 yards, in 6 minutes 41 seconds (Newmarket)	2400

	Foot-tons.
Firetail, 1 mile in 1 minute 40 seconds (in the year 1772) ...	800
Quibbler, 23 miles on the flat in 57 minutes 10 seconds (Newmarket, 1786)	13200
Trotting 16 miles in 2 hours	4200
Cantering 11 miles in 1 hour	3900
Walking 4 miles in 1 hour	609
„ 15 „ 5 hours	1700
„ 24 „ 8 „	2800
„ 12 „ 4 „ (Artillery horse, working in the wheel)	3000
'Horse power' employed for 8 hours	7000
Black Bess, 196 miles in 11 hours (?)	101000
American trotter, 1 mile in 2 minutes 10 seconds	750

Assuming, for the sake of comparison, that the total load carried or drawn, including the weight of the animal, is equal to 1,000 lbs., we would have about 3,000 foot-tons of work performed by either of the following :

Walking at	3 miles per hour	for	8·7	hours.
„ „	4 „	„	5·3	„
„ „	5 „	„	3·7	„
Trotting „	8 „	„	1·5	„
Cantering at	11 „	„	1	„

Some records of most extraordinary journeys made by horses have been noted from time to time. 'Captain Horne, of the Madras Horse Artillery, rode a little Arab named "Jumping Jenny," 100 miles a day for eight days ! This was in the hot season, and, although the gallant officer died soon after of dysentery, caused by exposure to the heat and showers while performing this remarkable feat, the horse was none the worse after the ride. About the same time, Mr. Bacon, of the Bombay Civil Service, rode one camel 800 miles in eight days, from Bombay to Allyghur. Lord Exmouth, then the Hon. C. Pellew, of the Bengal Civil Service, rode an English horse named "Cheroot Box" 100 miles in twenty-four hours easily, and soon after Lieutenant Lowry, of the 21st Bengal N.I., rode a little mare 110 miles in eleven hours. At the Cape of Good Hope, in 1858, Captain, then Lieutenant and Adjutant, Ashe, of the 85th Light Infantry, more than once rode a little gray horse, "Mons," 100 miles in one day, danced at a ball in the evening, and rode the same horse back 100 miles on the following day.'* Lord Lake marched 22 miles a day for twenty-one days and defeated Holkar's Horse at Futtyghur. In 1829 'Tom Thumb,' an American galloway, trotted 100 miles, in harness, in ten and a half successive hours. 'Rattler,' an American horse, in 1832 trotted 34 miles in 2 hours 18 minutes 56 seconds, carrying eleven stone. The poor animal died two days after, but his opponent, a 14-hand pony, recovered from the effects of this severe journey.

The greatest weight a horse can carry has not, so far as I am aware, been fixed by direct experiment. In the 'Ency. Architect.' it is stated that horses have been known to carry 650 to 700 lbs. for seven or eight miles without resting; and, according to Desaguliers ('Expt. Philos.,' vol. i.), a horse at Stourbridge carried 1,232 lbs. of iron for eight miles.

From some experiments made in Russia, and recorded in the *Militär Wochenblatt*, it was determined that horses in training could do from 56 to 62 miles per day of twenty-four hours. The weight of the men is not stated, but they were cavalry soldiers probably no lighter than our own. It is evident that this rate could not be kept up for more than three or four days in succession.

Saddlery.

Great as the difference is between a civil and a military saddle, yet the principles of fitting, and the injuries resulting from saddles are practically identical. It is not in civil

* *The Broad Arrow*, October 28, 1882.

life where the disastrous results arising from sore backs is felt. So important, however, is this in military service, that what we have to say of the saddle from the hygienist's point of view must mainly be directed to the military saddle, and the principles contained in these observations can readily be applied to any saddle used in civil life.

When we seriously consider the terrible consequences entailed through cavalry on service being dismounted* or placed *hors de combat* owing to their horses being sick, consequences which are apt to be lightly passed over, but on which may hang the fate of a nation and the lives of many human beings, we may be pardoned for inquiring how one fruitful cause of the above gets brought about, and the means by which the evil can be remedied. Let us imagine for a moment a squadron of cavalry, the eyes and ears of an army, lying idle at their pickets on account of sore backs. The readers of De Brack may call to mind that he says 'a wounded horse that *can* still serve *must* still serve;' and he gives as an example the horse his friend Guindet rode at the cavalry fight at Saalfield, which, in spite of having its back stripped of skin, carried the man who slew the Prince of Prussia. But although the General mentions this case, he is none the less alive to the seriousness of this accident, as his work proves.

I have no hesitation whatever in stating that the cause of sore backs is due to ignorance, which ignorance induces carelessness. Ignorance, inasmuch as it is impossible for

* 'Cavalry, once dismounted, is no longer formidable. Napoleon had in Moscow ten thousand dismounted cavalry. They were formed into companies, battalions and regiments, and armed like infantry ; but after the first three days' retreat from the Kremlin, this fine organization was destroyed. The men dispersed to the right and left of the road, in search of food, and either fell into the hands of the Cossacks, or were killed by the inhabitants.'—'Cavalry in War,' by Colonel Beamish.

anyone who has not received instruction in the subject to fit with success a saddle to a horse's back. Carelessness, in as far as it is difficult to make people believe that rubs on the back are due to a defect in the fitting of the saddle, or that wounds, no matter how slight, will never get well until the cause of irritation is removed. Ignorance, in not regarding the back of a horse as being composed of living and sensitive structures; carelessness, in subjecting it often for hours together to the continuous pressure of an unyielding machine and the weight of a tired dragoon.

So important to the army is the question of saddles and prevention of sore backs, that all mounted officers are specially instructed in the construction and fitting of saddles, and how to prevent and deal with the injuries the saddle produces. Horses on the march, or on service, require their saddles looking to *every day* if the backs are to be kept in serviceable order. One Saddler Sergeant, even if possessed of the necessary knowledge, cannot do the work, for a troop or squadron may be some distance from headquarters, and it is consequently to troop and squadron officers that the duty of alteration and fitting falls.

Before entering into a consideration of the fitting of the saddle, we must thoroughly understand the structures on which it rests. We therefore propose to give a brief outline of the anatomical formation of the back, for until this is clearly comprehended, the work of fitting must be entirely empirical and hap-hazard.*

The back has for its foundation a chain of bones consisting of eighteen pieces; each piece connected with two ribs, one on either side. Growing from the upper part of each piece is a bony process. These processes are of the

* I need hardly say that this information is only inserted for the non-professional reader.

greatest practical importance to us. They are of different sizes, for we notice that they increase greatly in length from the 1st vertebra to the 4th or 5th (this forms the summit of the withers), and from this to the 13th bone they rapidly decrease in size; from the 13th to the 18th they are almost uniform: we likewise notice that they do not all assume the same direction, for from the 1st to the 15th they incline backwards; the 16th is upright,

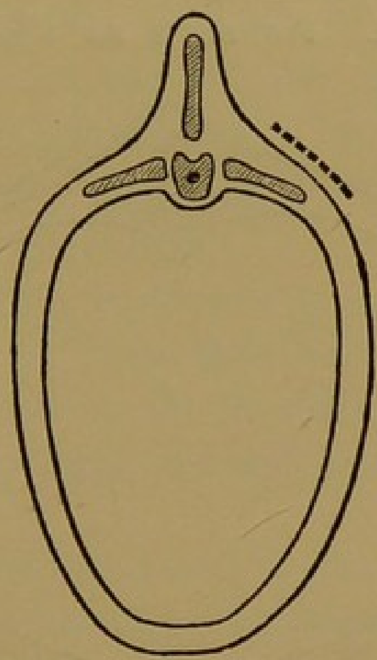


Fig. 77.—Section through the 8th Bone of the Back. The dotted line shows the position and direction of the side-board.

the 17th and 18th incline forwards. The bones of the back are arranged somewhat in the shape of an arch, and the 16th bone is the keystone, if we may so term it.*

The case formed by the ribs for the accommodation of the heart and lungs is very narrow in front and increases in width as we go backwards. The anterior ribs are consequently nearly straight, whilst the posterior ones are considerably arched. Compare the two Figs. 77 and 78;

* The 16th vertebra of the back is not invariably upright. Sometimes it is the 14th, at others the 15th bone.

they show sections through the body, one at the 8th bone of the back and the other at the 17th. Their difference in shape is too striking to need comment. The ribs that concern us (viz., from 8th to 18th) present at their upper part, close to where they unite with the backbone, a flat surface of variable width. For instance, the 8th and 9th ribs have a flat upper surface of about 2 inches in extent; the 10th, 11th, 12th, 13th and 14th one of about $3\frac{1}{2}$ inches; the 15th, 16th, 17th and 18th one of about 5 inches in length. As soon as these level places are

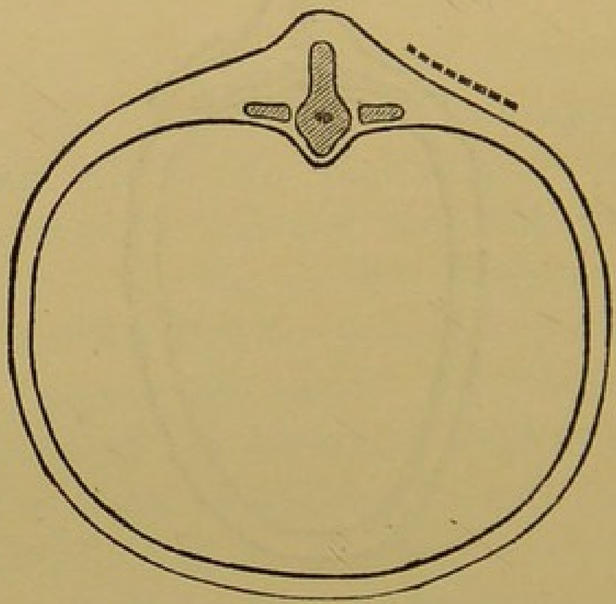


Fig. 78.—Section through the 17th Bone of the Back. The dotted line shows the position and direction of the side-board.

formed, the rib curves downwards to form the side of the chest. On the width of these level surfaces depends the width of the back, and on these should rest indirectly the side-boards of the saddle. But if we depended on the flat upper surface of the 8th and 9th ribs (the former, we may add, is about half a hand's breadth behind the play of the shoulder) to afford sufficient bearing for the front arch of the saddle, it would not be enough; for, as we have just shown, this surface is only 2 inches long; here we take advantage of these ribs being strong and firmly fixed below into the breastbone, to impose weight on their sides below their flat upper surface; the dotted line in Fig. 77 shows this. The direction of the side-board on the back is here at an angle of about 45°, and not only the upper surface but sides of the ribs participate in bearing weight, and from their strength and support they are well calculated to endure it. Compare this with Fig. 78, which shows a section though the 17th bone of the back; the dotted line represents again the side-board, but it rests wholly on the upper surface of the ribs, the sides of which are unable to bear compression; for the ribs are shorter, weaker, and receive no support from below. In true ribs, then, the weight must be transmitted from above and from the sides; in the false, only from above.

Viewed from above, we can see at a glance that the back is much narrower in front than behind. In the skeleton it measures from rib to rib through the 8th bone of the back about 7 inches, and through the 16th bone 13 or 14 inches in width.

The bladebone of the horse is flat and triangular, the apex being inferior, and placed opposite the 1st rib; the bone lies on the outside of the ribs, and takes the usual oblique direction downwards and forwards which we know shoulders to occupy. As we just inferred, the base of this bone is uppermost, and the posterior angle of the base is opposite the 7th rib.

The body is slung, as it were, between the fore-legs; at every movement of it the angle formed between the scapula and humerus is either made larger or smaller, and the changes in position which the upper half of this bone undergoes are as follow:

(1) As the leg is extended forward the anterior angle of the scapula is raised upwards and backwards, the posterior one depressed forwards and downwards.

(2) The knee being fixed, and the foot planted firmly on the ground, the whole body gradually passes over the limb, which from inclining downward and forward when the foot first made contact with the ground, gradually assumes the erect position; during this time the posterior angle is ascending, and after the body has passed its centre of gravity, and the limb assumes the position of being downwards and backwards, this ascent of the posterior angle continues until the propulsion is given by the limb preparatory to being advanced, when the whole of the posterior angle with its enveloping muscle and attached cartilage turns outwards, the bone as it were being pulled outwards at this part from off the ribs. This latter movement is most peculiar, and is caused, I believe, by the serratus magnus muscle. No description or plate will convey clearly the movements of the scapula, but they may readily be observed in the living subject.

I think we have said sufficient to prove that during locomotion the bladebone has certain movements to perform (the centre of motion in the anterior extremity is the scapula); that any interference with these movements must affect progression, owing to the angles formed by the bones being unable to open and close to the necessary degree; that this must affect the safety of both horse and rider, to say nothing of the pain the pressure must cause and the great waste of muscular force to overcome the obstruction: if these important points be thoroughly understood, one of the great secrets in fitting a military saddle is learned. We spoke just now of the fore-limb propelling the body. It was generally accepted, I believe, that the fore-limb was a supporter of weight and the hind-limb a propeller; but we now know, through the aid of photography, that the fore-limb is also a propeller, and that its propelling power is 'capable of deflecting the centre of gravity of the whole body of the horse going with a velocity of twenty miles an hour, 4 inches in a distance of 10 feet.'* Imagine the resistance offered by a badly fitting saddle to this important function, and the amount of muscular energy required to overcome this obstruction to the centre of motion.

While speaking of the physiology of the fore-limbs, it may not be out of place to notice the difference in the weight supported by the fore and hind extremities. The following experiment is recorded by Colin in his *Traité de Physiol. Comp.*:

A horse weighing 1,036 lbs. was placed with only his fore-legs on a weighing-machine, and in this position weighed 617¼ lbs.; he was next weighed with his hind-quarters on, and 423¼ lbs. was registered. Thus the fore extremity supported 194 lbs. more weight than did the hind, a weight equivalent to more than one-fifth of the entire body. A man weighing 165¼ lbs. was now placed on the animal's back, and the fore-legs being on the scale, 727½ lbs. was recorded the hind extremities were served in a similar manner, and 474 lbs. was noted; the excess of weight supported by the fore-limbs was consequently 253½ lbs. The same horse was again placed with his fore-feet on the scale, but the horseman was made to lean forwards, and the following were the weights: fore-limbs, 747¼ lbs.; hind, 458½ lbs.—difference in weight, 288¾ lbs. The man was now caused to lean backwards; the fore-limb now weighed 714¼ lbs., the hind 491½ lbs., the difference between them being 222¾ lbs. Thus in the vertical position the fore-limbs carry rather more than two-thirds of the rider's weight; in the leaning-forward position four-fifths, and in leaning backwards considerably three-fifths.

Or, to state the same thing in another way: When the man is sitting upright 66 per cent. of his weight is carried

* 'The Horse in Motion.'

by the fore-limbs; when he is leaning forwards 78 per cent. of his weight is imposed on these legs; and when leaning backwards 58 per cent. of his weight is carried by the fore-limbs.

I have repeated Colin's experiments and found them accurate. The lessons which they teach us are obvious. Keep the weight well back, let nothing touch the shoulder-blades; carry nothing in front of the saddle; get the rider further back, if possible, sitting over the 14th vertebra, and so save the fore-legs as far as possible from the unequal amount of lameness which at present falls to their share.

From our knowledge of the anatomy and physiology of the part, we are led, then, to the following conclusions:

1st. That the bladebone and its attached piece of cartilage must in nowise be interfered with (much less pressed upon), or its function is immediately seriously impaired; it must have free and uncontrolled play.

2nd. That the shape of the ribs proves to us where weight can be best supported and carried. The large true rib, with its small upper surface, will stand pressure in a downward and inward direction; the small false one, with its large upper surface, can only bear it in a downward direction.

3rd. The bony processes growing from the upper surface of the spine are unfit to bear weight.

4th. That any part of the back behind the last rib is unsuited to bear weight, for here we find the large muscles which propel the hind-limbs, whose function would become considerably impaired by pressure; here also there is no elastic support from below. The kidneys are also placed under this portion of the spine, and there is a peculiar rolling action—a side-to-side movement in the part, which can be readily felt by placing the hand over the loins when the horse is walking.

It is necessary to remember that no two horses' backs are alike in shape, any more than men's feet are, and although saddles are made according to regulation, horses' backs are not. Some are high in the withers, owing to excessive length of the bony processes we before described, others correspondingly low; some are short and broad, others long and thin; some with backs like a billiard-table, others razor-shaped; some with the muscles which run along the back well developed, others just as hollow at that part; some running high behind, others straight; some with a dip like a valley, and others with an arch like a bow. Any form or any extreme may be met with, and each requires to be dealt with differently. I think, perhaps, that the two most common conditions are the high and hollow withers and the low and thick ones. If ever I were in doubt about rejecting a horse for the service, and that horse happened to possess high hollow withers, my doubts would be at once settled, for without exception such shaped backs are the most difficult to fit and keep in order, and they require the most constant watching. The extremely low wither is objectionable from its thickness and liability to get pinched; the opposite condition to this occurs to the high wither, for this gets wounded on its upper surface.

With our knowledge of the theoretical structure of the back, we can now see how important it is that saddles should fit; this they never will do unless we carefully and systematically set to work to study the conformation of the animal we are about to fit, and obtain with exactitude the size of the different parts of the back on which the saddle rests. For the purpose of ascertaining this, I have used an instrument devised by Major Wilkinson, late Riding Master, Royal Artillery.

The simplest description is, that it is a hinged saddle which can be enlarged or made smaller at pleasure, and the direction of the side boards adjusted as required. I have arranged it so that it can be made to record the measurements on a scale. Such a measuring saddle should be found in every regiment. We have used, however, a very simple contrivance, which for measuring acts well; it is simply two pieces of wood fastened together like the letter V; they open and close at pleasure, and the size is obtained by placing our wooden compasses on a foot-rule. These could be made like a large pair of calipers, with a registering scale, and as such would certainly be more quickly worked.

Measurement brings out most strikingly how horses differ in the size of their backs. Before me I have the measurements of the front arch for seventy-two horses. These were selected promiscuously, twelve being taken out of each troop. The measurements are interesting. *The greatest number of horses whose backs were the same size was four*, and there were thirty-four horses whose measurement corresponded with none of the others; *each of these thirty-four had a different-sized back.* There are only three sizes of saddle for the whole service; who can wonder at injuries!

The Cavalry regulations say: 'The saddle should be placed in the middle of the horse's back, about the breadth of the hand behind the play of the shoulder.'

No truer paragraph than this was ever written in the regulations, yet it is a perfect impossibility with the present, or even any past saddle, to carry it out: to attempt to do so would be to produce a facsimile of Nolan's picture, 'The military seat as it is,' wherein a hussar is shown mounted, sitting on his horse's loins, and the girth placed midway between the elbow and stifle.

The regulation saddle cannot be fitted properly, owing to the length of the side-boards; and even if it were placed in the position ordered it would leave the man sitting over his horse's kidneys, and very little movement would suffice to either push the saddle forwards, or cause it to turn under the belly. It is the *front arch* of the saddle which should be from half to one hand's breadth behind the play of the shoulder ; but then there must be no side-board in front of this arch, or it will produce exactly what is required to be prevented, viz., pressure on the bladebones.

A military saddle should have very little, if any, more bearing on the back than a roomy hunting saddle has, and this is precisely what we require. All our saddles are too long (not in the seat but in the side boards), and hamper the movements of the horse by the way they have to be adjusted.

What more ridiculous sight can be witnessed than a troop horse with a saddle extending from his neck to his loins ? and yet positively this is no exaggeration, especially with a short-backed animal. Can we wonder at horses soon getting tired with heavy weights up, when they have an iron machine strapped on to the back, pressing on their shoulder-blades like a vice, preventing the free movement of the fore-limbs, and pushed forward at every movement of the hind-quarters, owing to the absurd length and direction the rear fans are made to assume ? Can we, while our horses are thus maltreated, wonder at broken knees, injuries to men, incurable lamenesses being so frequent, and that every day we have horses reported 'as unable to keep up in the ranks.' Too frequently the troop horse's movements are confined in a veritable strait-jacket. Put a plain saddle on the horse that is always stumbling and cannot go the pace, and see what effect that will have before he becomes a chronic stumbler from inability to flex his knees through repeated injuries, and is condemned to be cast 'as unsafe to ride.'

The only thing to do in order to remove the bladebones from pressure, is to have an arrangement for the wallets to rest on independent of the side-boards ; these latter should be cut off just at the front arch, so that the saddle can bed itself behind the shoulder; as some arrangement is necessary for the wallets, I devised what may be termed a 'wallet-rest,' which is a piece of bent iron attached to the saddle standing well away from the body, on to which the wallets can be strapped (see Fig. 79). In this way, with short side-bars, it is possible to carry wallets without inflicting any pressure on the shoulder-blades.

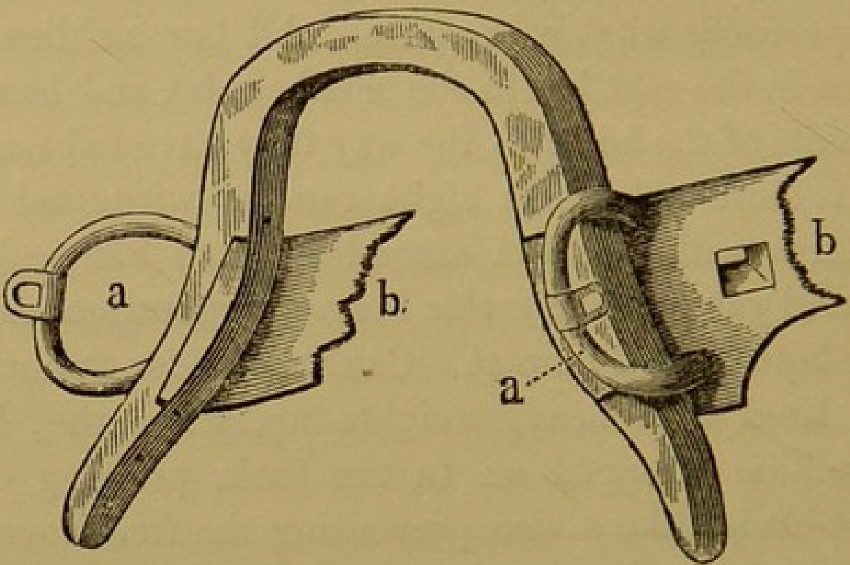


Fig. 79.—Front arch of a Wooden Saddle, showing the Wallet-rests, a a, in position; a movable D is placed on them to take the Wallet-straps; b b are the Side-boards cut off in front flush with the arch. The mortise for the stirrup-leather is in the best place, and the shape precludes the possibility of the buckle damaging the back.

My views on what a cavalry saddle should be are as follow: The tree should be made of beech strengthened with iron; or, if possible, the Austrian automatic tree should be adopted, which, by an ingenious combination of hinges in the side-bars, and between the latter and the arches, may be made to fit any size or shape of back, lying evenly over the whole surface, and producing a perfect distribution of weight. The pommel cannot well be cut too low, nor the cantle too high; the former allows the man to keep his hands well down, the latter retains the baggage well above the spine. Besides keeping everything well off the spine, the cantle assists in mounting hurriedly, and the effort to clear the cantle with the leg must also clear the butt of the carbine, which is far from being the case at present.

The side-boards should be wider, more curved upwards posteriorly, and cut off in front so as to lie well behind the bladebone: they should bear on the back from this part as far as the last rib, but from here they should be raised clear of the loins. An iron wallet-rest with a D in it should be secured to the outside of the side-board and front arch, standing well out from the shoulder-blade and its enveloping mass of muscle, and to these the wallets should be secured. Thus the shoulder-blades have free and uncontrolled movement, so necessary to the safety of both horse and rider. The boards should be made wider so as to diffuse the weight over a larger surface; they ought also to be made stronger. The mortise for the stirrup-leather should be cut in the lower and not the upper edge of the board, so that the buckle can never touch the back. The seat to be riveted to the arches, and not stitched; the flaps to be covered with some material, such as coarse leather, to give a grip, and to be provided with knee-rollers. The girths to be of webbing. The pannels should buckle on to the front arch, and they should have no stuffing put in them over the loins. Under the saddle a numnah, with two straps, one to loop on to the cantle, the other on the pommel, so that there is a free current of air along the spine. No breastplate or crupper, but an overgirth, whose chief office is to be used as a roller to keep the blanket on when the horse is at his picket. And for service, a blanket for the purpose of keeping the horse warm, but, above all, for the purpose of being placed under the saddle to make it fit, and to make it soft.

In **Fitting a Saddle** the tree should be placed on the bare back, and the fitting of front and rear arch and side-boards should first be observed. The **front arch** should rest evenly in the hollow behind the bladebone at half a hand's breadth from it; it must be sufficiently wide to admit the numnah without pinching the withers, around which the breadth of two fingers should be easily admitted; the points of the arch should lightly touch the side (beware of pinching), and not stand out at nearly right angles, doing harm by wearing a hole in the flaps. They are here to give the saddle a hold on the back and prevent it turning.

Side-boards.—These to fit must take the shape of the back they are intended for; if not, undue pressure will be exercised on one or more parts. If too curved the bearing will be all on the centre, and the saddle will work up and down and from side to side, and injury result; if too straight only the extremities of the boards receive the weight, and the places where these rest will suffer.

The side-boards should lie evenly everywhere on that portion of the back situated between half a hand's breadth behind the play of the shoulder and the last rib; that portion situated anterior to the front arch on which the wallets rest *should touch nowhere*, and stand well out;* the rear fans, the portion on which the valise rests, should be well raised and *touch the loins nowhere.* The secret of fitting a saddle lies in the side-bars. These must conform in shape to the part on which they rest, so that the rider's weight is evenly distributed over the whole surface.

The Rear Arch offers nothing of importance; it must be high, and well clear of the spine.

The tree should next be fitted on the numnah, and then on numnah and pannels; and we should notice that it

* I am describing the regulation saddle; my own arrangement does away with this precaution.

is well clear of both the sides and top of the withers, that it lies evenly on the back from fork to fork without rocking or moving up and down. A man should now be placed in the saddle, and the above points again examined; in addition, the place where the wallets and valise rest should receive our particular attention. The hand should be placed beneath the numnah under the wallets and forced back to the play of the shoulder. The leg on this side should now be lifted by an assistant and fully extended; if during this operation the fingers are unduly squeezed, it is certain that the action of the bladebone is being seriously interfered with. The only remedy in default of the 'wallet-rest' is to remove the stuffing completely at this part, and stitch the pannel across to keep it empty. The same attention should be paid to the 'rear fans'; the hand should easily be able to pass under them within 2 inches of where the rear arch joins the side-board. If this cannot be done, we may be sure the loins are receiving pressure which they are not intended to bear. The remedy is to remove the stuffing from the pannels at this part, and stitch them across to keep them empty.

The Pannels.—The stuffing of these must depend entirely on the fit of the side-boards; theoretically it should not, but saddle-trees cannot always be altered to fit. With the iron saddle of 1875, which opened at a weight of 280 lbs., it was absolutely necessary to stuff the pannels to make the saddle fit. The rule is, no more stuffing should be used than is absolutely necessary to prevent the back from being bruised, it not being put there to make the saddle fit. Whatever amount of stuffing is placed in a pannel it should always be flat, not like a 'bolster,' allowing the saddle to roll about in all directions.

There are minor points to be attended to if our fitting is to be complete, such as the numnah being well up in the fork, the absence of strain on its strap, the position of the buckles under the seat, the stirrup-leather buckles, the girth buckles, etc.; but several of the defects attendant on fitting we will allude to, and suggest remedies for, when speaking of injuries to the back.

There are many complications connected with saddlery which it is our duty now to notice.

Shifting of the Saddle.—In nearly every case this occurs forwards, the saddle getting on to the horse's neck. There are two chief causes of this: 1. Badly-fitting front arch and side-boards, the former getting no grip behind the shoulder, and the latter resting on the bladebones. 2. Malformations—shallow chests and excessively arched ribs; the first gives the girth no grip, and the second drives the saddle forward. Hollow backs—the saddle, bearing on the loins, is often driven forward when the horse is at a canter or gallop, owing to the loin-pressure. To point out the cause is to remedy the defect in some of these cases, but those due to malformation require special treatment. A 'big belly' may be removed by attention to feeding, but a shallow chest cannot be deepened, nor arched ribs made flatter, and with age a hollow back increases; still, with a simple contrivance a saddle may be made to keep in its place even under these adverse conditions.

Some time ago I was induced to make experiments as to what would keep a saddle in its place, as there was a horse in my regiment which possessed such tremendously arched bulging ribs, and big belly, that his saddle was on the top of his neck before he had been out ten minutes. The consequence of this was that in addition to interfering with his movements, and the discomfort and inconvenience to the man riding on his horse's neck, the animal girth-galled so badly that it was always in a state of inefficiency. With this horse I found the following contrivance most effectual:

The saddle being on the back in its proper place and the girths fairly tight, I took the overgirth and passed it under the seat of the saddle in front of the rear arch, and buckled it under the belly about a foot or so behind the girth; from this to the girth was a strap, and by means of it the girth was strapped back. The saddle will now never shift forward, for the overgirth being drawn against the ribs entirely prevents this. The horse I am speaking of wore this contrivance for months, at the field, riding-school, and on a long march; and he never afterwards galled, nor did the saddle shift its place. It is not very unsightly, and in the ranks is of course not seen; it does not interfere with breathing; it is a specific for girth-galls when it is necessary to work a horse, for an animal can be ridden with his sides raw if the connecting strap be drawn sufficiently tight to keep the girth back off the injured place. If applied as I have directed I have never known this contrivance fail; but I may remark that I have met with a few horses which refused to allow a strap to be passed around their bellies.

Girth-galling is a common complaint amongst cavalry horses. Young horses on going to school invariably gall, either from being out of condition or from defective saddle-fitting. The saddle shifting forward, the girth will gall the back of the elbow and sides; shallow chests, big bellies, girths hard from sweat, careless saddling, are all causes more or less common.

The only remedy is to remove the cause; in many cases a change of girth, such as split, Cape, or Australian, or the ordinary service-girth made round, may be found of advantage; in inveterate girth-galling from malformation I would recommend my plan of strapping the girth back.

Carbine-Bucket Galls are caused through the friction of the bucket against the skin, or through it banging up and down owing to being improperly fastened to the girth.

The actual injury is caused by a stud found on the inner side of the bucket. The only remedy is to leave it off until the part heals.

Sword Galls are very common with horses in bad working condition; the portion of the sword which causes the injury is the ring on the scabbard to which the 'long carriage' is fastened. The remedy is to hook the sword up.

Shoe-Case Galls, if the near-side shoe-case, are produced by the strap being too long, allowing the case with its two shoes to beat up and down, or rub to and fro, until the side is raw; if the off-side case, by the strap being too long, and the contents of the case being pressed into the side by the breech of the carbine. The remedy is to strap the cases close up to the rear arch, and so prevent all movement in them.

Crupper Galls are caused through a tight crupper, either from it being put on so, or from the saddle slipping forward. When galling occurs the crupper is best left off.

Breastplate Galls are rather rare; they are usually the result of carelessness in having the strap which fixes on to the girth too short. The galling occurs just on the inside of one arm. The breastplate should be left off until the part is cured.

Sore Backs may, for convenience of description, be divided into two classes—first, injuries to the withers; second, injuries affecting the spine and back proper.

Injuries to the Withers may occur to their top or sides; the former is produced by the saddle resting on or touching the part—a common condition in the iron saddle, the front arch of which *opened some inches*—or by the numnah resting on the withers, either through bad saddling or the strap being too long. Injuries to the sides of the withers occur from the front arch being too narrow; the withers get pinched at their root, particularly in horses which are formed thick and fleshy at this part: the buckles on the underneath part of the seat of the iron saddle will, when the seat sinks through weight, or the stitching of the straps gives way, touch and press on the withers. General Fitz-wygram points out that injuries to the withers generally occur on the *near* side, attributable, he says, to the extra weight of the carbine on the off-side causing the saddle to 'heel over.'

The prevention of this class of injury is most simple; if the front arch is narrow (it should always freely admit the hand between it and the sides and top of the withers *when the man is in the saddle*), change it for a wider; and if this is impracticable, let the horse be saddled without the numnah: it is wonderful the difference which the thickness of a numnah will make. Should the front arch be too wide, and the top of the withers touched, change the saddle for a narrower one; or, as a makeshift, put more stuffing in the pannels, and so raise it. This latter expediency should only be a makeshift; for, of course, the ultimate effect of putting more stuffing in an expanding arch is to make it wider. The hand should easily find admittance between the withers and the numnah; but in some cases where the strap has stretched, or stitching given way, or the horse been badly saddled, it is with difficulty that the finger can be admitted. The remedy is, of course, obvious. In inspecting backs, if it be noticed that the hair on the withers stands erect, it may be foretold for a certainty that this is caused by the numnah chafing the part. Lastly, should the buckles under the seat be the cause of injury, the seat should be drawn up tighter; or should the buckle be in the top hole, shorten the straps. This is the most difficult cause to detect, but it may be known by the following characters: the position of the injury on the withers; the edge of the buckle being polished by friction against the numnah; the mark left on the latter by the friction of the buckle.

Injuries to the Back may be produced by any of the following causes, singly or combined :

a. Badly fitting side-boards and improperly stuffed pannels ; or the latter being hard, lumpy, and unyielding.

b. Through the pannels resting on the loins instead of being clear of this part. The rolling motion of the horse's loins produces friction against the pannel ; first the hair is removed, then the skin chafed, and ultimately a wound results.

c. From the seat on the iron saddle giving to the weight of the man, and resting on or rubbing the spine ; and this evil is increased by a tight overgirth.

d. From the valise not being strapped up high enough in its centre, and so resting on the back ; and the damage is still greater if the buckle of the crupper is under it.

e. Numnahs hard from sweat, or placed on the back with mud and dirt on, as in saddling in the dark ; or from being placed too far back over the loins (causing the hair to stand erect), are all sources of injury.

f. Loss of flesh acts in many ways :

Through bringing the saddle nearer to the bony structures of the back and sides.

Bringing the piece of webbing which runs across the saddle from side-board to side-board down on the spine.

Through the buckles on the stirrup-leathers pressing into the back, and those on the girth, and the keepers on the girth-straps, injuring the sides.

Starvation and hard work produce what may be termed, for want of a better word, a loss of vitality in the skin, and render it most intolerant of pressure, which when exercised produces rapid destruction of the part.

All these are injuries generally dependent on loss of condition.

g. Men rolling in their saddles, either from careless riding or fatigue.

h. Many hours under saddle, with no relief from weight.

i. Saddles being removed while the back is wet and hot, predisposing the part to injury by producing tenderness of the skin, lumps, and swelling.

j. From the straps of the shoe-cases and carbine-bucket being placed *under* the side-board, forming a lump which, when pannels are thin and flat, is sure to do damage.

Indicating, as we have, all these causes in detail, will, in most cases, point out what is required to remedy the evil; but there are some few things we may notice. Causes *a*, *b*, and *c* may be corrected from what we have previously written: *d* suggests itself; the crupper should also be left off: *e* in many cases cannot be prevented; numnahs will not dry in wet weather, and saddle-racks are not found on service or on the march; but too much care cannot be exercised to take every advantage to dry numnahs, and, when dry, to beat them soft with a light stick: *f* is our most serious foe, and is only averted by giving sufficient food, and by having the necessary means at hand to *restore artificially in the shape of the blanket what the animal has lost naturally in flesh;* the piece of webbing spoken of should be cut out—it is of no use where there are no saddle-trees; the buckles on the stirrup-leathers should not be drawn up to the mortise; those on the girth may have a piece of numnah, or a rubber placed under them, or better still a shorter girth used; the keepers or the girth-straps may with advantage be reversed, and the inside turned outwards: *i* is common amongst horses in soft condition. I have seen after long marches, with heavy weights up and in hot weather, the saddles taken off a regiment of horses in hard condition with hardly a wet back; backs may be hot and not wet, yet if the saddles be removed too early, before they have time to cool, lumps will appear on them.

We may here consider the proper mode in which an examination of horse and saddle should be conducted when an injury has occurred. Let us suppose a case:—A saddle on being removed has brought to light an abrasion or perhaps wound; first determine whether it is an old injury rubbed, or whether it has existed two or three days and not been reported, in the hope that matters would right themselves, or whether it is really a fresh injury. The first is not difficult to settle; the thickened skin covered with white hairs, thick, coarse, and perhaps curly, with not unlikely the presence of a scar, will at once determine this; the neglected wound is more difficult to settle, and an opinion should be given with great caution; if, however, there is the sign of a sitfast or pus, we may be certain that was not caused in a day. The saddle should next be examined as to the probable cause; marks of blood on the numnah should be looked for, etc.; when this is completed, the saddle should be placed on the horse's back if possible by the man who rides him (this is a small but important point, as we shall presently see), who should place the girths in their usual holes. When the injury is to the spine, withers, or loins, leave the numnah on the saddle, if the wound is on the back, put the saddle on without the numnah, mount the man, and then commence the inspection. Endeavour to pass the hand to the seat of injury, when the cause may be at once detected; the fingers should, however, be kept on the spot, the girths undone, and the saddle lifted straight up off the back for a few inches, when an inspection may determine the cause; the place where the fingers are should be marked with a blacklead pencil, and thus the exact spot on the saddle which produces the injury is shown. When the place is not accessible to the hand or fingers, touch the sore with a black ointment of charcoal and vaseline, put the saddle on carefully, and press it down.

This marking is most important, for it shows without doubt the exact place on the saddle which is giving rise to the mischief; and now the reason why the man who rides the horse should put the saddle on is apparent—it is in order to ensure that it is put on, and occupies the same position as it probably occupied when the accident happened. No saddle should ever be altered without first being put on the back and marked; to guess at the probable cause of an injury, unless with extensive experience, will be only to fail signally; *nothing is so deceptive* as the position which the various articles of saddlery occupy on the back. The experienced eye can tell what part of the saddle produces an abrasion or wound, but the surest plan is to see the saddle on.

The man should be placed in the saddle for the reason that a part may appear well out of harm's way when simply looked at, but when 13 to 15 stone is placed on it, the saddle will occupy a very different position.

A place that has once been rubbed is liable to be so again, even on removal of the cause, unless it is given an opportunity of healing; but as this is often impossible, we adopt measures to prevent the saddle touching it by making what is termed a 'chamber' in the pannel.

A chamber should be deep, sufficiently wide to more than cover the wound, well stitched around, and the stuffing pressed closely up outside the stitching to ensure the depth of the chamber being maintained. *With a properly-made chamber a horse can be worked with a wound on its back of considerable size*, not only without ill-effects, but the part healing the whole time; but then the chamber must be looked to *every day*, and *on no account should the numnah be worn.*

It may be stated, as a rule to which I know no exception, that *when the withers or back are injured no numnah should be worn until the injured place is perfectly healed.* I have seen horses with good chambers in their saddles wearing numnahs, and it was wondered how it was possible the part could continue to chafe when the pressure was removed: the pressure was only partially removed, the numnah kept up the evil.

After alterations have been made in a saddle it should be again placed on the back in the manner before described, and a careful inspection instituted, chambers examined, if possible with the finger, and the same process gone through *daily*, as it must be remembered that stuffing eventually settles down, and the chamber to an extent becomes obliterated.

In concluding the subject of galls, injuries, etc., we may observe that before men are appointed to the position of Saddler Sergeant they should be as carefully instructed by a long course of training in their trade as the Armourer Sergeant is in his; to which end classes should be formed under competent direction, and the making and fitting of saddlery thoroughly dealt with. It is not sufficient that a man be sent to an arsenal and instructed in the making and fitting of a saddle by some one who has not the most remote idea what the horse's requirements are; but he should be taught the theory and practice of fitting, the why and wherefore, and so enable him to deal with individual peculiarities. It requires no great genius to push hair into a pannel with a stick, but it requires a deal of judgment, and a thorough knowledge of the subject, to adapt saddles to the ever-varying conditions of peace and war.

A Saddler Sergeant is not always at hand; every officer, non-commissioned officer, and man should know what measures to adopt in the event of his horse's back or sides being injured, how to recognise the cause, and what expedients to adopt to prevent its continuance.

The **Fitting of Bits** is important: the chief points to observe are that they fit the mouth, and are neither too wide nor too narrow. The mouthpiece wants fitting with great care, and on the Continent they always measure the mouth, so important is it considered that the exact size should be obtained. The curb should lie in the groove above the under lip, and the position of the curb when gentle pressure is placed on the bit is the best criterion of the fit.* The mouthpiece of the bit should lie about the breadth of two fingers above the corner teeth. A great mistake is made in having it higher than this, as displacement of the angles of the mouth occurs. The severity of a bit depends upon the length of the lower cheek-piece—it should be double the length of the upper one, and no more. A portmouth bit is severe for the reason that the entire pressure comes on the jaw, and is not shared by the tongue. Bitting horses requires considerable care and experience, and is a very important part of their training.

Injuries from the bit are common; the jaw is often splintered, and gives rise to considerable pain and swelling; the broken piece has always to be removed, for the pressure has destroyed its vitality. Curb-chain galls are frequent; any soft material, such as a piece of numnah, placed between the curb and chin is a preventive.

Injuries from the snaffle occur at the angles of the mouth, and in the tropics give rise to very indolent ulcers. The chief precaution to adopt is to fit them properly; they are generally placed so high in the mouth as to pucker the angles of the lips; this should be avoided; the angles should not even be wrinkled.

* An excellent account of bits and bitting is given in the work 'Seats and Saddles,' by Major Dwyer.

Draught.

The subject of draught was very fully and philosophically described many years ago by Brunel, the engineer, who, with Tredgold and others, made it a special study. We are indebted to his article in Youatt's work on 'The Horse' for the present section.

The word 'draught' is applied in two senses; it is used to indicate the act of dragging, and also as signifying the resistance a body meets with when being dragged. It would be best to speak of the act of pulling as the force of traction.

Traction is performed by throwing the body beyond the feet, which form the fulcrum, and allowing the weight of the body in its tendency to descend to act against the obstruction. It can be shown mathematically that the horse is designed for draught, and man for carrying weights. Man is not adapted for dragging, as his weight is small compared to his strength; his centre of gravity is too low, and his body cannot be thrown far beyond the fulcrum at his feet.

Generally speaking, a horse can draw no more up a steep hill than three men can carry; work uphill is the most disadvantageous method of applying a horse's force, be he carrying or dragging a weight.—'Ency. Architect.'

The angle of traction is the angle of inclination of the traces. Much has been written about the angle of traction best suited to different kinds of labour, but Brunel gives his opinion as follows:

A large, heavy horse, not strong, or one which it was not desirable to fatigue, might pull better and longer if part of the weight was borne by the carriage, the traces inclining up from the horse to the carriage. It is disadvantageous in stage-coaches, where the horse's weight is already a burden to him, to increase that weight by inclining the traces much downwards, viz., from the horse to the carriage; but, on the contrary, to obtain the utmost effect of a powerful horse, or of a horse that is muscular, but without much weight forward, it is highly advantageous to augment the effect of his gravity by inclining the traces even as much as 15°, or 1 upon 3, ordinarily 1 in 4 or 5. As far as the mere force of traction is concerned, there is no particular angle which will always produce the greatest effect. At high velocities the traces should always be horizontal.

The disadvantage of an elastic resistance in draught is well known. An animal works better close to his work, where every impulse is at once conveyed to the carriage. The leaders of a team have much of their power wasted through the distance they are from their work, and the elastic strain and want of unity in work at the critical moment.

If a team of horses be harnessed to a waggon, the effective power will not be increased in the same ratio as the number of horses.

Springs to carriages diminish to an extent the force of traction, and a load of from one-fourth to one-sixth more may be carried (*Aide-Mémoire*, R.E.).

It is stated by postmasters and horse proprietors that a flat piece of road is more destructive of horses than the same length of road where a gentle rise and alternate flat and swelling ground occurs, and that a long hill is easier surmounted where there are occasional short levels, than when the whole is one uniform ascent. It is explained by saying that a uniform and constant strain is more felt by the animals.

In dealing with the subject of labour we described the serious source of resistance experienced through friction between the wheel and axle. The force necessary to advance a wheel is inversely as the square root of its diameter; if a wheel be increased four times in diameter, the resistance arising from overcoming obstacles on the road will be reduced to $\frac{1}{\sqrt{4}}$, or $\frac{1}{2}$; and if increased nine times in diameter, the resistance will be reduced to $\frac{1}{\sqrt{9}}$, or $\frac{1}{3}$ (Brunel).

Fitting a Collar for harness is a point of hygienic importance. The main things to attend to are that it has an even bearing on the shoulders, that it is deep enough below so as to avoid any pressure on the wind-pipe and vessels of the neck, that it does not pinch from side to side, and that the traces should be attached to it half-way up the collar.* The evils of a badly-fitting collar are great: injuries to the shoulder and neck, congestion of the brain from pressure on the jugular, and partial suffocation from pressure on the trachea. It is uphill work which practically demonstrates a badly-fitting collar.

A 'breeching' I consider important in not only saving the hind limbs, particularly the hocks, but also in preventing that strain on the back of the neck, and consequent stumbling, which is produced when the collar alone is depended upon for pulling up, as in pole draught.

The utility of bearing-reins has been much discussed; distortions of the trachea and larynx, it is said, have been produced by them. I think there are some cases where they prove useful, and many others where they are useless and hurtful.

* This is Major Dwyer's idea, and it is a good one; the present trace is attached too low. Consult 'Seats and Saddles' for valuable information on the subject of draught.

CHAPTER X.

INDIVIDUAL HYGIENE.

HITHERTO we have been dealing with special subjects of great importance in the general hygiene of animals; we have now briefly to note those operations of the stable which are devised for the purpose of obtaining body cleanliness or comfort, and other points connected with individual hygiene.

Grooming.—The objects aimed at by grooming are to get rid of dust, dirt, and the superficial layers of the skin which are constantly being cast off; to obtain a smooth glossy coat; to stimulate the action of the skin by the process of friction, and restore to it what may be termed tone, and so act beneficially on the muscular structure by a process not unlike shampooing.

The good effects of this daily friction are great, even apart from the matter of cleanliness and appearance. The sebaceous glands are stimulated, and their oily secretion acts the part of a pomade in the glossy appearance produced on the coat, and, moreover, is of decided use in protecting the skin against cold or wet.

The neglect of grooming produces skin disease, particularly the parasitic forms caused by pediculi and acari.

The process of dressing horses requires great practice and experience; the brush should be used with and across the hair; it should be drawn firmly through the hair to ensure its penetration to the skin. Few men are willing to expend the time and strength required in grooming a horse properly; the brush is generally applied in such a manner that superficial and not deep-seated dirt is removed. They trust more to the curry-comb than the brush, and scrape the dirt out, instead of brushing it out. The legitimate use of the curry-comb is to clean the brush, and no other.

I have shown that the dandruff removed from a horse's skin consists largely of the natural skin fat lanolin. This material acts as a protection to the surface of the body against cold and rain. It is probable, therefore, that the prejudice against the too frequent grooming of horses living in the open has a physiological basis; further, the harm arising from washing is also perfectly explained.

The thorough cleaning of a mane and tail are important points; the dirt shows here the quickest, for the exfoliation of epithelium appears to be more rapid. Much art is required in cleaning these parts; the hair must be separated in small groups, and the brush applied with considerable force, until the whole of the dandruff is brushed out.

Cleaning legs is an important point in grooming. In dry weather a simple brushing out is sufficient, followed by hand rubbing; but in wet and winter weather we have the element mud to contend against. To brush at wet mud would be to make matters worse; as a result of this, washing is generally resorted to, and in white-legged horses soap is used to restore the colour of the hair. Leg-washing is a practice which, as generally performed, must be wholly condemned. It is not the actual washing, but the fact that the legs are invariably left damp, or even wet. Experience shows that this is a prolific source of skin affection; the part becomes inflamed, the inflammation being exceedingly intense, sometimes running on to destruction of a portion of the skin. In the heels, where the skin is particularly sensitive, the greatest damage occurs. This inflammation of the skin of the legs is commonly termed 'mud fever,' and inflammation of the heels 'cracked heels.' The mud gets the blame; experience shows it is not the mud, but the washing which produces the evil, which is aggravated by cold weather. Washing the legs with hot water is particularly productive of inflammation of the skin; the use of cold water is by no means so dangerous. In large establishments it is the rule not to touch the legs until the mud is thoroughly dry, when it is brushed out in the ordinary manner. Where this system is carried out, 'mud fever' does not occur. If legs are washed they must be thoroughly dried; it takes a long time to dry legs properly, more time in fact than the ordinary groom is willing to spare; the heels particularly must receive careful attention, and the legs must be worked at with rubber, wisp, and hand, until they are not only perfectly dry, but warm. After this they should be bandaged.

Attention to the cleaning of eyes, nostrils and anus should be paid; they must be sponged out at each dressing. The sheath is a portion often neglected; some horses refuse to be manipulated in this region, and the result is that the secretion of this part accumulates, the penis in many cases cannot be protruded, and in hot climates flies get in, and maggots soon appear and work considerable damage before anything is noticed. With care and patience most horses will admit of this simple operation being performed. Soap and water should be used for the cleaning, and the difference in comfort to the animal between a clean and dirty prepuce must be very great. In hot climates it is so absolutely essential, that if the animal will not submit to the cleaning, methods of restraint should be applied.

Washing horses is a practice that must wholly be condemned; there is nothing to justify it; it is a plea for laziness, and should be discountenanced as unnecessary and harmful. A horse whose coat is washed never possesses the glossy appearance of the well-groomed animal; moreover, the protective sebaceous material is removed, and the danger from chill is considerable. A man lazy enough to wash his horse will certainly not be energetic enough to dry it. With grey horses excuses are often made; but the fact is that if stains are removed as they appear, washing never becomes necessary: it is the constant staining which remains permanent.

Washing the mane and tail is considered essential at regular intervals. If the parts are daily and thoroughly cleaned it is not required.

When horses return from work with wet skins they should be at once attended to; if drying is impossible they should be walked quietly about until the coat dries, and the breathing settles down. Many of our chest affections are due to the want of care shown when horses return from work. The proper method of drying a wet horse is by means of wisps of straw, the rubbing must be vigorous, against and across the hair principally; it is a tedious operation, and requires skill and patience; some horses after thorough drying break out again into a sweat, and the whole operation requires repeating.

Clipping.—The natural winter coat of the horse is a source of trouble when he comes to be worked, for the reason that owing to the warmth it produces, the skin acts more freely during exertion, and the constant sweating thus caused is a direct source of waste to the system, which shows itself in loss of condition; moreover, the heavy coat from being constantly wet exposes the horse to the risk of chills, and there is great trouble in drying and grooming him.

All these are very strong arguments in favour of removing the coat by artificial means, a process which I regard as most essential and beneficial to the horse; as one of our most practical veterinary surgeons has expressed it: 'I regard clipping as being equivalent to an extra pound of corn per day.' The prejudice against clipping is the risk of cold and chill to which the horse is exposed when first shorn. This is by no means an imaginary evil, but it is a result which can be guarded against by the use of clothing for the first few days after clipping. It is during the week succeeding clipping that the greatest risk from cold is experienced. The influence of clipping on the body temperature has been studied by Siedamgrotzky;* after clipping the normal temperature rises and is restored in three or four days; clipped horses at work afford a higher temperature than unclipped, and the return to normal temperature is more steady and regular than with the unclipped. It must remain an undoubted fact that if horses are clipped they should be clothed. To clip horses which are never clothed, such as army horses, is folly and dangerous, for the reason that though the effects of clipping will enable them to perform their work without sweating, yet the loss to the system in endeavouring to keep up the body temperature would considerably outbalance its good effects, and the risk to the animals is a constant one. If clipping is practised amongst a body of horses under these conditions, the best system to adopt is clipping half-way up the body, and as low as the knees and hocks.

The presence of hair on the legs is protective against rain and cold, but from the difficulty of drying the part it is a frequent source of skin affections, such as are common amongst the heavier breeds; a little hair left at the back of the fetlock, though unsightly, is certainly useful in protecting the heels, for the water which runs down the legs drips off here on to the ground instead of running into the heels. Hair left on the legs of hunters is considered to be protective against thorns and inflammation of the skin.

As the effect of warm stables and heavy clothing is the production of a fine thin coat, we have many horses which

* *Veterinary Journal*, vol. i.

never require clipping, as they never lose their summer coat. It is a matter of common observation that clipping spoils a horse's coat, and that once clipped it must always be clipped.

The process of singeing has been almost completely supplanted by that of clipping; the long hairs of the jowl, belly, thighs, etc., are those usually removed by this method; when clipping half-way up the body is practised, singeing is useful in softening the sharp line of demarcation.

Clothing.—In spite of hot stables, clothing has been considered essential for horses; if we were to limit the application of clothing to Stewart's definition—to keep horses warm without endangering the purity of the air they breathe—we would then be applying it in strict accordance with hygienic rules.

It is not so much the comfort of the horse as the fine coat which is aimed at by the application of clothing. When used in stables all the year round, different degrees of thickness should be provided; the light summer clothing is protective against flies and dust; heavy clothing during summer is positive cruelty.

The clothing should be thoroughly cleaned every day by shaking—beating with a light stick will get rid of hairs and dust, but good brushing may be required; the clothing should be aired while the horse is being dressed.

The roller used to keep on the rug is invariably drawn too tight; this should be avoided.

Army horses are never clothed except when living in the open.

In India clothing is of great importance; it should be worn every night excepting during the very hot weather, when special rugs for protecting the spine should be used. The cool winds of the early morning in the tropics are considered, and, I think, with a certain amount of reason, to be productive of paralysis.

Harness horses, which have to work out in all weathers, are often provided with a waterproof loin-covering. This is a very humane and wise precaution; the waterproof should have a woollen lining to absorb the perspiration, and it should certainly be ventilated.

Bedding.—Like most other stable operations, bedding-down a horse requires some art and much practice. The comfort of a good bed must be very great; where bedding is absent or scarce, the horses lie but seldom, and for very short periods; they also suffer from bruises and wounds; the hocks, particularly on the outside-hollow, and the points of the hips are the parts most affected; capped elbows are frequent and unavoidable.

The Indian Government provide no bedding for their horses; most of them are blemished on the hocks, hips, and fetlocks, and more cases of capped elbow are seen in regimental practice in a month than a practitioner at home would meet with in a year.

There are some horses, particularly amongst the heavier breeds, which never lie down. The cause is often due to anchylosis of the spine, and if these animals do by any chance get down, they are unable to rise without assistance, and very often injure themselves fatally. With horses of this sort a sling should be placed under them at night, to admit of their obtaining rest and preventing accidents.

A horse only sleeps for short periods at a time, and, in my experience, lies more often on the off than on the near side. I think this is due to the position of the heart.

Wheat straw is generally used for bedding, and makes the best and most durable bed. Oat straw is sometimes used; it does not make such a good bed as wheat, and horses are more inclined to eat it than the other.

The removal of the whole of the bedding from the stable should be practised once a day; it is necessary for the drying of the soiled portions, and for the thorough airing of the remainder; it is also essential for the ventilation and drying of the stable floor, and also to ensure the air being kept sweet. Litter-sheds should be found adjacent to every stable, where the whole of the litter can be placed to air in wet weather. The practice of keeping the bedding in a spare stall to dry must be strongly condemned.

Saw-dust, tan, and moss-litter* are sometimes used as bedding; the latter is very popular in some stables; it has been stated, however, to be destructive to the feet, and that the horn rots under its action. All absorbent beddings produce the same result; it is due to the strong alkali of the urine acting chemically on the horn. Moss-litter is very absorbent; 1 lb. of the litter will hold about 1 gallon of water; this should be a great saving to the stable drains. Absorbent beddings are not self-cleaning; this is where they are abused—the soiled portions are not removed with sufficient care, and the bedding soon becomes offensive and filthy.

Where horses eat the ordinary bedding, the use of saw-dust, tan, or moss-litter is quite effective in correcting the habit.

The Management of the Feet can be comprehended in a few words. Have them picked out after work, dirt washed out, frog dried; avoid stoppings as being unnecessary, if not harmful; let the horse be regularly shod; little or no interference with the foot permitted, excepting the removal of the month's growth; the shoe must fit the foot, the nails kept as low as possible, the wall on no account rasped; the frog to receive pressure, and nothing but the loose portions

* Analysis of moss-litter:

Organic matter	98·760
Salts	1·146
Silica	·094
	100·000

The salts consisted of small quantities of phosphate and sulphate of lime, and magnesia.

removed with the knife. This really comprises the hygienic care of the feet. The results of neglect are often very troublesome, and sometimes incurable. Thrush is the most common result of neglect due to not giving the frog pressure and keeping the feet clean and dry. The disease may spread, and produce what is often a perfectly incurable affection, canker; both of these diseases are under the control of hygiene.

Respecting the best form of shoe to be used, I am a believer in the rim of iron; there is no form of shoe, particularly if machine made, which I consider superior to another. Horses go equally as well, provided the feet and limbs are sound, in a fullered or plain shoe, seated or concave, ground-surface round or flat, turned-up toe or not turned up; let the shoe fit the foot, be as light as consistent with the work the animal performs, no more nails used than necessary, be the same width of web all round, and from careful and unbiassed observation I confess to see no difference in the soundness enjoyed under any pattern.

Horses' feet are stopped to make them soft, and to allow soles to descend under the weight of the animal. This explanation of the effects desired to be produced will be sufficient to condemn stopping as useless and mischievous.

Some feet are unnaturally brittle, and hoof ointments are applied to prevent this. Such cases are best treated through the system; brittle feet are often due to digestive derangement. I think I have observed in some cases that greasy applications to the wall of the foot have assisted in rendering the horn less brittle; excepting in special cases, all hoof applications are to be condemned.

Clean stable flooring is essential to sound and healthy feet.

We have other points in hygiene which might have been treated under other sections, but from their peculiar individual character are discussed here.

Pasturing and Soiling are two methods adopted when a is required that animals should have perfect rest from work, and a complete change of diet. By pasturing is understood ordinary 'turning out to grass'; by soiling is expressed a life of idleness in a loose box on a soft diet, the most part of which is green meat. Pasturing or soiling when applied to hunters is termed 'summering.' It was 'Nimrod' who first introduced the process of the home-summering or soiling of hunters; previous to his time all hunters were turned out to grass as soon as the season was over. The arguments in favour of and against each method of dealing with hunters have occupied the pages of our sporting journals for years. I think it very likely that too much prejudice in favour of one particular method has been exercised, or we would have found before this that the two systems, both acknowledged to have good points, would have found partisans who would have supported a combined method of turning out and home-summering.

The arguments against turning out, are that if the pasture is poor the animal becomes irretrievably damaged in condition for the ensuing season; or if rich, that he acquires so much flesh that his legs are damaged by taking it off him; that he is worried by flies and insects; affected by the heat of the sun; knocks his legs about by galloping; breaks his feet away, and is likely to receive injuries from other horses turned out: the chief argument is that the horse at grass requires more preparation, and longer time to be made fit again, than does the one stabled and receiving an allowance of corn.

Cost is the great objection to home-summering; in other respects it appears to be generally considered the most satisfactory method of disposing of hunters. I cannot believe that the life of idleness which the stabled animal leads can be good for him. I consider that daily exercise is necessary; and if the horse which is turned out received an allowance of corn, and a shed provided for his shelter, I am certainly of opinion that he is better suited for the work expected from him than the one stabled for months.

A combined method of turning out and home-summering would, I think, be found by far the best. The hunter to be turned out for a month or two, when the weather becomes suited for such a sudden change, and while the grass is fresh and flies not troublesome; at the end of this time taken up and home-summered in the ordinary manner, including daily exercise.

Other animals besides hunters are turned out, but the majority of these are invalids, many of them cases of chronic lameness which are benefited by bringing the parts into play after a long rest. The nature of the soil, the quantity of herbage, the supply of water, shelter from weather, etc., are points to be considered. In cases of foot-disease marshy lands are generally preferred, and it is evident that hard, stony, uneven land would not be suited for any case of lameness.

It is generally supposed that an obliterated jugular vein, or the dependent position of the head during grazing, predisposes to attacks of brain disease. Animals with 'parrot mouths' are, beyond doubt, incapable of supporting themselves at pasture: these are points which require attention in considering the advisability of turning a horse out to grass. It must be remembered that if animals are fed out of a manger for years, they must experience some inconvenience in being called upon to feed persistently off the ground; Stewart tells us it was often several weeks before an old coach-horse could graze with ease.

The advisability of removing shoes from all animals turned out to grass, or thrown out of work, is much discussed. My own opinion is, remove the hind shoes always if the horse is being turned out with others; remove the fore-shoes if the feet will stand it, viz., if they are not brittle or broken. To remove the shoes of a brittle-footed horse will produce considerable harm, which may take two or more months' growth after returning from grass to put right again.

A simple shed as shelter for horses at grass should always be provided.

A horse should be prepared for the exposure of living in the open by gradually doing away with the clothing in the stable, and keeping the building at the temperature of the outside air.

Horses are often turned out in what is known as a straw-yard—it might with propriety be termed a manure-yard; it is usually a filthy spot, knee-deep in mud in wet weather, and little better in dry. The cost of this method of *keep* is its recommendation; it is cheap, insanitary, and disease-begetting. If a straw-yard is determined on it should certainly afford shelter, and clean water must be obtained. The animal should receive hay and a little corn, and the feet should be regularly attended to.

Crib-biting and Wind-sucking, their causes and prevention, come under the head of individual hygiene. The best mode of prevention is a muzzle with a bar, which admits of the animal feeding through, but will not allow him to take hold of the manger with his teeth (see Fig. 80). This muzzle should never be removed in the stable. If the horse cannot take his hay through it, have him fed on chaff. A special form of stall devised by Professor Varnell is sometimes erected for the use of a cribber; it is really a collapsable manger, which can be pushed back into a recess in the wall when not in use. It is said to have been used very successfully.

The effects of crib-biting and wind-sucking are often serious; the former completely damages the incisor teeth, and the latter lays the seeds of abdominal disease, particularly dilatation and thinning of the walls of the stomach. Animals which practise these vices are, as a result, generally in bad condition.

Kicking.—This is a very troublesome stable vice which causes great damage and considerable annoyance. There are some horses which amuse themselves kicking the greater part of the night; the cause is difficult to determine; the effects are disastrous to legs, which become swollen, causing great pain and lameness, and permanent thickening. The remedy to be applied is the wooden or gutta-percha kicking block, which fits close into the hollow of the pastern, and

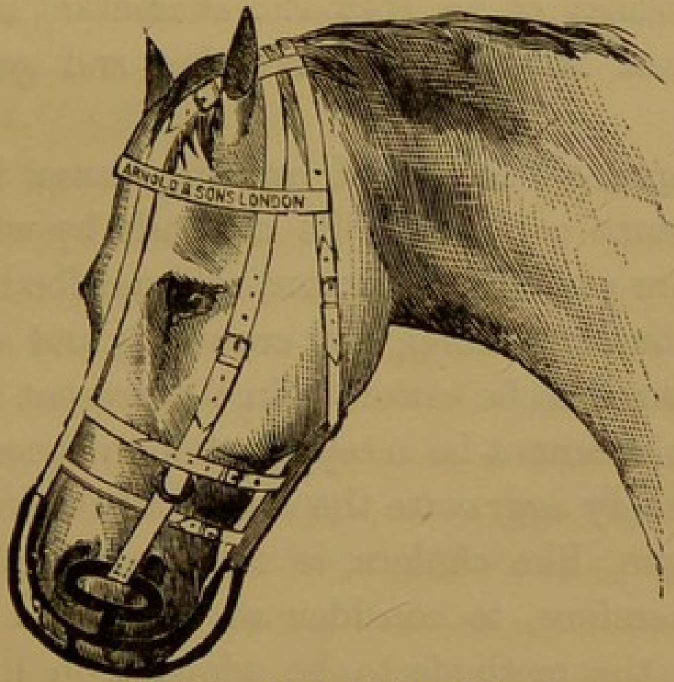


Fig. 80.—Crib-biting Muzzle.

prevents the animal bending or lifting its leg. Another method is to have several heavy links of chain attached by a strap and buckle to the pastern; if made heavy enough this is quite effectual.

Weaving.—This is a singular vice for which I know no remedy; there can be no doubt that the constant movement must affect the fore-legs prejudicially. I am convinced that horses in the army learn the vice from the pleasure they take in drawing up and down through the ring or hole in the manger the chain they are secured with. Once the habit is contracted it never seems to be forgotten, and, like wind-sucking and crib-biting, I think it is often learned by example.

CHAPTER XI.

THE ERADICATION OF EPIZOOTIC DISEASES.

THIS subject has been very completely placed before the profession in Dr. Fleming's 'Manual of Veterinary Sanitary Science and Police'; all we purpose doing here is to note the chief diseases of an epizootic character, and describe briefly the best methods of preventing and getting rid of them.

Cattle-Plague.—The actual exciting cause is, without doubt, a minute organism; the methods by which this is propagated are probably by water, air, and food.

Food affected with fungi, over-crowding, and over-driving have been stated to be causes. In the present light of our knowledge this cannot be accepted, though these conditions may considerably aggravate the causes when existing.

Cattle-plague, like cholera, is an imported disease; we have not, therefore, to consider so much the causes producing it as the methods to be adopted on its detection. Our safeguard against this affection is our system of port inspection, isolation of suspected animals, and prompt destruction on detection of the disease. As the mean period of incubation appears to be ten days, a quarantine of four or five days, depending upon the length of the voyage, will be found sufficient.

It is certain that a Foreign and Home Cattle Market should be distinct places, in order to avoid as far as possible the introduction of disease amongst our own stock.

The destruction of all infected and all suspected animals should take place at the port of landing; the utilization of their flesh or offal should not be allowed. The disinfection and destruction of such a large amount of material is difficult to carry out. Probably the best method would be to convey it well out to sea; in this case, carcases should be opened so as to prevent the development of putrefactive gases bringing them to the surface.

The effect on human beings consuming the flesh of diseased animals appears to be unimportant; but it is certain that if the flesh or other parts be utilized, every portion of it sent over the country may act as a separate centre of infection.

Where the disease has been introduced into the country, the methods to adopt are well recognised. All fairs and markets should be suspended; the complete isolation of infected places carried out; no movement of animals should be allowed in the district; the immediate destruction of all affected animals, and those which have been in contact with them, also skins, carcases, and offal, such are the chief measures to be adopted to check the progress of the disease. The greatest care must be exercised that the destruction of excreta, etc., of diseased animals is carried out, such as indicated under 'Disinfection.'

Pleuro-Pneumonia is a disease due to a specific poison. The causes combining to aggravate the malady are improper feeding, cold and damp, too rapid fattening, excessive milking, etc.

The disease is of a very insidious nature, and often difficult of diagnosis. The poison is conveyed by means of the secretions and excretions, but particularly by the air given off from the lungs of the infected animals. The period of incubation is variable, but generally considered to be from six weeks to two months. The measures to be adopted on an outbreak of the disease are indicated under the head of 'Cattle-Plague'; our recent experience in this country goes to prove that destruction of all affected animals, and those which have been in contact with them, is the only certain method of stamping out the disease. The efficacy of inoculation is gravely doubted by many, but Mr. Rutherford, of Edinburgh, and others have obtained excellent results; and V.-Col. Duck tells me that in the Bechuanaland Expedition the disease broke out amongst the transport cattle, 2,000 of them were inoculated, and the affection was at once stamped out.

The period of incubation of this disease is so long that the system of home quarantine is often adopted, which consists in keeping all new purchases together until danger has passed, and there is no longer any fear of allowing them to mix with the other stock on the farm. When an outbreak occurs, the importance of aërial disinfection of occupied buildings must impress itself on our minds.

Epizootic Aphtha.—Food affected with fungi, putrid water, and sudden changes of food, mal-hygiene in all forms, have been blamed for the production of this specific disease, which, like others of its class, it is only reasonable to believe is due to an organism.

The milk of animals suffering from foot-and-mouth disease has produced an aphthous eruption in man.

The virus is very difficult to destroy. Infection is probably brought about by direct contact with the poison. The period of incubation is from three to six days. On the disease appearing, the place should be declared infected, and the machinery of suppression placed in movement; viz., a sanitary cordon established, all movements of animals in the district prevented, fairs and markets prohibited, etc., and these should not be relaxed until the place is declared by competent veterinary authority to be free from the disease. The disinfection of buildings occupied by diseased animals must be thoroughly carried out as before directed.

Glanders-Farcy.—We have the unanimous opinion of the profession that both badly-ventilated and indifferently drained stables, coarse innutritious fodder, overwork, starvation, cold and damp, are the causes which expose the system to the development of the disease. The actual disease-producing agent is a bacillus, which is obtained through contagion. Animals debilitated by attacks of disease, as strangles, diabetes and mange, have often been observed to contract glanders. In all these cases a suitable soil for the development of the organism has been prepared.

The period of incubation is very variable, from ten days in the inoculated form of the disease, to often as many months where it has been contracted naturally.

The steps to adopt when an outbreak of glanders-farcy appears in a stable are, the immediate destruction of all infected and suspected animals; the complete isolation of those which have been in contact with them; the disinfection of stable utensils, fittings, flooring, water-troughs, clothing, saddlery, harness, and attendants; destruction of forage, and the complete disinfection of the stable, based on the lines before laid down. *The daily inspection of all animals is absolutely necessary.* Our greatest difficulty is in obtaining that complete isolation of suspected cases so essential to the stamping out of the disease; no trouble or expense should be spared to obtain it. If the disease occurs in a town all the water-troughs should be closed.

In the army, where every facility is afforded for getting rid of this scourge should it get introduced, we may carry our measures further. The affected troops of cavalry, or divisions of artillery, should be isolated. They should neither drill nor come in contact with the other units of the regiment, but should be removed from their stables and picketed out in the open; all their manure should be burned. If fresh cases occur in the isolated unit, the animals in immediate contact with the affected ones should form a distinct group, and be isolated separately. All horses should be watered from buckets, one per head; the buckets to be of galvanized iron; the greatest care paid by all ranks that the buckets are not mixed; each should have on it in large figures the number of the horse, and with its blanket, grooming utensils, etc., should, when not in use, be placed either to the rear or front of the picket. The distance between each horse should not be less than 15 feet, and every animal must be inspected once a day.

The variable duration of incubation and insidious nature of the disease are very trying to our patience. When we have cases we suspect, either from the condition of the animal or other reasons, our best plan is to test them by inoculation; Guinea pigs, or, better still, donkeys, should be used; the nasal discharge or blood of the suspected patient being tried. Negative results must not lull us into false security. A full dose of aloes will often bring out latent glanders in the form of farcy, and this is a very valuable and practical method of diagnosis. The work which these isolated horses should perform must be regular, the attention to stable-management good, and every care observed that no mixing of bridles, bits, saddles, buckets, halters, sponges, etc., occurs.

If at the end of six months from the last case nothing fresh has shown itself, I should consider it *probable* that the disease had been stamped out; at the expiration of twelve months, and nothing having occurred in the meantime, I should consider the unit free from disease, and fit to mix with other horses. I do not think, considering the very insidious nature of the disease, that we could possibly be warranted in shortening these periods; we certainly could not where many cases had presented themselves.

It need hardly be mentioned that every opportunity must be taken for impressing upon the men in charge of suspected cases the necessity of exercising extreme care to avoid inoculation. The safest plan is to look at the hands and arms of each man as we inspect his horse. Men, particularly soldiers, are most careless and indifferent to any risks they may run. The bodies of animals destroyed for glanders should either be burned or deeply buried, the hides being slashed (see 'Disinfection,' page 347).

Strangles.—The contagiousness of strangles is generally acknowledged; essentially a disease of the young horse, we know that it runs through a stable often very rapidly, and this can only be explained by saying that the disease is due to a specific germ.

The isolation of cases of strangles is rarely carried out; it is necessary, however, on the disease declaring itself in a stable full of young horses, that the affected animals should be at once removed to the infirmary, and the stable they occupied disinfected; particular care should be paid to the disinfection of the mangers, bails, etc. I should be inclined to place considerable reliance on thorough aërial disinfection with sulphurous acid gas, in the proportions named in the article on 'Disinfectants.'

Influenza.—Certain electrical changes in the atmosphere, causing a large development of ozone, have been blamed for producing this disease. This affection has made considerable havoc in America and our own islands; quite lately it was enzootic in the north of England: but the disease is really never absent from us, particularly in young-horse stables. It is due to a specific poison, and is undoubtedly communicable; the period of incubation is short, perhaps a few days, and the spread of the disease occurs principally through the atmosphere. On an outbreak of influenza, segregation of the affected animals should be practised, and the stable and utensils thoroughly disinfected with sulphurous acid gas. Too much stress cannot be laid on this disinfection of the stable atmosphere.

Variola affects most of our domesticated animals. The disease is due to a microbe, which appears to be distinct for each species. Animals are very differently affected: with sheep it is exceedingly fatal, and a most serious disease; with horses, as far as my experience goes, it is very mild, though on the Continent of Europe cases of a very serious nature are reported, in some respects resembling glanders; with cows the disease is very mild. Variola of animals is a disease of peculiar interest to the human physician, from the protective power which cow vaccine is capable of affording against small-pox.

When sheep are the subjects of the disease it is always through importation. Strict watch should be exercised over foreign sheep at the landing ports, and it may be necessary to prescribe a quarantine of two or three weeks. The infected district must be proclaimed, movements of sheep in the neighbourhood stopped, and sheep fairs and markets prohibited. The affected animals should be destroyed, those in contact with them isolated, and thorough disinfection of the place performed, particularly aërial disinfection.

In dealing with equine variola, the separation of diseased from healthy animals, disinfection of stables, mangers, utensils, etc., and the destruction of all fodder or bedding soiled by the affected animals, is essential. Cow-pox requires no special precautions; the eruption is usually limited to the teats and udder, and it is recommended by Fleming to milk the affected animals last. With care, this will be sufficient to prevent the disease being communicated to the healthy, which it can only be by actual contact. It would, perhaps, be better to tell off one person to milk affected cows and no others; the milk should not be used.

Anthrax.—We have, for practical purposes, two forms of anthrax affecting cattle, and one form affecting sheep and horses. It is the most fatal and wide-spread disease of animals, and due to an organism of the life-history of which we have the most perfect knowledge. The causes producing the disease are generally associated with great heat and moisture, and a rise in the level of the ground-water; animals grazed on swampy land, or, as in South Africa, grazed on grass before the morning dew is off it, or brought suddenly from a poor to a rich pasture, are all recognised factors in the production of the disease. We cannot attempt here to notice the pathology of the affection; but it is important to observe that, whether depending upon geographical distribution, breed, temperament, difference in feeding, or general care, it is certain that the same organism does not produce in all climates, or all continents, or even all portions of the same continent, the same symptoms or individual peculiarities. The diseases are common only in one respect; that is, intense virulence, rapid course, and extreme fatality.

It is certain that the form of anthrax in cattle known as black-quarter is produced by quite a distinct organism from the disease where general systemic infection and splenic enlargement appear as the most prominent features.

The period of incubation with the horse I have ascertained to be about seventy hours; the poison is not conveyed by the air, but, I think, invariably gains an entry into the system through the digestive passages.

When a case of anthrax occurs, it is best to consider it both an infectious and contagious disease. If occurring amongst stabled animals, those standing near the affected one should be isolated; everything belonging to the sick creature should be kept with it, and the stable evacuated. The healthy animals should be picketed out with a good interval between them—I have sometimes thought that one single line was best—they should be inspected three times a day, and at the least sign of refusing food should be removed to a special site set apart for cases under observation, or, if necessary, taken direct to the place used as an infirmary. In a small number of animals daily thermometric observations may help one in selecting those which are likely to become affected; but, as a rule, the veterinary surgeon's hands are too full to admit of this.

It is most essential that a special staff should be told off to look after affected animals and no others; these men should on no account be allowed to have any intercourse with the healthy. As soon as a patient dies it should be burned on the ground where it has expired, and not dragged about the country in carts, or otherwise, to be disposed of; for the method of cremation see the article on 'Disinfection,' page 348. Everything belonging to the diseased patient should be burned—blanket, head-collar, ropes, picket-pegs, brushes, rubbers, etc.; all ironwork passed through the fire. The ground on which the animal stood when attacked should be left vacant, and thoroughly burned by spreading litter over it and setting fire to the same. The excretions of both sick and healthy should be destroyed by fire, to avoid any chance of the germs being returned to the soil.

The stalls of the stables occupied by diseased animals should have their flooring, mangers, bails, walls—as high as the animal could reach—burned in the way before described; walls scraped and lime-washed; flooring, if of earth, removed for the depth of several inches, buried, and replaced by clean material.

If burning the bodies is impracticable, *deep burial* should be resorted to; superficial burial only propagates the disease.

It is obvious that where the disease affects herds of cattle or housed animals, a modification of the above measures may be required; the guiding principles must not, however, be lost sight of—the land must be evacuated, suspected animals kept together, sick treated separately, and every precaution observed to prevent infection. In the case of cattle and sheep, also perhaps horses, the advisability of protecting the unattacked by inoculating them with Pasteur's vaccine may be considered.

Tuberculosis is considered to be produced by ill ventilated and badly drained stables, excessive milking, cold, and damp; the disease is produced by a specific bacillus which generally affects cattle. Apart from the actual loss produced by tuberculosis, the serious dangers to which the public are exposed by consuming the milk of phthisical animals cannot be too strongly insisted upon.

The modes by which the poison is conveyed are through the air and food soiled by the tubercular animal, and to human beings through the flesh and milk.

It is quite evident, in the present light of our knowledge, that animals suffering from tuberculosis should be destroyed, and the use of their flesh prohibited.

Scabies affects all domesticated animals. Poor living, dirt, neglect, starvation, exposure to weather, are the usual predisposing causes.

Should mange break out in a stable, commence its eradication by giving the affected animals a thorough dressing with one of the recognised mixtures, the body being previously clipped, if necessary; collect brushes, rubbers, curry-combs, blankets, etc., and boil them; throw boiling water into the stall, and wash down the mangers, pillars, etc., with the same; or, better still, spread a little litter on the surface of the floor, and set fire to it; burn walls, mangers, etc., and afterwards lime wash. Saddlery and harness must be our next care; burn the stuffing and lining of these, scrub the leather-work, and afterwards thoroughly grease. After the brushes, blankets, etc., have been boiled, have them put away and not used if it can be avoided until the disease ceases; the same remark applies to the saddlery and harness. The dressing of the animals and scalding out of the stables will probably require repetition. Allow the patients no bedding, burn the litter which remains, and keep all the horses racked up until cured.

Sheep-mange is sometimes a very serious complaint. Isolate the flock, stop all animal traffic, particularly that of sheep, over the infected area. Disinfect posts, rails, fences, etc., where the animals may have rubbed themselves; the usual effective sheep-dips should be used; great care should be observed in those which are poisonous, such as arsenic dressings, that the animals are not turned on to their pastures with a dripping fleece, as many cases of poisoning from this cause have been recorded. Turn them as dipped into an empty yard or fold, and allow them to remain there until dry. Non-poisonous sheep dips are now largely used, of which, perhaps, Little's and McDougall's are the best known.

Foot-rot is a highly contagious disease affecting the feet of sheep. It is caused by a specific poison, and aggravated by standing on filthy soil, inattention to the feet, allowing them to grow too long, etc. The disease runs a slow course, and is difficult to eradicate. The period of incubation is about a week. The suppressive measures are separation of sick from healthy; enforce a rigid quarantine of the infected area; regular inspection of the flocks; the sick to be confined to one place for treatment, and the soil on which they stand to be kept clean and disinfected where practicable; it would be well if some dry and easily removable material like moss-litter be placed down in the pens occupied by the sick; this could afterwards be collected and destroyed. The ground on which the sick animals have been confined should be removed for a depth of a few inches, and the soil should be buried if possible. No healthy sheep should be allowed on pastures which have been recently occupied by diseased animals, for the poison is left on the grass.

Swine-plague is a very serious disease, extremely fatal, highly contagious, and produced by a micro-organism. Suppressive measures are destruction of all affected or suspicious cases. Perfect disinfection of piggeries; if iron, these can be burned with litter; if of wood, boiling water and carbolic acid should be used, and the place afterwards coated with tar. The soil should be removed for half a foot and buried; aërial disinfection may be practised. Fairs and markets must be prohibited, and the affected area quarantined.

Fluke-disease.—This parasitic disease affects most herbivorous animals—sheep in particular, producing during some years enormous losses. The life history of the parasite has been beautifully worked out by Professor Thomas, late of Oxford, and to his writings we are indebted for the following information.

Fluke-disease is an affection which alternates between a particular snail and the sheep; the latter, by means of its fæces, spreads the eggs over the soil, and these, passing into the body of the snail, undergo certain changes, and are then taken into the body of sheep during grazing. Marshes and badly drained lands are prolific sources of sheep-rot.

The preventive measures to adopt are destruction of the manure from affected animals, or if used for agricultural purposes, it must not be placed on wet lands. All heavy or wet ground must be thoroughly drained. The lands affected with the disease must be dressed with salt or lime, to destroy both the eggs and snail. Sheep must not be allowed to graze closely, as the risk of obtaining the eggs is considerably increased. Salt should be given daily to animals on dangerous land, also an allowance of dry fodder. It must be remembered that hares and rabbits may prove a means of distributing the parasite.

Fly-attacks upon animals can hardly be considered as an epizootic disease, yet so great is the loss from this cause, that we have thought the subject of their prevention might be dealt with in the present chapter.*

The flies which attack animals are the horse-bot, or *Œstrus equi;* cattle-bot, or *Œstrus bovis;* sheep-bot, or *Œstrus ovis;* and the gad-fly.

The *horse bot-fly* (Figs. 81 and 82) is exceedingly common; animals at grass are very much tormented by it. The female deposits her eggs on the hair, to which they become attached (Fig. 83); the favourite place of deposit is about the limbs, particularly the knee; the eggs are licked into the stomach and become converted into maggots, which attach themselves to its walls and remain

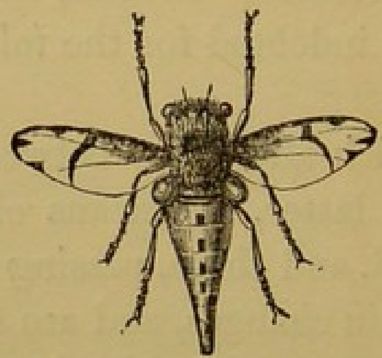


Fig. 81.—Horse Bot-fly (Female). Fig. 82.—Horse Bot-fly (Male). (McDougall.)

there, often doing considerable harm to the coats of the viscus, and interfering with the digestive processes. The maggot remains in the stomach for eight or nine months, then loses its hold, and is expelled; the chrysalis stage is now reached, and in six weeks a fly emerges. Our difficulty is to prevent the bot-egg entering the stomach; animals at grass are most exposed to the attacks. It is said that dressing the skin with McDougall's non-poisonous dressing will prevent the eggs being deposited, or kill them if they are on the hair. I have no experience

* The scientific and agricultural world is much indebted to Miss Ormerod for her researches on bot-flies and other subjects of agricultural interest.

of this as a preventive, but it appears to be well spoken of. All eggs when seen should be clipped off, or destroyed by some parasiticide. Occasionally the bot-fly deposits her eggs under the skin, particularly that of the back; the result is the formation of warbles, inside of which will be found a maggot.

The *ox bot-fly* is a source of terror to cattle, and

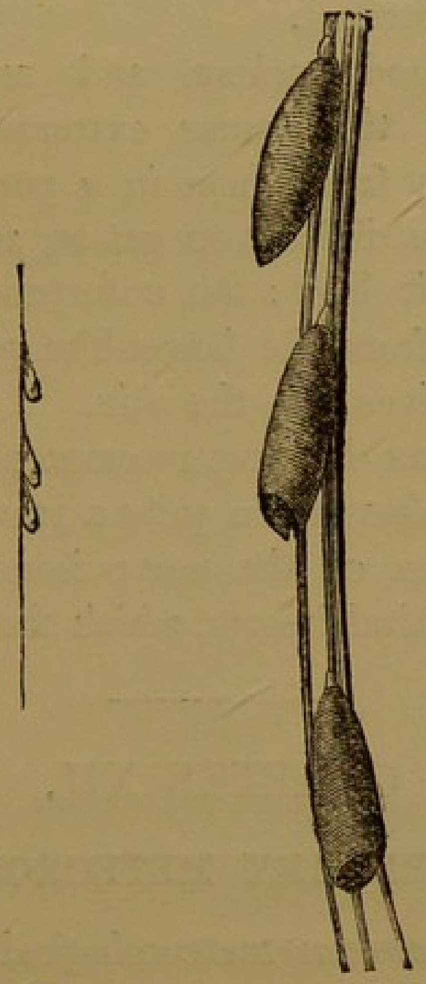


Fig. 83.—Eggs of Horse Bot-fly, natural size and magnified (McDougall).

moreover, owing to the fact that the eggs are deposited under the skin (producing warbles), such destruction is effected that the hides are much depreciated in value. The annual loss from this cause is estimated at some millions of money. Cattle on hearing this fly rush about in a state of extreme terror; the damage this causes to fattening cattle, milch cows, and cows in calf, can easily be imagined. The preventive treatment is the application to the skin of some material which the flies will not go near, and McDougall's dressing is said to meet this requirement.

The *sheep bot-fly* chooses for its particular seat of development the nostrils of sheep; the poor animals are dreadfully punished by their tormentor; the eggs, as usual, develop into maggots. The preventive treatment is to keep the head and face dressed with some of the non-poisonous remedies before described.

Gad-flies are blood suckers, and are not connected with the bot-fly; they cause extreme terror to cattle and horses, who fly from them in a perfect panic. Once they settle they are difficult to get at, and even if driven off, follow up their host; the unfortunate animal suffers considerable pain from the lancet-like points on the fly's head, which are driven into the skin.

The non-poisonous dressing recommended for the bot-fly is stated by the makers to be quite a preventive against the gad-fly. The action of the non-poisonous dressing is to coagulate all parasitical insects, which then cease to breathe.

CHAPTER XII.

ELEMENTARY METEOROLOGY.

THE connection between meteorological changes and the production of disease are points on which we know little, but they are nevertheless of great interest. A reduction in the pressure of the air, an increase in its moisture, high or low temperatures, and an extremely electrical condition of the atmosphere, are conditions readily appreciated by ourselves, and undoubtedly also by animals; a careful study of them may in the future throw some light on the often mysterious outbreaks of epizootic diseases.

A reduction in atmospheric pressure on some people exerts very marked depressing effects, due to the vessels and viscera having a less external load to bear; an atmosphere loaded with moisture, with a high temperature, produces extreme innervation and languor, owing to the evaporation from the surface of the body being interfered with, and so on. It is, however, not upon individual condi-

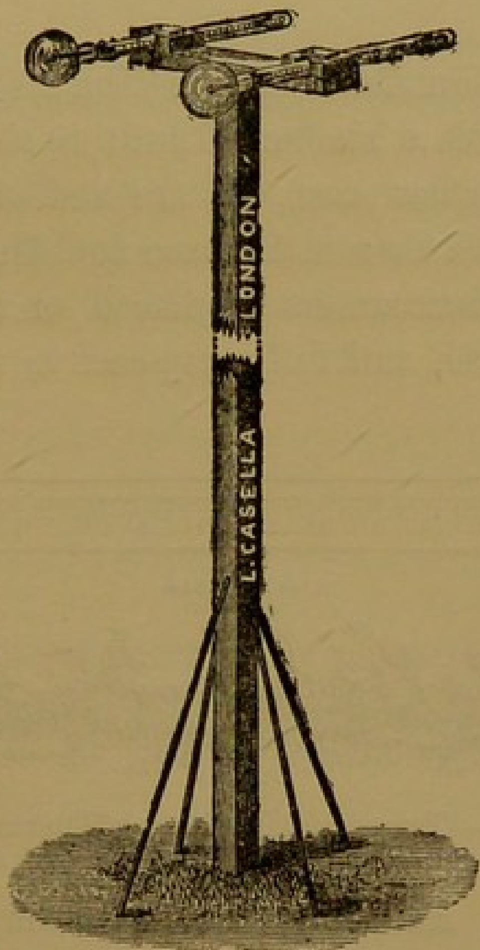


Fig. 84.—A pair of Solar Radiation Thermometers.

tions, but principally with reference to the outbreak or spread of epizootic diseases, that it is to be hoped meteorology may throw some light, notably in such diseases as influenza, catarrh, anthrax, and in the tropics fever and liver disorders.

The object of this chapter is to briefly describe those meteorological instruments commonly in use, and the general laws which they illustrate and are based upon.

Thermometers are used for the purpose of (1) ascertaining the heat which the earth receives from the sun—these are termed *sun maximum* or *solar radiation thermometers*; (2) to find out how much of that heat the earth gives back to the air—this is ascertained by the *terrestrial radiation thermometer*; (3) to determine the highest and lowest temperatures of the air in the shade by means of the *maximum and minimum thermometers.*

The solar radiation thermometer (Fig. 84) is a self-registering instrument with a blackened bulb to absorb the rays; it is enclosed in a glass case, on one end of which a bulb is formed; the space between the case and the thermometer is a vacuum. The instrument is placed on a stand about 4 feet above the earth, and fully exposed to the sun.

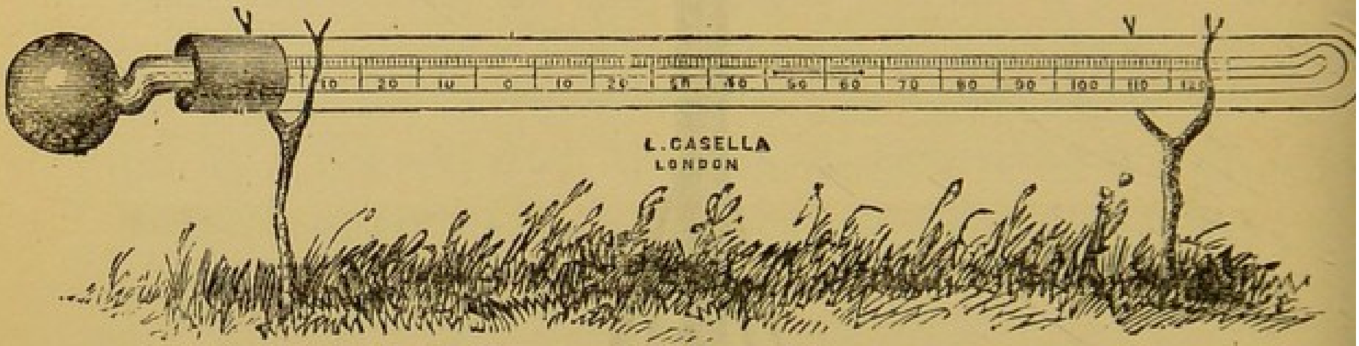


Fig. 85.—Terrestrial Radiation Thermometer.

The terrestrial radiation thermometer (Fig. 85) is a minimum one, for the reason that the abstraction of heat from the earth produces a cooling, the amount of which this instrument, which is a spirit self-registering one, indicates; the thermometer is placed on wooden Y's close to the ground, but not touching it.

The shade maximum is a self-registering mercurial thermometer (Fig. 86) placed completely in the shade, about 4 feet from the ground; the shade minimum (Fig. 87) is an alcoholic thermometer with a metallic index which renders it self-registering; it requires great care in use. The reading of all these thermometers is from the top of the index, viz., that extremity farthest from the bulb.

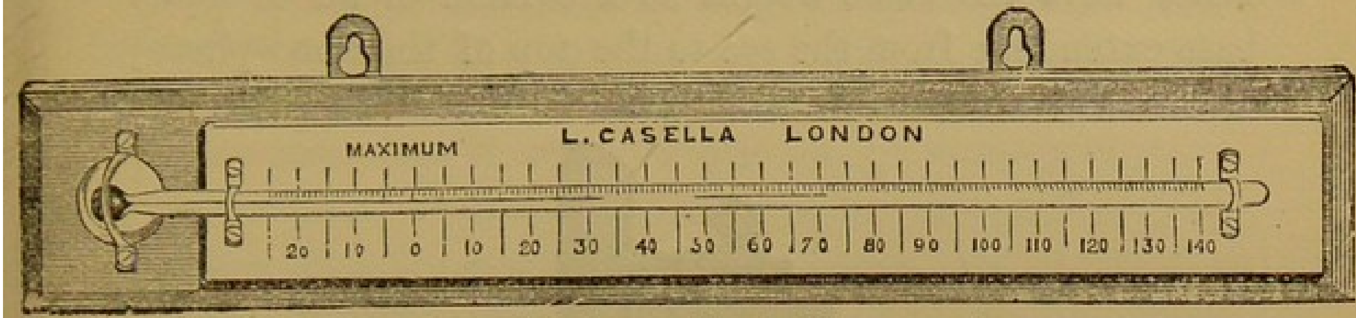


Fig. 86.—Maximum Shade Thermometer.

The difference between the readings of the maximum and minimum thermometers is the range of fluctuations, which may be expressed as daily, monthly, etc. The

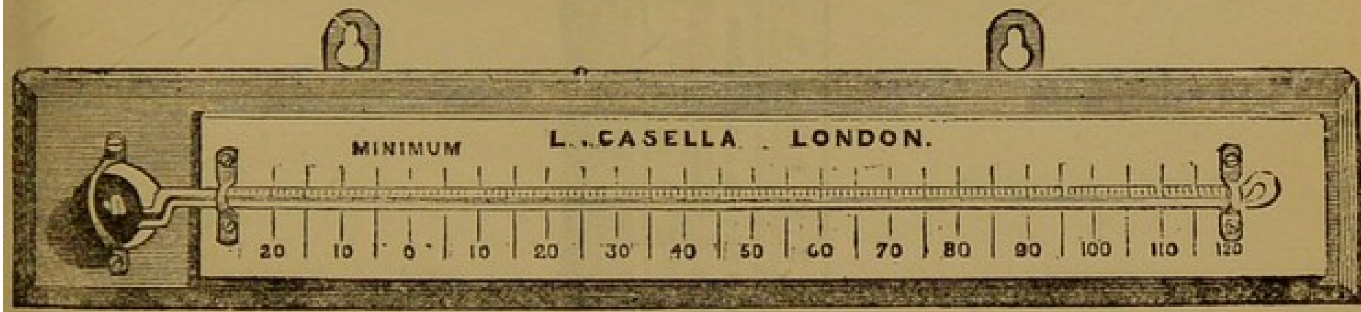


Fig. 87.—Minimum Shade Thermometer.

temperature of any place is affected by certain conditions, such as elevation above the sea-level, distance from the equator, nature of the soil, etc.

Isothermal lines are lines which encircle the earth, connecting places of equal temperature; they occasionally run parallel, but often widely diverge.

Self-registering thermometers such as Sixe's (Fig. 88), which mark the greatest heat and cold, are useful for ascertaining the temperature of stables and the daily variation. The index is metallic, and is set by means of a magnet. Readings are made from the top of the index.

A column of air, with its vapour, extending from the surface of the sea to the top of the atmosphere, will support a column of water 34 feet high, or a column of mercury 30 inches; therefore 30 inches of mercury or 34 feet of water have the same weight as a column of air of equal base extending from the sea to the top of the atmosphere;

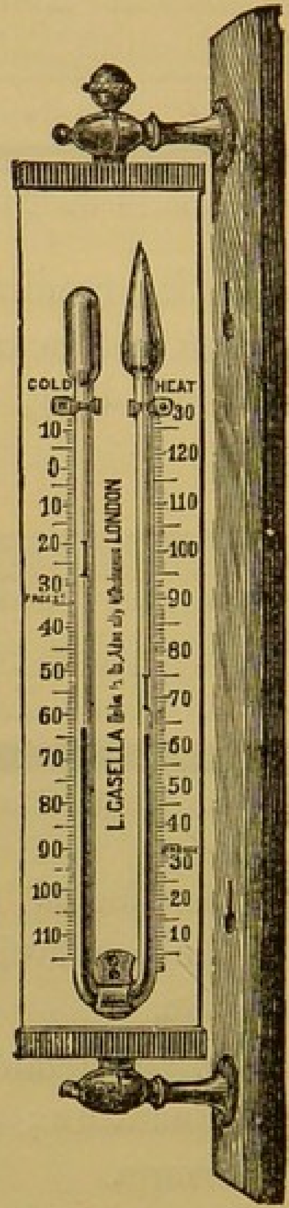


Fig. 88.—Sixe's Self-Registering Thermometer.

30 cubic inches of mercury weigh 14·75 lbs., so that the air exercises a pressure of 14·75 lbs. or, roughly, 15 lbs. on every square inch of the animal body. The body of an average-sized horse presents a surface of about 59·2 square feet, consequently the atmosphere presses upon it with a force

equal to 57.1 tons; but as the pressure is exercised in all directions this enormous weight is not felt. The density or weight of the atmosphere is not the same at all heights; the higher we ascend the less the weight: hence the rule, the density of the atmosphere is in proportion to the force which compresses it, or to its elasticity. The volume of a gas is inversely as the pressure; thus a cubic foot of air at the sea-level will occupy a bulk of 2 cubic feet at a height of $3\frac{1}{2}$ miles, or 16 cubic feet at 14 miles; on the other hand, 1 cubic foot of air taken at sea-level with the barometer at 30 inches will become half a cubic foot if the atmospheric pressure be doubled.

The Barometer (Fig. 89) is the instrument used for ascertaining the pressure or weight of the atmosphere. Many kinds are in use, of which the aneroid is the most convenient and simple; but for scientific work the standard barometer must be employed. The reading of the barometer requires a little practice, for the reason that the measurement of the height of the mercury must be read to the thousandth of of an inch; for this purpose the barometer has two scales, one on which the inches, tenths, and half-tenths are read, and the other a sliding scale or vernier by which the hundredths and thousands are read.

To Set the Barometer.—First read the attached thermometer, then adjust the mercury, by means of the bottom-screw, so that it barely touches the ivory point in the cistern, which, with its reflection, will then appear as a double cone; the height of the column is then taken by adjusting the lower edge of the vernier, so that it shall exactly form a tangent to the convex surface of the mercury in the tube, just excluding the light from the apex when the eye is in the same plane with the back and front lower edges of the vernier. Every care should be taken to avoid influencing the temperature whilst making the observation.

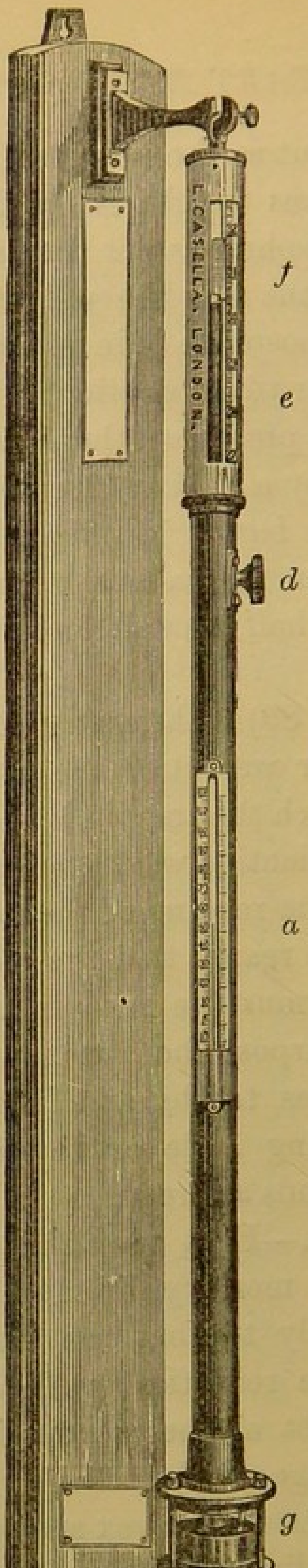


Fig. 89.—Fortin's Standard Barometer. *a*, Attached Thermometer ; *b*, Screw for adjusting the Mercury in the cistern *c*; *d*, Screw for adjusting the Vernier ; *e*, the Brass Scale ; *f*, the Vernier, to the left of the Brass Scale ; *g*, the Ivory Point in the Cistern.

In adjusting the level in the cistern, the mercury should always be *screwed up* to the ivory point; and if the point of the cone is submerged, the screw must be turned down until it is quite clear of the surface before the final adjustment

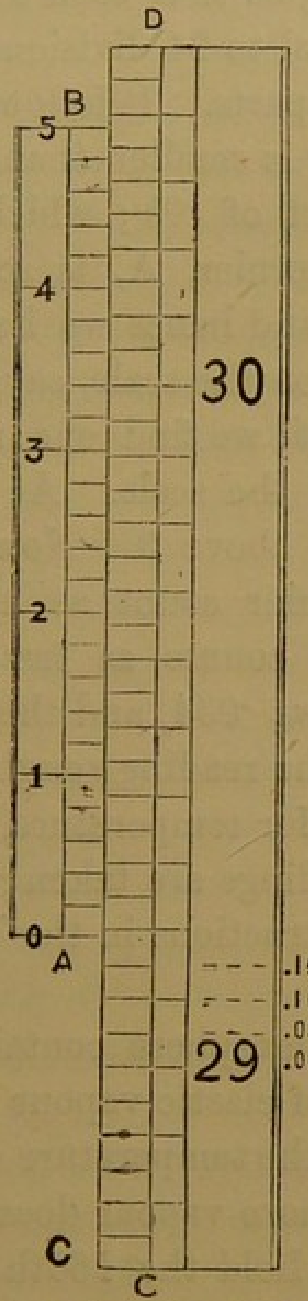


Fig. 90.—Diagram of Scale and Vernier (Casella).

is made. This precaution is necessary in order to preserve the same form of surface of mercury in the tube at different readings.

How to Read the Vernier.—By means of the annexed diagram (Fig. 90), the use of the vernier in ensuring accurate measurement is readily understood. C D represents part of the fixed scale of the barometer, and A B is the sliding scale or vernier. The scale C D is divided into inches, tenths, and half-tenths of an inch, so that each division of the scale is ·05; A B is made equal to 24 divisions of the scale, and is divided into 25 equal parts. It follows, therefore, that each division of the vernier is smaller than each division of the scale by the 25th part of ·05; which is ·002 inch. The lower edge of the vernier, A, is set to the top of the barometrical column, and hence we have to find the height of A. First we read on the scale, say, 29·15; next we look along the vernier until we find one of its lines which lies evenly with a line of the scale. As shown in the figure, this line is the second above 3. Now each of the figures engraved on the vernier count as hundredths, and each intermediate division counts as *two* thousandths (·002); hence the vernier shows ·034, and this added to the scale-reading 29·15, gives the reading sought, 29·184.

Certain corrections for temperature, altitude, etc., have to be made after the readings are taken; for a full account of these see Scott's 'Instructions in the Use of Meteorological Instruments.'

Humidity.—The atmosphere contains a certain amount of water in the form of elastic vapour; the quantity of this vapour depends upon the temperature of the air; the higher the temperature the more vapour does the air contain. Air at freezing-point will hold the 160th part of its weight as vapour, whereas at a temperature of 140° it will hold the 10th part; it therefore follows that if air at 140° is saturated with vapour, and this air becomes cooled down to 40°, it can no longer at this temperature hold the same vapour that it did at 140°; therefore all that it cannot take up is deposited in the form of rain, dew, etc.

The vapour of the air is elastic; the elasticity exerted will depend upon the temperature; the force it will exert on the mercurial column is known as its tension. A cubic foot of air may be regarded as made up of a cubic foot of *dry* air and a cubic foot of vapour. A cubic foot of dry air under a pressure of 30 inches of mercury will weigh at 32°, 566·85 grains, and at 60°, 536·28 grains. A cubic foot of vapour, under the same pressure, will at 32° weigh 2·13 grains, and at 60°, 5·77 grains; whilst a cubic foot of saturated air at 32° will weigh 565·58 grains, and at 60°, 532·84 grains; when dry air is mixed with watery vapour an increase in its bulk occurs, and the actual weight of the cubic foot is less than when in the dry state.

The *Dew-point* is that temperature at which the watery vapour present in the atmosphere is in a complete state of saturation, so that any further reduction of temperature will deposit the excess of vapour as dew. *Dew* is produced by the cooling of the earth—due to radiation of its heat into space—lowering the temperature of the air in contact with the earth, and cooling it below the point of saturation, the excess of moisture over and above that proper to the temperature being deposited. Radiation and cooling is greatly prevented by protecting the earth; on cloudy nights dew is rarely formed; on clear starry nights it is deposited in large amounts.

The dew-point is ascertained by means of the hygrometer, the most convenient form of which is the wet and dry bulb thermometers, Fig. 91. This consists of two delicate thermometers; the bulb of one is covered with muslin and kept constantly wet by a thread immersed in a vessel of water. The temperature of the dry bulb is the temperature of the air; whilst that of the wet bulb is the temperature of evaporation. If the air be saturated with vapour no evaporation will occur, and the temperatures of the two thermometers will read alike; whilst if the air be dry, evaporation is occurring, and the temperature of the wet bulb will read below that of the dry. The number of degrees the thermometer-readings differ, multiplied by a certain factor corresponding to the temperature of the dry bulb, produces a number which, if subtracted from the

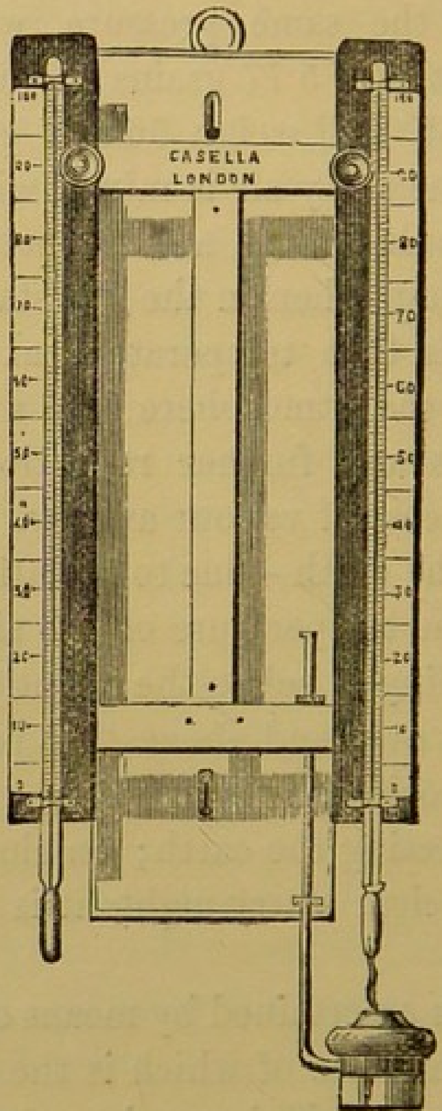


Fig. 91.—Wet and Dry Bulb Thermometers.

dry-bulb temperature, will give the dew-point. Thus: the dry bulb reads 66°, the wet 57°; difference = 9°. Factor corresponding to $66° = 1{\cdot}8$; $9 \times 1{\cdot}8 = 16{\cdot}2$; $66° - 16{\cdot}2° = 49{\cdot}8°$, the dew-point. The factors can be obtained in any work on meteorology, and are often supplied with the instrument.

From the dew-point the weight of vapour per cubic foot, and elastic tension in inches of mercury, can be ascertained by calculation or by tables.

The *Relative Humidity* of the air is a term used to denote comparative dryness or moisture; 100 being considered as complete saturation, any degree of dryness is expressed as a percentage of this (Parkes).

Rain is produced by the mixing of two currents of air of different temperatures, each saturated with the amount of vapour proper to their temperature; the cooling of the

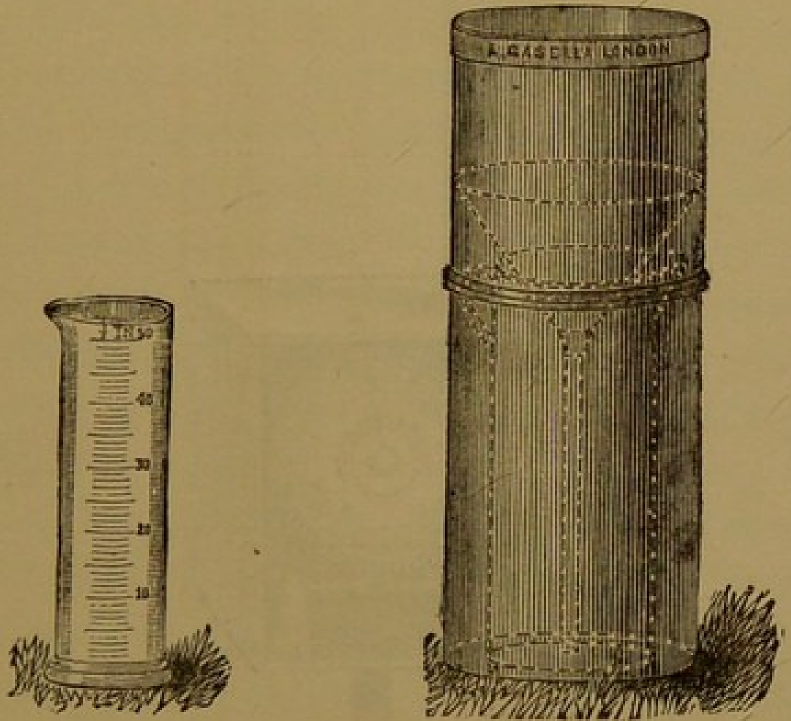


Fig. 92.—Rain Gauge.

vapour will produce an excess, which is deposited; rain may be produced by the ascent of damp air into the colder regions of the atmosphere.

Rain is measured by the inch, the amount being collected in a rain-gauge, Fig. 92, and poured into a glass vessel, which indicates cubic inches.

Wind.—The velocity is determined by means of the anemometer, Fig. 93, an instrument which registers the velocity by means of dials. The anemometer should not be placed near buildings or trees, or the record will not be correct. Instruments have been devised for recording the pressure of the wind, which is expressed in lbs. per square

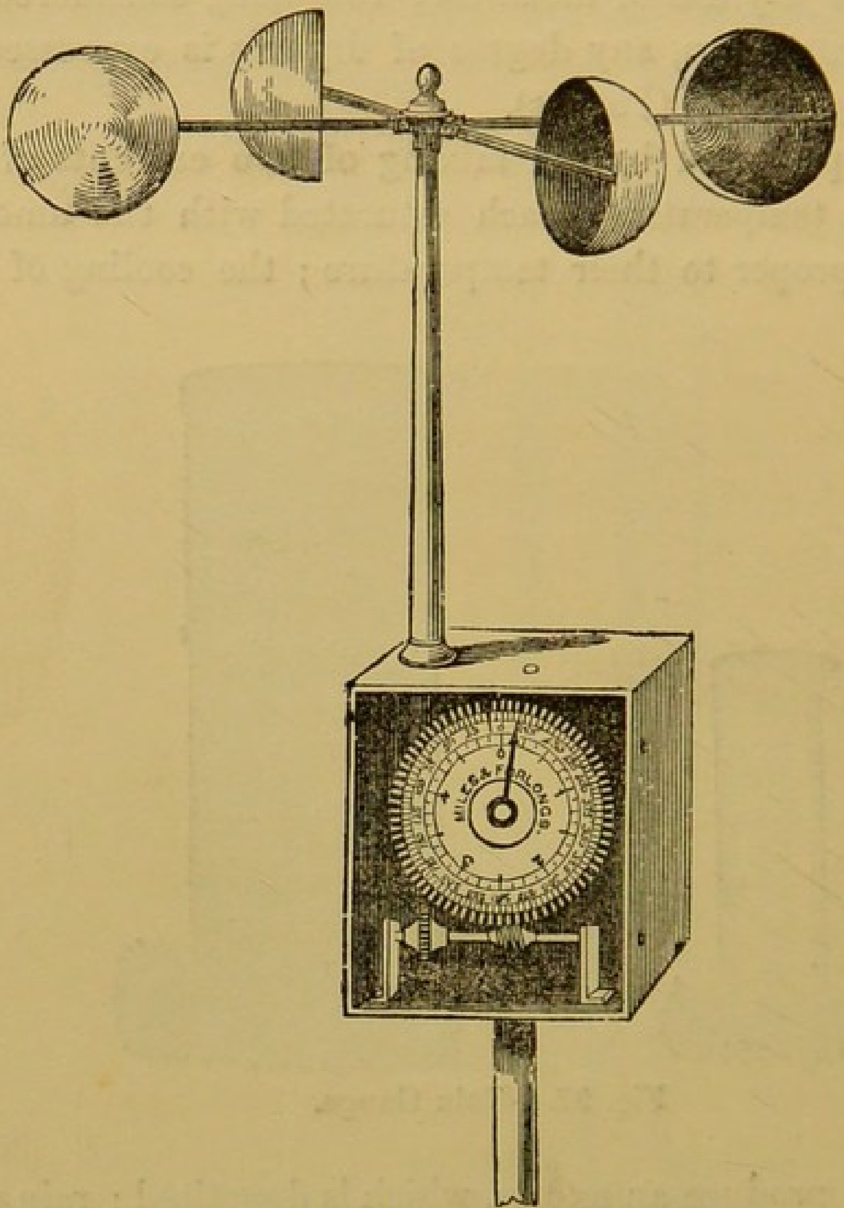


Fig. 93.—Robinson's Anemometer.

foot. Roughly, the velocity and pressure may be found in the Beaufort scale of wind, given in works on meteorology.

Clouds are masses of aqueous vapour; some of them in the higher regions of the atmosphere consist of needles of ice. Clouds have been named according to their shape; the primary types are *Cirrus*, or the mare's-tail cloud;

Stratus, the ground fog; and *Cumulus*, the woolpack cloud. By the different combinations of these types we have three more varieties formed.

Climate.—The extremes of temperature which the animal body will endure are remarkable. The highest monthly average temperature recorded amounts to 99°; this is at Massowah. Observations of the temperature in the sun's rays have registered as much as 150° in this country; in dry climates much more than this has been observed. Scott says that 214° has been registered in Cashmere, and in the Arctic regions as low as −81° have been recorded. A difference of over 200° can therefore be borne by man.

The heat which horses will stand is very great; provided they are not doing work, but simply standing for hours in the sun's rays, cases of insolation are very rare. If put to hard work during a high temperature, then cases of cerebral disturbance will occur. This would point to the fact that the carbonic acid generated in the system during work may have much to say to the production of insolation. In Calcutta, Bombay, and Madras, horses working during the heat of the day have their heads protected by means of a pith-hat, which fits over the ears and covers the forehead and top of the neck. This affords them that protection against the sun which working animals require in close streets at a high temperature.

Parkes records two long marches made by the Prussian army during very hot weather, when pack-animals and horses died from the severe exertion and high temperature. During the Afghan War horses died from the intense heat experienced in the still air of the passes leading into that country. An example of the endurance of cold by horses is recorded * of an expeditionary column of the French

* *Veterinarian*, 1869.

army operating in Algeria; the men suffered severely, but none of the horses were in the least affected by the cold. It is also stated that horses did not appear to suffer from the intense cold experienced in the Crimea, though living in the open air, and the thermometer so low that in one case a horse had his hoof frozen so firmly to the ground that a pickaxe had to be used to liberate it. On the other hand, we have recorded by Alison* the enormous losses of the French in their retreat from Moscow, during which hundreds of horses died every night from cold; and Napoleon himself stated that losses amounting to 10,000 horses in a single night were reported to him. In less than a week after leaving Moscow 30,000 horses had perished.

The influence of temperature on the production of disease has received much attention from medical men. William Farr first directed notice to the subject; he it was who stated that, after twenty years of age, the danger of dying from a fall of temperature is doubled every nine years.† We know nothing from a veterinary point of view in regard to the subject, although the influence of temperature must be undoubted. Speaking broadly, we may say that during high temperatures diseases of the bowels, liver, and nervous system are more frequent; and that when the mercury is low, diseases of the air-passages, influenza (?), and lameness (?), are more common.

The effects of atmospheric pressure on health have long been studied in man. The pressure of the blood in the vessels is greater, and the vital stamina less, when the barometer is low. In a paper published by Fleming,‡ on the 'Influence of Atmospheric Pressure and Altitude,' some very interesting points on this subject are discussed. It is

* 'History of Europe,' vol. viii.

† 'The Field of Disease,' Dr. Richardson.

‡ *Veterinarian*, 1868.

said that when the barometer is high, horses suffering from 'broken-wind' respire with more difficulty; and that convalescence from pneumonia is retarded. Increased atmospheric pressure has produced abortion amongst cows and mares in Italy. Animals working at very high altitudes, as on the Cordillera of Peru, suffer from a disease termed *veta*, due to the reduction in atmospheric pressure; there is great difficulty of breathing, and trembling, and if not rested they die: the air at this place is also remarkably dry, so much so that a dead mule is in the course of a few days converted into a mummy, there not being the least sign of decomposition. Jourdanet states that in the highlands of Mexico horses work badly, are often sick, and suffer from rheumatism and pleurisy as the result of the diminution in atmospheric pressure. To those interested in the geographical distribution of disease at different altitudes, this paper of Dr. Fleming's commends itself.

The influence of wind in the production of disease is proverbial. An easterly wind claims many victims every year. Exposure to certain winds in the tropics is supposed to produce paraplegia both in man and animals, and it is certain that all experience points to protecting the spine both from sun and wind. The sirocco of Africa is a moist hot wind, which produces considerable languor and depression.

An excess of moisture in the air is considered to favour the spread of contagious diseases; dryness of the atmosphere retards the reproduction of their virus to a considerable extent.

In the tropics during wet weather wounds assume an unhealthy appearance and often refuse to heal, sores become indolent and converted into ulcers, and anthrax is prevalent.

CHAPTER XIII.

STATISTICAL INQUIRY.

A LARGE and interesting field is open to the veterinary statistician, for the reason that with the exception of the returns furnished by the Privy Council regarding those diseases recognised by Act of Parliament as contagious, and the returns furnished by the Veterinary Department of the army, nothing has been done in the matter.

We have no idea what the loss of horses is in civil life, from either old age, accident, or disease; we do not even know how many horses there are in Britain, or the equine population of any of our large towns. The value of such information would be great, especially to the political economist.

We require reliable information respecting the distribution of disease in all classes of animals, and their mortality; the influence of season, sex, age, work, and management on the production of disease. We require to know for what period horses may be reasonably expected to last in our big cities, employed in the different capacities assigned to them; the influence of veterinary science in prolonging the useful life of the horse; the proportion of sound and unsound horses of different breeds; the common causes of unsoundness of each breed; and many other points of importance to the economist, veterinary surgeon, and private owner.

Many persons affect to ignore statistics, and it is usual to say that figures may be made to prove anything. This is not correct; statistics have their value when the data are reliable, and the matter carefully handled with the object of eliminating error. It is this last which must be so jealously guarded against, for, simple as it may appear to be to prevent errors entering into calculations, yet the subject is one which requires the most careful and logical handling to avoid arriving at incorrect conclusions.

The causes which may vitiate statistics are an incorrect, incomplete, and insufficient number of facts, and illogical grouping.

In compiling statistics, we have thus certain distinct points which require our careful attention.

An accurate collection of facts forms the foundation of statistical inquiry; without this it is impossible to avoid error. The importance of a correct diagnosis is here exemplified, there must be no doubt whatever as to the nature of the cases we are examining; if there is any doubt, such cases must be rejected from the inquiry. Let us take one or two practical examples. Suppose we wish to ascertain from a body of horses the number which have suffered from sprain of ligaments or tendons during the year. We must take care that every unit we accept has undoubtedly suffered from sprain, and that the word 'sprain' has not been used in the record of cases to cover any lameness which could not be diagnosed. In other words, unless we can see or feel the sprain, we cannot be warranted in recording the case as such; if we use the term 'sprain' to cover the many forms of obscure lameness to which the horse is liable, it is evident that the statistical results obtained from such data are worthless. Where it is difficult to make a diagnosis the case must be shown by itself as obscure, and only when the nature of the lameness is beyond all shadow of doubt should it receive a name.

Practical men well know how many cases of lameness they see, the nature of which is beyond all *shadow of doubt*;*

* My own opinion is that 50 per cent. of our lame cases are obscure, at any rate during the earlier stages of lameness.

and it only shows us how careful we should be, if our statistical results are to be worth anything, in assigning to no lameness a cause we cannot feel or see, or of which, from peculiarity of action, changes in the shape of a part, or history of the case, there can be no reasonable doubt as to the seat and nature of the disease.

One more example to show the necessity of accurately collecting facts. We will suppose a horse is seized with colic: he suffers pain for several hours; this ultimately subsides, and is succeeded by obstinate constipation, lasting for a few days, and ending in death from impaction and enteritis. At the post-mortem examination the cause of the trouble is found to be an intestinal calculus. There can be no doubt in a logical mind in which class such a case should be included; yet, according to a system which we have known pursued, the case would first be admitted for the attack of colic, and discharged relieved; re-admitted for constipation, and discharged relieved; and finally admitted for intestinal calculus or enteritis, and discharged died. Therefore, during this one illness, this horse swelled the list of admissions of two diseases which were only present in his particular case as symptoms, and he would accordingly vitiate the whole of the returns connected with the admissions and recoveries of these diseases. If this method of collecting facts regarding disease be carried out in a number of cases, it is easy to be seen how devoid of all value such statistical results must be.

Every unit forming part of a series representing any disease, must without doubt belong to this disease and to no other; if there is a doubt about it omit the unit entirely, and account for it under the heading of 'obscure.' It is not the compiler of statistics who is answerable for the correctness of the units; the responsibility rests with those who furnish them.

The second point to attend to is the grouping or arranging of the figures, so as to analyse what they really represent. This group-building, as Parkes says, seems simple, but in reality 'to properly group complex facts, so as to analyse them, and to bring out all the possible inferences, can only be done by the most subtle and logical minds.'

Let us suppose that we have collected the record of 12,000 cases of pneumonia, and we wish to learn from them the lessons they are certainly capable of teaching, if we only know how to extract them; we can ascertain the various causes producing the disease, the mean duration of the affection, the effects of certain methods of treatment, the mortality, etc. The part which will, however, most interest us as hygienists, are the causes in operation and the mortality; and one would probably find that some such plan as the following will be the most suitable method of inquiry: we should study the influence of season, age, pure and vitiated stable air, work, and the poison of influenza; these would be termed the dividing characters.

The influence of season we would ascertain by arranging the cases in the four quarters of the year in which they occurred, and comparing them; the influence of age would be obtained by arranging the cases according to their ages; the influence of work, sex, and temperament would all be ascertained in like manner.

In grouping results, it is very difficult to arrange the dividing characters so that all the cases selected will fit into them, and that one case will fall only to one group, and to no other; a disregard of this latter rule, viz., that no case can appear in two groups at the same time, will render all groupings worthless.

In observations extending over a series of years, we have an opportunity afforded us of ascertaining whether there is an improvement in the general health, and a decrease in the mortality; and by a careful consideration of facts we can be led to determine the causes acting beneficially or otherwise in this direction.

A sufficient number of facts is absolutely essential if any correct deductions are to be drawn. Conclusions based on a small number of observations are insufficient to establish a fact, for the reason that it can be mathematically demonstrated, that where the number of units is small, the chances that the same result will be obtained again with a similar number of cases is highly improbable; whereas, when deductions are drawn from a large number of units the chances of error are less, and the probability is that with a similar number like results will be obtained on another occasion. The reason why this is so can be readily appreciated; errors in a few numbers alter considerably the value of the results, whereas errors acting through a large series of numbers tend to neutralize each other, owing to some being greater and others less than the real value.

To ascertain the possible error in excess or defect of the truth Poisson's formula is used; it is absolutely necessary to employ this method of ascertaining the limits of error when the units on which the calculations are based are small in number, and especially when the results affect such important subjects as mortality.

Poisson's Rule for Calculating the Limits of Error (Parkes).

Suppose there are two events, E and F, say death or recovery in a certain disease, and let

m = the number of times that E has occurred
n = " " " F " "
μ = the total number of cases (*i.e.*, of death and recovery).

If B represents the mean chance that the event E will occur, then it is 212 to 1 that the mean chance will lie within the limits given by the following calculation:

$$\frac{m}{\mu}+2\sqrt{\frac{2\,.\,m\,.\,n}{\mu^3}}$$

$$\frac{m}{\mu}-2\sqrt{\frac{2\,.\,m\,.\,n}{\mu^3}}$$

That is to say, two sums are to be done:

1st, $m \div \mu$ and *added* to the square root of $2 \times m \times n$, divided by μ^3, and the product doubled.

2nd, $m \div \mu$ and *substracted* from the square root of $2 \times m \times n$, divided by μ^3, and the product doubled.

Example.—A practitioner, by a certain method of treatment, has saved seven horses out of ten affected with tetanus; his mortality is therefore considered to be 30 per cent., or 30,000 deaths in 100,000 cases, which would be marvellously low. Ascertain by means of the above rule how near this is to the real percentage, viz., find out the amount of error resulting from the use of a small number of events.

$m=3$, the number of deaths.
$n=7$, " recoveries.
$\mu=10$, the total number of cases.

The limit of error is ascertained by the second half of the formula:

$$2\sqrt{\frac{2\,.\,m\,.\,n}{\mu^3}}$$

which will be thus arranged:

$$2\sqrt{\frac{2\times3\times7}{(10)^3}}$$

$2\times3\times7\div1000=\cdot042$ and $2\sqrt{\cdot042}=\cdot4$ to unity (the possible error), or an error of 40,000 in 100,000 cases.

Deaths per 100,000.		Error per 100,000.		
30,000	+	40,000	=	70,000
30,000	−	40,000	=	—

In other words, the possible error is *greater* than the number of cases, and the original statistical deduction of 30 per cent. deaths is an absurdity.

Or, if we apply the limit of error to the recoveries, it will perhaps illustrate the point more clearly.

The recoveries were 70 per cent., or 70,000 in 100,000 cases. The limit of error is 40,000 in 100,000 cases. Therefore,

$$70{,}000 + 40{,}000 = 110{,}000 = 110 \text{ per cent. recoveries.}$$
$$70{,}000 - 40{,}000 = 30{,}000 = 30 \quad \text{,,} \qquad \text{,,}$$

The recoveries would therefore range between 30 per cent. and 110 per cent., which is nonsense.

When we have a large number of units collected, which have been operating through a length of time, representing such events as ages, deaths, castings, destructions, etc., we can ascertain by means of an average the mean value of these collected figures. The average will not necessarily give the value of any one unit of the group, for, by producing an average, it is almost sure to be either above or below the actual value of any one unit; but it will give us a general value of the whole series. For example, a regiment of 365 horses has an average age of 8 years; it by no means follows that all or any of the horses are 8 years old, many will be above or below—in fact the ages of the horses will vary from 3 years to 20 years old. The quantities either above or below the average are termed the extreme values; as Dr. Parkes expresses it, extreme values are the two ends of the scale, of which the average is the middle.

In expressing statistical results some constant means of comparison must be adopted, such as per cent., per 1,000, or per 10,000, etc. The most common standard used is per cent.

To ascertain the percentage is a rule-of-three sum. Suppose, for instance, that in a strength of 3,978 horses

428 cases of strangles occurred, causing 12 deaths, we can ascertain—

(1) What proportion of the horses were attacked.

(2) Of those attacked, what was the mortality.

(3) Of those attacked, what were the recoveries.

(4) What was the mortality on the total strength.

One or two examples of the working will suffice for the others :

In 428 cases of strangles there are 12 deaths, what is the mortality per cent. of those attacked ?

$$\frac{12 \times 100}{428} = 2 \cdot 804 \text{ per cent.}$$

In 428 cases of disease there are 12 deaths, what proportion per cent. recovered ?

$$\frac{416 \times 100}{428} = 97 \cdot 196 \text{ per cent.}$$

The value of statistical inquiry in questions relating to health, disease, mortality, castings, etc., is obvious. We should know the proportion of horses which are constantly sick, the average length of time under treatment, and the money loss to their owners which this represents. We should prove by figures the value of our services to the State and public in the suppression of epizootics, the rational treatment of disease, and, above all, its prevention among large bodies of animals by the exercise of that most exact branch of our science—hygiene.

The most important points which require to be dealt with in veterinary statistics are :

(1) The animal population, and its rate of increase.

(2) Regarding the increase, we should know the proportion of male and female births ; of premature and still-born births ; also the proportion of animals which may prove

barren, and the proportion of deaths occurring amongst young animals during their first year of life.

(3) The amount of sickness and mortality among horses in military and civil employment, grouped according to diseases, seasons, ages, sex, and occupation.

(4) The mean duration of life, grouped according to occupation.

(5) The principal causes of unsoundness among horses, grouped according to breed and occupation, showing the mean age at which permanent unsoundness becomes developed.

(6) The mean period for which useful work may be expected from a horse, grouped according to occupation.

I may say at once that we have very little information on any of these points; taking the first, we have no knowledge of the total number of horses in the United Kingdom; the information furnished by the Privy Council only deals with horses of the agricultural class, and horses kept solely for breeding.

	England.	Wales.	Scotland.	Great Britain.
Number of Horses of the above class in 1876 ...	1,057,545	128,363	188,688	1,374,576
Number in 1886 ...	1,094,116	140,113	191,130	1,425,359
Cattle*—1875† ...	4,054,074	631,712	1,127,337	5,813,123
" 1885	4,324,640	666,286	1,116,876	6,109,803
Sheep—1875†	18,717,511	2,911,385	7,161,122	28,790,018
" 1885	15,832,670	2,598,153	6,883,592	25,314,416
Swine—1875†	2,100,314	218,410	166,148	2,484,872
" 1885	2,066,241	117,713	148,850	2,432,804

Births.—The proportion of male and female births I have ascertained for the thoroughbred horse to be as follows:‡

* These figures I have taken from the statistical tables of the Agricultural Department of the Privy Council, kindly furnished me by Professor Brown.

† The numbers given for the year 1875 are the mean of the years 1871-75; and those for 1885 are for the years 1881-85.

‡ Obtained from the figures given in the 'Stud Book.'

49·7 per cent. of the total births are colts, and 50·3 are fillies. For every 1,000 fillies there are 989·06 colts born. I do not know what the proportions are among other animals. With the human race there are more males than females born.

Of every 100 mares (thoroughbred) put to the horse, 25·5 per cent. prove barren; the returns do not show whether the mares were permanently barren, or whether they proved fruitful in after years or in alternate years; of every 100 mares in foal, 4·04 per cent. abort.

The mortality among brood mares is 4·27 per cent. per annum; of the ages at death I have no data to hand; this death-rate would correspond in a woman to living to between 60 and 70 years of age.

The mortality among army horses, including destructions, will vary from $1\frac{1}{2}$ per cent. to $2\frac{1}{2}$ per cent.; after the first Egyptian campaign, the mortality rose to 4·7 per cent., which was exceedingly high.

The amount of sickness among animals in civil life we have no idea of. The returns furnished by the Agricultural Department of the Privy Council only deal with epizootic diseases; in the army alone, and a few public companies which keep returns, can we obtain the required information.

Between 60 per cent. and 70 per cent. on the total strength of army horses are admitted to treatment during a year; many of the diseases are wounds and contusions, which in civil life would not be allowed to interfere with the animal's work; the number of days' service lost yearly to the State, by each horse sick, is about twenty.

Where care is exercised, and an animal's work only stopped when really necessary, it will generally be found, among any large body of horses, that from 4 per cent. to 5 per cent. are constantly sick or lame.

The normal duration of life, for obvious reasons, is very difficult to fix. I considered the best plan of obtaining it would be to ascertain the age at death of all animals which during their life had been well cared for and not overworked; for this reason I selected the thoroughbred stallion, and obtained the age from the 'Stud Book.' The mean age at death from natural causes is 17·34 years. The mean age of those destroyed (old age, broken legs, etc.) was 22·84 years.

The probable duration of life is about 18·29 years. In the figures examined, the extremes were 5 years and 33 years.

From the elaborate article by Dr. Balfour,* which we have previously had occasion to refer to, we can obtain much information respecting the age at death of working horses (the observations are from the records of the French cavalry): the highest mortality occurs at 4 years of age, and decreases till 11, when it reaches the minimum. The chief deaths occur at 4, 5, and 6 years of age. More mares die than horses—the excess is equal to $4\frac{1}{4}$ per 1,000; on the other hand, 11 per 1,000 more horses are cast than mares. The total loss of geldings over mares is $6\frac{3}{4}$ per 1,000 greater.

Castings.—The chief cause of casting is for worn-out legs, 2·8 per cent.; incurable lameness, 1 per cent.; broken wind, 5 per cent.; old age, 13·4 per cent.

Influence of Season.—More horses are sick in April, May, and June, and fewer in October, November, and December. Diseases of the lungs are most frequent during the second quarter of the year. Strangles is most frequent in the second quarter, and least in the fourth. Diseases of the bowels are more frequent during the third quarter, and least during the first quarter of the year.

* 'Vital Statistics of Cavalry Horses,' Journal of the Statistical Society, June, 1880.

It must be remembered that these results are from French army horses. Climate, breed, stable management, and many other points may cause them to differ widely from what occurs in England.

The period for which horses will stand work varies with its nature. Cab-horses work for about 2 or 3 years; from information kindly furnished by the companies, I learn that the horses of the London General Omnibus last about $5\frac{1}{2}$ years, and those of the Tramway Companies for a similar period. These companies only purchase between the ages of 5 and 7 years.

The army horse works for about 8 or 9 years; but as he is purchased between 3 and 4 years of age, we get but a few more months' work out of him than the Omnibus and Tramway Companies get out of their horses, and have to give in return for it at least 2 years' keep, and run the risks incidental to youth. Before army animals arrive at the mature age of those purchased by big companies, *they cost in keep what would buy another horse.* In other words, the Government pays twice for what the private individual pays once.

APPENDIX.

Decimal Parts of a Foot.

12 inches	=	1·00	decimal part	of a foot.
11 „	=	·92	„	„
10 „	=	·83	„	„
9 „	=	·75	„	„
8 „	=	·67	„	„
7 „	=	·58	„	„
6 „	=	·50	„	„
5 „	=	·42	„	„
4 „	=	·33	„	„
3 „	=	·25	„	„
2 „	=	·17	„	„
1 „	=	·08	„	„

Liquid Measures.

The imperial gallon	=	10 lbs. water at 62° Fahr.
1 pint	=	34·66 cubic inches.
1 quart	=	69·318 „

Dry Measures.

4 quarts	=	1 gallon.
2 quarts	=	1 pottle.
2 pottles	=	1 gallon.
2 gallons	=	1 peck.
4 pecks	=	1 bushel.
1 bushel	=	8 gallons.
8 bushels	=	1 quarter.

According to Act of Parliament a bushel is defined as a hollow cylinder having a plane base, the internal diameter of which is double the internal depth. The imperial bushel will contain 80 lbs. weight of water.

1	bushel of	Wheat	is on an average		60 lbs.
1	,,	Barley	,,	,,	47 ,,
1	,,	Oats	,,	,,	40 ,,
1	,,	Oatmeal	,,	,,	50½ ,,
1	,,	Peas	,,	,,	64 ,,
1	,,	Beans	,,	,,	63 ,,
1	,,	Malt	,,	,,	38 ,,
1	,,	Linseed	,,	,,	53 ,,
1	,,	Maize	,,	,,	66 ,,
1	truss of	Straw	,,	,,	36 ,,
1	,,	old Hay	,,	,,	56 ,,
1	,,	new Hay	,,	,,	60 ,,
1	load of Hay or Straw			=	36 trusses.

Hay is considered new until 1st September.

Measures of Surface and Solidity.

144	square inches	=	1	square	foot.
9	,, feet	=	1	,,	yard.
1728	cubic inches	=	1	cubic	foot.
27	,, feet	=	1	,,	yard.

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