THE GEOLOGIC HISTORY OF CHINA AND ITS INFLUENCE UPON THE CHINESE PEOPLE

BY

PROF. ELIOT BLACKWELDER
University of Wisconsin

FROM THE SMITHSONIAN REPORT FOR 1913, PAGES 385-396
(WITH PLATES 1-9)

(PUBLICATION 2292)

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[With 9 plates.]

The Chinese Empire includes an area larger than the United States with the addition of Alaska and our insular possessions. A large part of this vast area, however, is made up of dependencies which are but loosely joined to China proper, and are not essential to its integrity. She has lost and regained these dependencies from time to time in the past, and the same process may continue. The accompanying map will serve to show the relation of these component parts of the Empire to each other and to surrounding countries.

Divested of its outlying possessions, China consists of 18 Provinces, which may be compared in a general way to our States. The Provinces are, however, generally larger than the States and, on the whole, much more populous. There is still greater dissimilarity in government because, whereas our States are representative democracies, the Chinese Provinces were, at least until within a year or two, satrapies ruled absolutely by imperial governors or viceroys.

Not a few people in America picture China as a vast fertile plain, perhaps like the upper Mississippi Valley, densely populated and intensively cultivated. In fact, however, it is so generally mountainous that less than one-tenth of its surface is even moderately flat. On the west, especially, it is ribbed with cordilleras from which its two great rivers, the Yangtze and the Hwang, flow eastward to the Pacific.

In addition to this diversity of surface, there is also much variety of climate. In the northwest the conditions are dry and severe, like those of Montana and central Wyoming, while in the southeast they are humid and subtropical, approaching those of the Philippine Islands. Such are the extremes.

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It is a fact well known to geologists that continents, and therefore countries, have not always existed in their present state, but that they have been built as a result of successive events and changes of conditions. If we were to dig beneath the surface in any part of China, we should find first one stratum and then another, and we should see also that these strata have been bent, cracked, and otherwise disturbed. Some of these structures are old and some young. It would be somewhat like excavating in an ancient city, where one house or temple has been built upon the ruins of its predecessor, and each affords a crude record of its time. The geologic structure of such a country as China has been determined largely by the rocks of which it consists, partly by the climate to which it has been subject, but chiefly by the geologic events which have occurred during its history. Of course the beginnings of that history are unknown, just as the human history of China shades into darkness when we attempt to trace it back into the remote ages. But the present features of the land are chiefly due to the later events in its life, and these have been partly worked out by the geologists who have explored its surface.

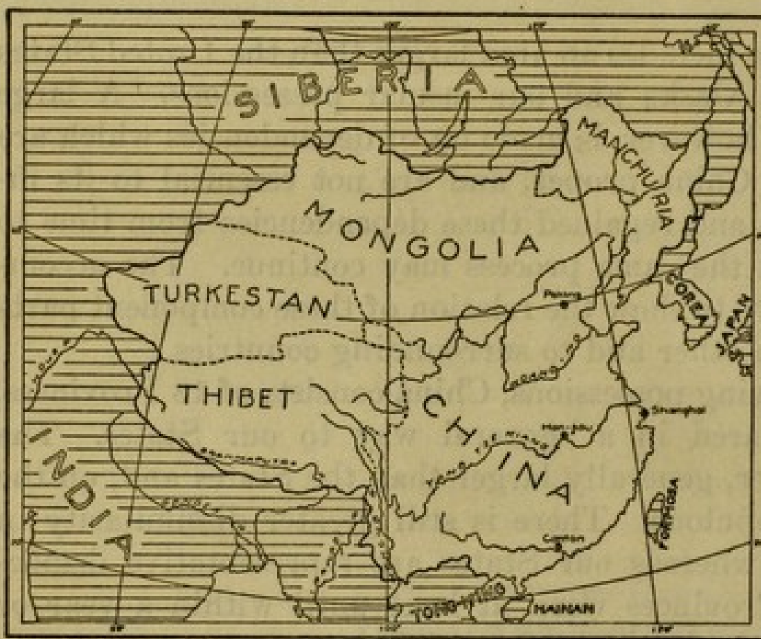


Fig. 1.—Sketch Map of China.
Showing its outlying dependencies and its relation to other countries.

We may take as a convenient starting point for our interpretation a time far back in geologic chronology,[1] when China was a land surface which had been exposed to erosion so long that nearly all the hills and mountains that may have existed there before had been worn away, leaving a relatively flat plain, with groups of low hills here and there. The rocks beneath this plain were of various kinds, most of them highly folded. Eventually this surface was submerged beneath a comparatively shallow inland sea; and although the uneasy movements of the earth's body caused the sea bottom to emerge occasionally, it remained below the water nearly all through the geologic periods which constitute the Paleozoic era. By the end of that time

[1] Just before the Cambrian period.

RELIEF MAP OF CHINA PROPER, SHOWING THE RELATIONS OF PLAINS TO MOUNTAINS.

we may picture China as a shallow sea bottom rising very gradually to a marshy coastal plain on the east. During the long intervening ages the accumulation of sediments upon the sea bottom had formed successive layers of limestone, shale, and sandstone, which eventually reached a thickness of 5,000–10,000 feet.

This condition did not hold without end, for eventually[1] strong compressive forces engendered in the underlying body of the earth squeezed the superficial rocks into folds, and thus bulged the surface high above sea level in the region so affected. By the prompt attack of streams, winds, glaciers, and the other agencies which are incessantly sculpturing the surface of the earth, these elevated districts were, even while rising, carved into rugged mountains and deep valleys, so that the original folds were greatly disfigured, even before the compressive forces ceased to operate.

It is a fact generally recognized among geologists that in terms of geologic time such episodes of compression and folding are short lived. They are soon followed by much longer periods, during which the internal forces of the earth are quiescent but in which the erosive agencies have free play. If any land remains indefinitely above sea level and is not disturbed by movements from below, the mountains and hills will eventually be worn away and there will be left only a broad, almost featureless, plain. It is believed that China, in consequence of such a period of quiescence,[2] was reduced to a lowland from which almost all of the preexisting mountains had been removed. In this condition it probably remained for more than one geologic period, and the western part may even have been submerged beneath the sea which at that time covered northern India and part of Tibet. In that sea were deposited the thick beds of limestone which are now found in some of the western mountain ridges.

Again, in the Miocene period the forces of distortion within the earth accumulated to such strength that they were able to repeat the mashing and folding, but this time the area affected lay farther to the west and south. At the same time, or perhaps earlier, the eastern part of China was cracked in various directions; and the intervening blocks, settling somewhat unevenly upon their bases, left a group of escarpments and depressions comparable to those now to be found in western Nevada and southern Oregon. As before, the work of erosion and the leveling of the surface was at once accelerated, so that even before the deformation had spent itself the blocks were deeply scarred. It is uncertain how far this period of erosion succeeded in reducing China to base level. The consummation may have been prevented by gentle warpings of the surface, rising very slowly here and sinking there. When compared with the great breadth of the

[1] Jurassic period.

[2] Cretaceous and Eocene periods.

areas affected, these changes of level seem very slight, but they are nevertheless sufficient to cause great changes in the aspect of the country.

It is one of the basal principles of physiography that streams tend to produce in their channels an almost uniform slope from their headwaters to the sea. If any part of the channel is so flat that the stream

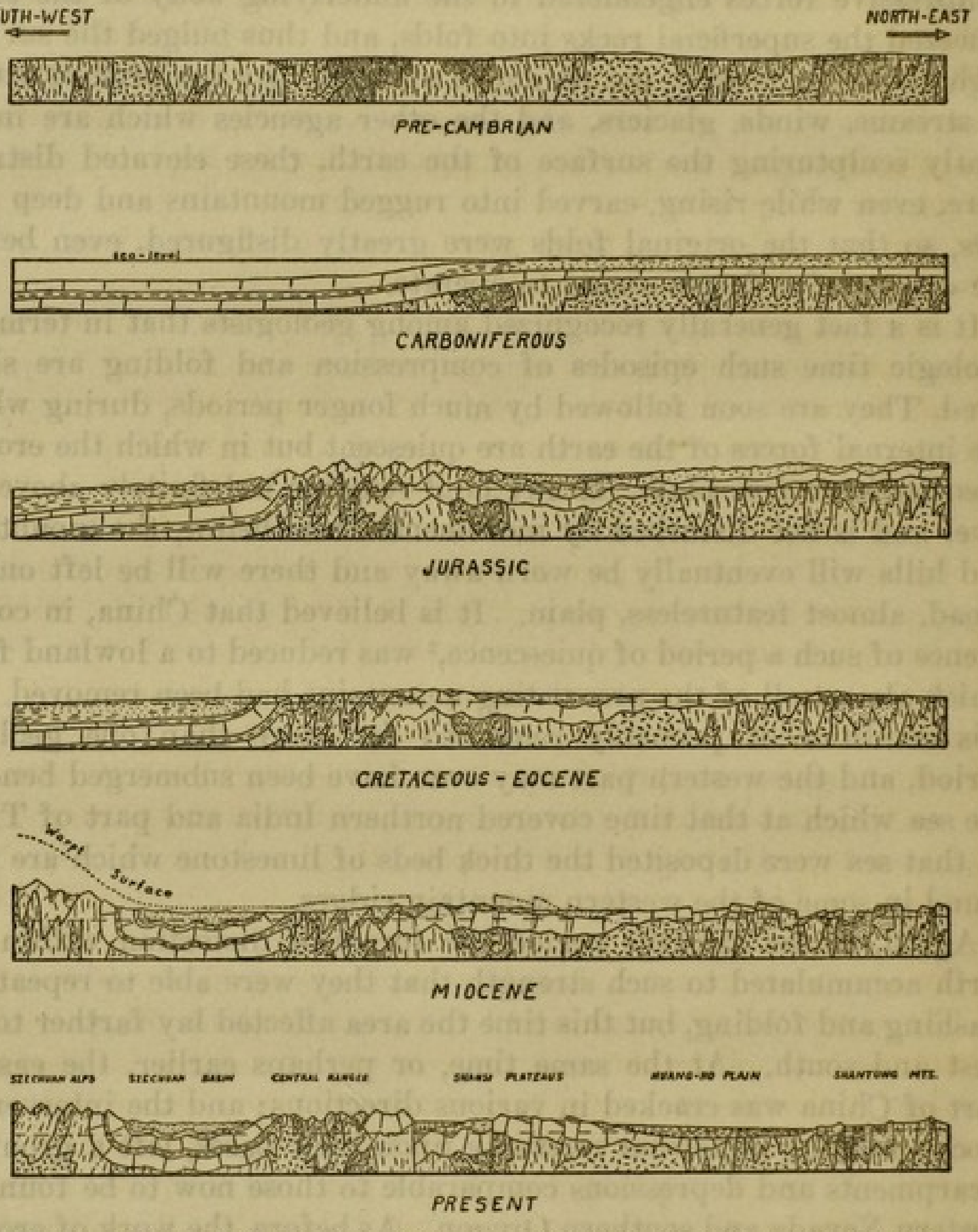


FIG. 2.—DIAGRAMS TO ILLUSTRATE GEOLOGICAL CONDITIONS IN CHINA AT DIFFERENT PERIODS IN ITS HISTORY.

The features are necessarily much generalized and in part hypothetical.

is too sluggish to carry sediment, it is built up until it reaches the required gradient; and on the other hand, if any part has too steep a declivity, it is gradually worn down to the proper slope. In consequence of this law, the parts of China which were slightly bulged above their original levels were reattacked by the branching systems of rivers with renewed vigor. By carving out the softer rocks, these have made deep valleys with intervening mountain ranges. Some of the larger rivers, such as the Yangtze, maintained their courses in spite of the slow uplifts directly athwart their courses. A result is the magnificent series of gorges along the central Yangtze where the great river has sawed its way through a slowly rising mass of hard, complexly folded rocks.

On the other hand, the broad areas which were depressed not only below the general level of stream action, but below sea level, were rapidly filled with sand, loam, and clay washed down out of the adjacent mountains by the streams. The process of filling the depressions is the exact complement of the process of etching out the highlands. No doubt the rivers have been able in large measure to keep pace with the sinking movement of the ground, so that great rivers like the Hwang may have maintained perfectly graded courses across the region of depression from the mountains to the sea. While thus engaged in building up its channel, the river in time of flood frequently breaks through its low banks, shifts its channel, and then begins to fill up a new and hitherto lower part of its surroundings. By the long continuance of this process of repeated shiftings and fillings, the great eastern plain of China and many smaller plains have been produced. It is here, where the population is densest and the rivers least confined, that the devastation by floods and their attendant famines is greatest.

By this succession of events the surface of China is believed to have reached its modern condition. We may now consider it piecemeal and see how the existing geologic conditions, which are the result of this long series of past changes, influence the habits, occupations, and even mental traits of the people. Because space is limited and also because I have not seen all the physiographic divisions of China, it will not be possible for me, even briefly, to describe each of them. A few are therefore selected to show the range of variety of the whole.

The mountains of northeastern China, typified by the province of Shantung, are unlike those of the rest of the country in several respects. Although the individual peaks are often sharp and rocky, they are generally separated by wide, flat-bottomed valleys. The process of erosion has here gone so far that the rivers have already carried away most of the land, leaving only isolated groups of low mountains. The broad valleys accommodate a relatively large number of people, who congregate in the villages dotting the intermontane plains. In contrast with most mountainous regions, travel between the different valleys is comparatively easy here, because many of the passes are but little higher than the plains themselves, and constitute scarcely any obstacle to progress. Roads are plentiful, and so the cart and the wheelbarrow are the principal vehicles for through traffic.

This is one of the few parts of China where boats can be but little used. The streams are shallow and full of sand bars, and on account of the pronounced wet and dry seasons many of them are intermittent. For these reasons the majority of them are not navigable. The deeply eroded land of Shantung has, however, suffered a relatively recent movement—apparently a sinking of the land—which has allowed the ocean to penetrate the mouths of many of the coastal valleys. This marginal drowning has produced some excellent harbors, such as that of Chefoo, the great silk port, and Tsingtau, the German stronghold.

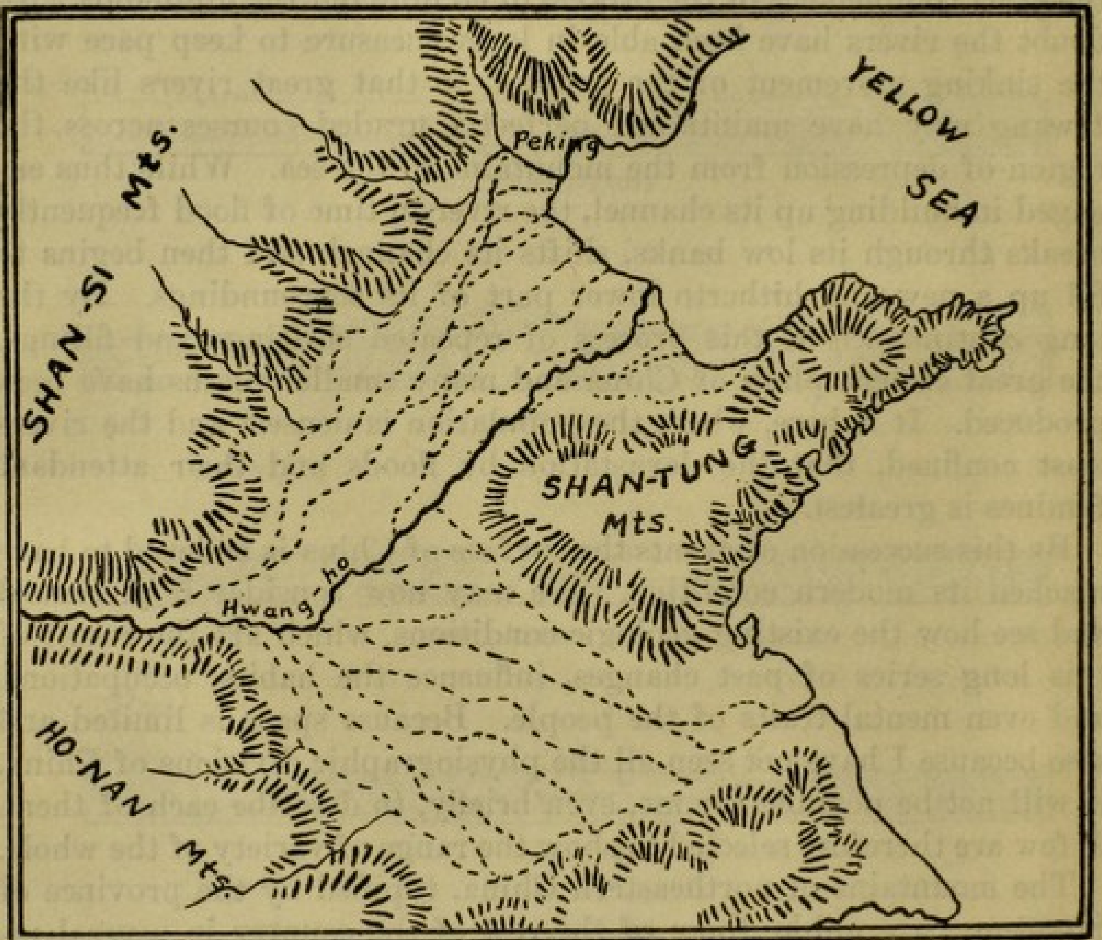


FIG. 3.—SKETCH MAP OF THE SILT PLAIN OF THE YELLOW RIVER.
The dotted lines indicate former courses of the river, as it spread over its alluvial fan.

On the west, and encircling the Shantung hills, lies the great plain of the Hwang or Yellow River, which will serve as the type of many much smaller plains in various parts of China. As explained before, this vast gently sloping plain has been built by the Yellow River and some of its tributaries in an effort to preserve a uniform gradient across the sunken portion of eastern China. Like the Lower Mississippi and all other rivers which are building up rather than cutting down their beds, the Hwang is subject to frequent floods and occasional shiftings of its channel. Its course between the mountains and the sea has thus been changed more than

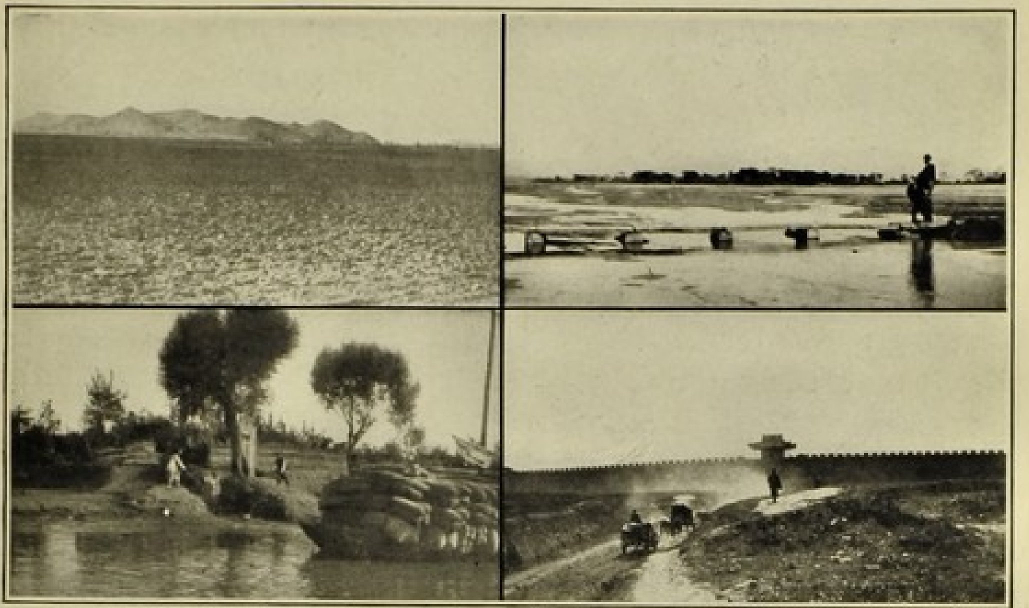


Fig. 1.—Low isolated mountain group in northeastern China.
Fig. 2.—Two farmers raising water from the grand canal into the head of an irrigating ditch by means of a wicker basket slung between them.
Fig. 3.—A wide River Plain among the mountains of Shan-Tung. The bridge of stone slabs across the sand-laden river is part of the principal wheelbarrow road of the valley.
Fig. 4.—A typical city wall, with gate tower.

Fig. 5.—Heavily loaded freight wheelbarrows with mules for motive power.
Fig. 6.—A typical passenger cart.
Fig. 7.—Freight wheelbarrows rigged to take advantage of a favorable wind.
Fig. 8.—A medium-sized house-boat used on the Yang-tze-Kiang and its tributaries.

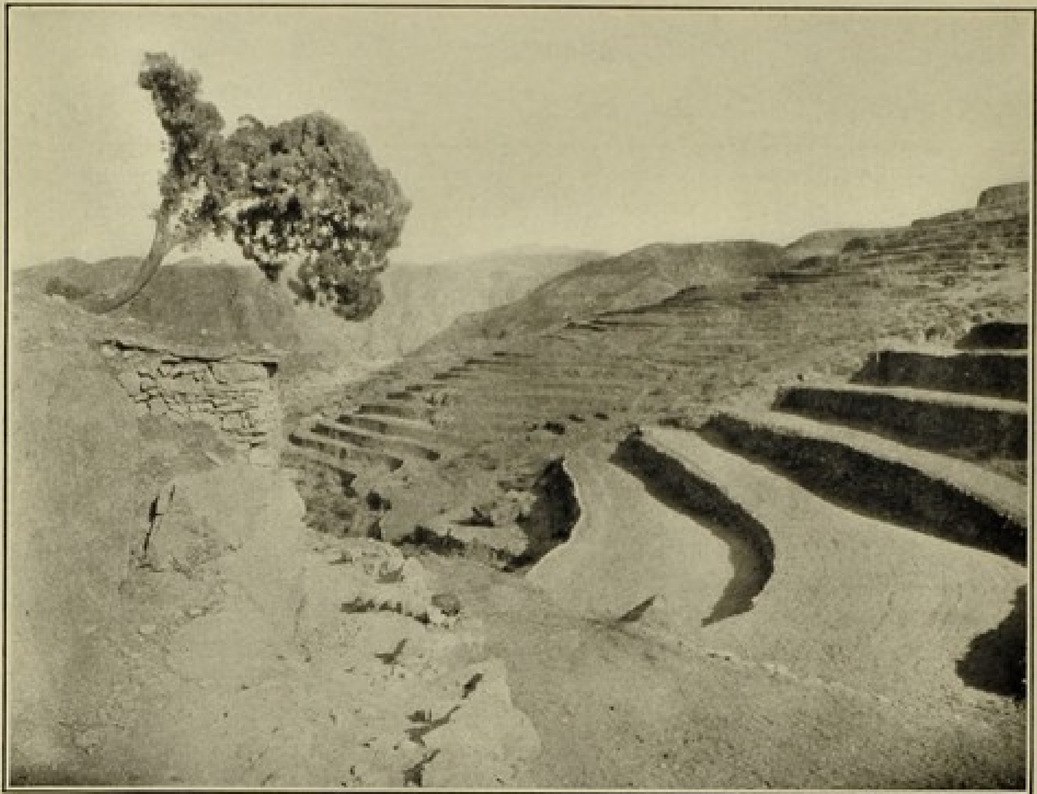


FIG. 1.—SOIL RESERVOIRS ON A HILLSIDE IN THE LOESS COUNTRY.

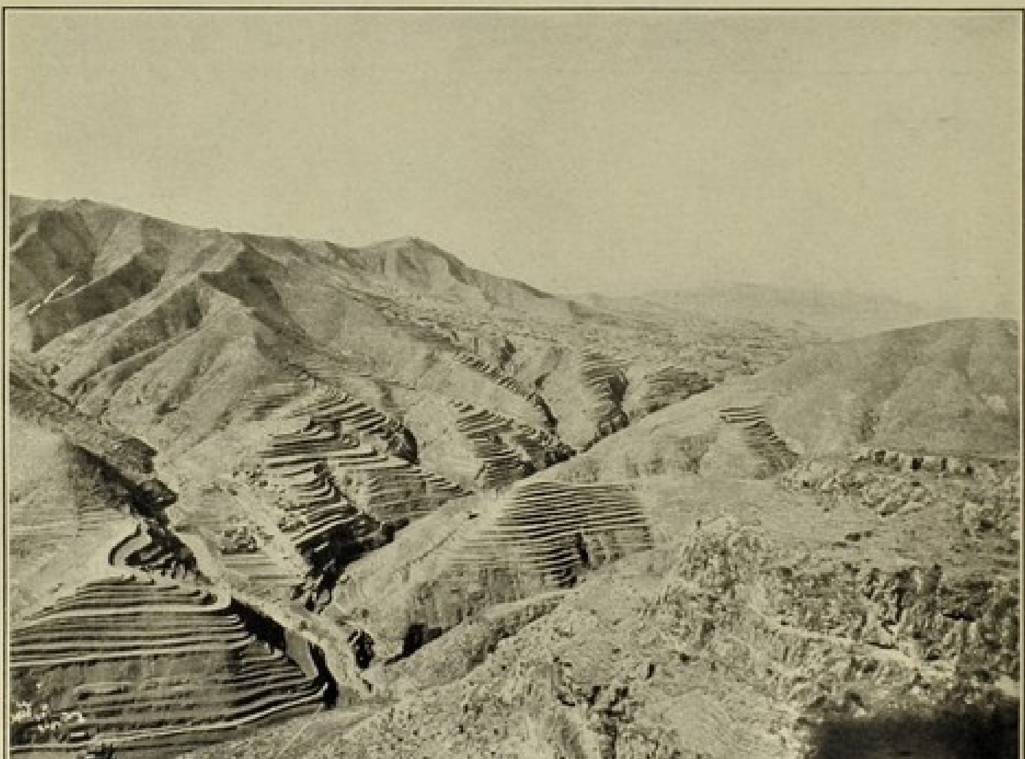


FIG. 2.—MOUNTAIN SLOPES IN NORTHWESTERN CHINA, TERRACED TO PREVENT THE EROSION OF THE LOESS.

fifteen times in the last 3,000 years. In these incessant shiftings the river has strewn all over an enormous area, 500 miles from north to south by 300 miles from east to west, layer after layer of fine yellow loam or silt; the very name "Yellow River," which is a translation of the Chinese "Hwang-ho," suggests the close resemblance to our own mud-laden Missouri. Almost every square foot of this vast alluvial fan is, of course, underlain by a deep and fertile soil, and is intensively cultivated by the industrious Chinese inhabitants. One sees no large fields of grain, such as those on our Dakota prairies, but, instead, thousands of small truck gardens belonging to the inhabitants of the hundreds of little mud-walled villages with which the plain is dotted. The ever-present town walls have doubtless been built, because the inhabitants have no natural refuges, as their mountain cousins have, and their very accessibility has made them in the past the frequent prey of Mongol and Tartar invaders or of rebels and rioters from within their own country.

Since the water supply of the plain is not lavish but little rice is grown there. The dry-land grains and such vegetables as cabbages and potatoes are the staple crops. The small gardens are sparingly irrigated, however, in times of drought, by water taken from the canals or wells, with the help of various types of crude pumps operated by men or by donkeys (pl. 2, fig. 5; pl. 5, fig. 5).

In this densely populated alluvial plain there is practically no pasturage and no woodland. From the very nature of the plain it could not yield coal, which is always associated with the solid rocks. To bring fuel, as we do, from distant parts of the country is impossibly expensive for the Chinese, without an adequate railroad system, and that is still a thing of the future. When the harvest has been gathered in the autumn the village children are therefore sent out to gather up every scrap of straw or stubble that can be used either for fodder or for fuel. The fields thus left perfectly bare in the dry winter season afford an unlimited supply of fine dust to every wind that blows. This is doubtless the explanation of the disagreeable winter dust storms with which every foreigner who has lived in northern China is only too familiar.

Although carts and wheelbarrows are much used on the Hwang Plain, their traffic is chiefly local. That may be due in part to the fact that the numerous wide and shifty rivers are difficult to bridge, while ferrying is relatively expensive. Another, and perhaps more important, reason is that the rivers, and particularly their old, abandoned courses, afford natural waterways which are available nearly everywhere. By taking advantage of these or by deepening them, and in some places by actually digging canals through the soft material of the plain, the Chinese have put together the wonderful system of interlaced canals for which they have been renowned since

Europeans first visited them. The thousands of junks which ply these waterways maintain a volume of inland commerce, which is inferior only to that of the great railroad countries, such as the United States. The relative freedom of communication in this great plain of the Yellow River has helped to bring about a greater homogeneity in the people than in any other equally large part of China. Here we find a single dialect in use over the entire region, whereas in some parts of southern China the natives of even adjacent valleys speak languages almost unintelligible to each other. The other common effects of isolation, such as the lack of acquaintance with the customs of outside peoples, the hatred of foreigners, the peculiar local usages, and many other things, are less prominent here than in other parts of the empire. Excepting the coastal cities, there is no safer part of China for foreigners to travel through.

West and northwest of the Yellow River Plain lie the more rugged plateaus and mountains of northwest China, with their subarid climate presaging the approach to the deserts of Mongolia. Over much of this region the ancient limestones and sandstones are still horizontal or are gently folded, with occasional dislocations along faults. On account of the comparatively recent uplift and differential warping which this part of China has suffered, the streams have been greatly accelerated in their work, so that they have hollowed out canyons in the raised portions and have filled in the depressed basins with sand and silt. This is the region celebrated among geologists on account of the loess, or yellow earth, which lines the basins and mantles the hillsides everywhere. It is believed that this is very largely a deposit of wind-blown dust, although it has been worked over considerably by the streams from time to time. No doubt Baron von Richthofen, the distinguished German explorer, was near the truth when he concluded more than 40 years ago, that the "yellow earth" was the dust of the central Asian deserts carried into China by the northwest winds. The presence of the loess determines, in large measure, the mode of living adopted by the inhabitants. Because of its fertility and moisture-conserving properties, it is well adapted to dry farming, and there is little water for irrigation. The Chinese are not content with using the level bottom lands, but successfully cultivate the hillsides wherever a deposit of the loess remains. In order to prevent the soil from washing off from these steep slopes, they build a series of stone walls, thus forming soil reservoirs or terraces. In this way nearly all of the soil is utilized.

In such a country rivers are not numerous and those which exist have many rapids and shoals. Boats are therefore but little used in northwest China. For both passenger and freight traffic, pack animals or rude vehicles are the chief reliance. For passengers there are also the palanquin or sedan chair and the mule litter. Where the

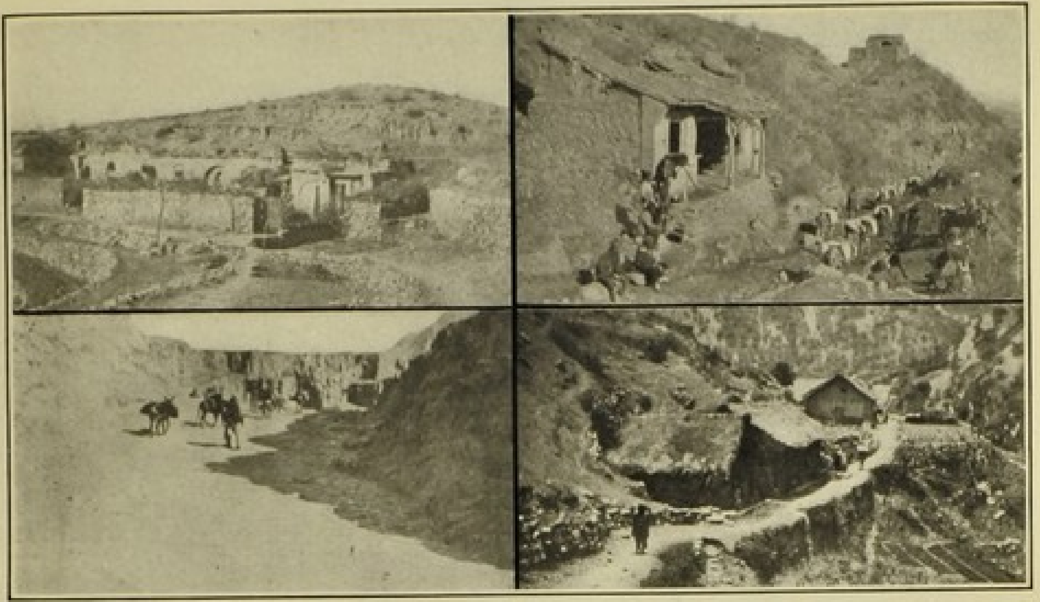


Fig. 1.—Cave houses in the loess, faced with stone.
Fig. 2.—Men and donkeys carrying coal from the mines in Shansi.
Fig. 3.—A pack train of donkeys, on the imperial highway over the Loess Plateau.
Fig. 4.—A roadside village and small fields at the bottom of the mountain valley.

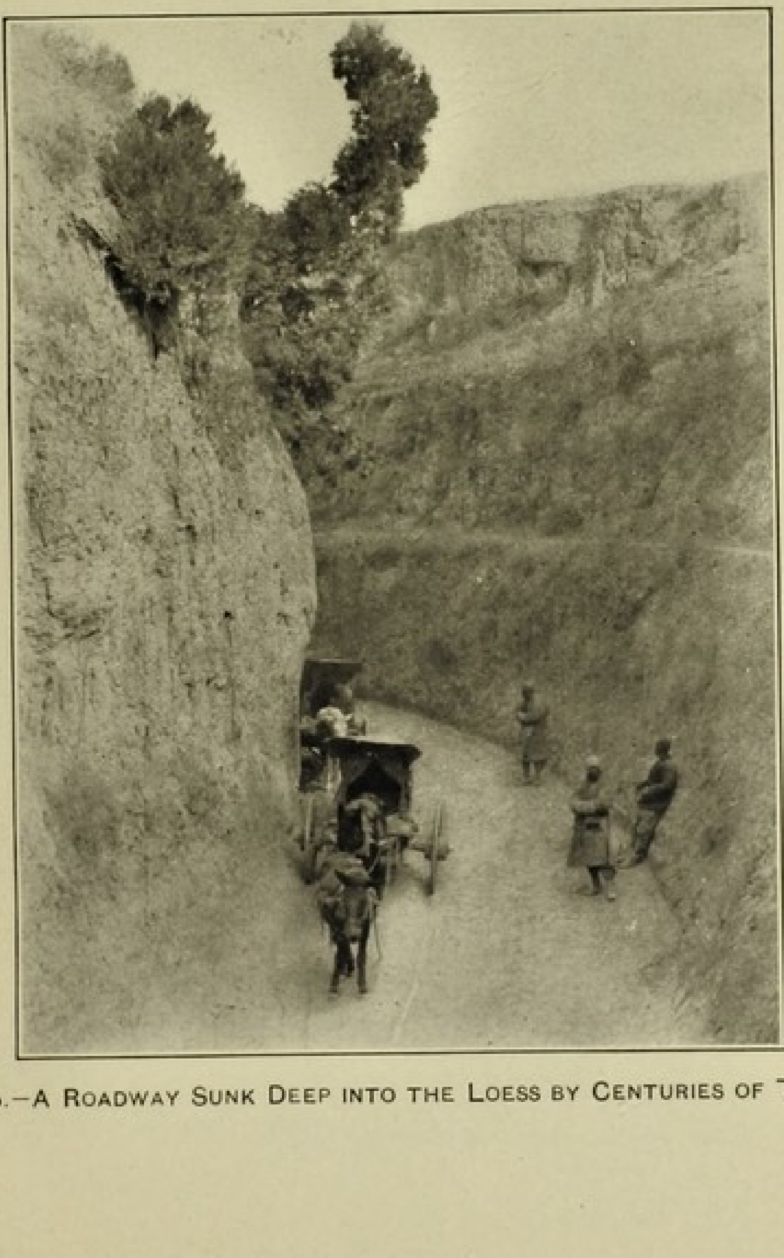


FIG. 5.—A ROADWAY SUNK DEEP INTO THE LOESS BY CENTURIES OF TRAVEL.

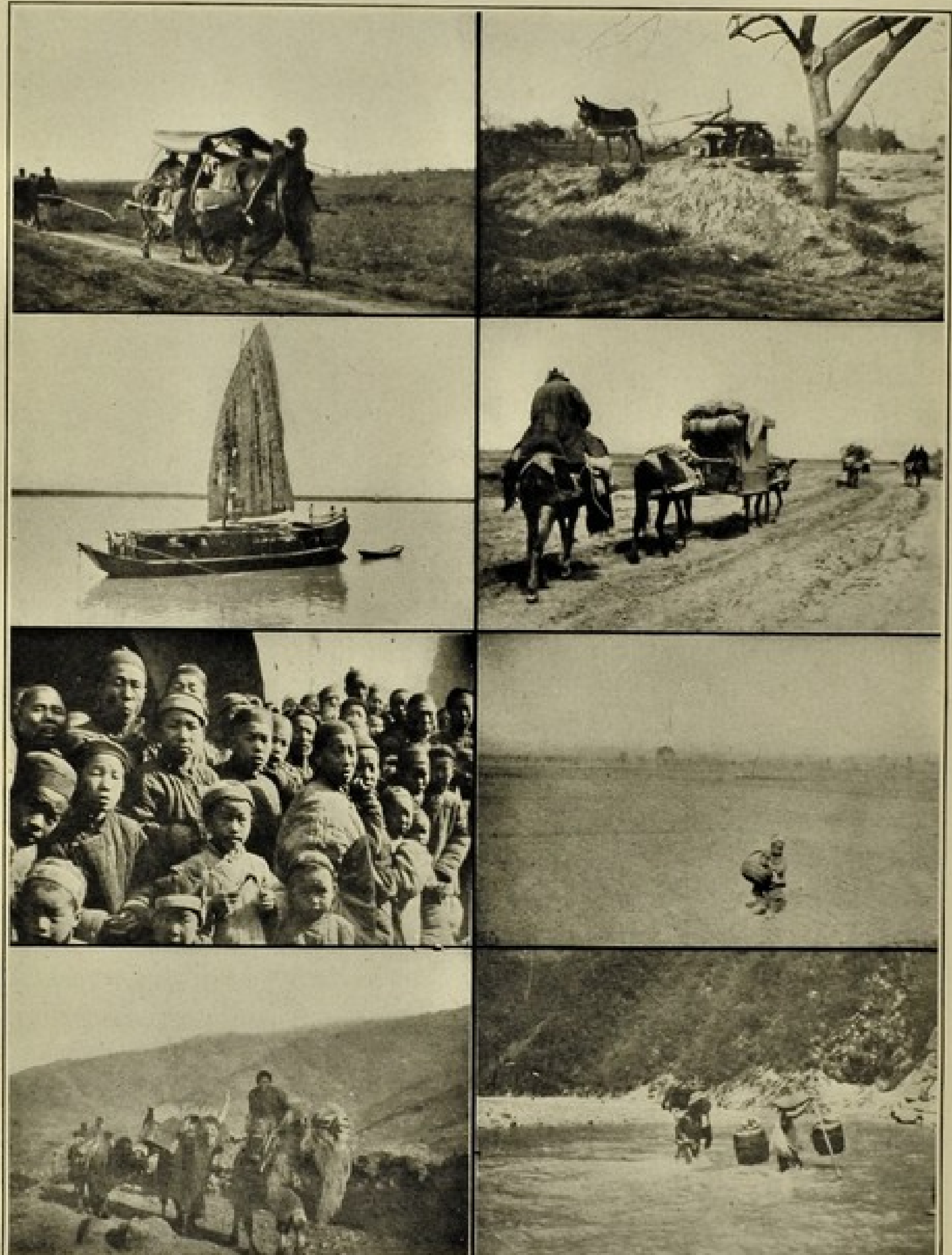


Fig. 1.—A two-man wheelbarrow carrying a merchant and his stock of goods.
Fig. 2.—A river junk.
Fig. 3.—A friendly crowd in an inland town.
Fig. 4.—Mongolian camels in northwestern China.
Fig. 5.—Irrigating with water pumped from a well.
Fig. 6.—A sedan chair swung between two mules.
Fig. 7.—Getting his initiation into farming with grub hook and basket.
Fig. 8.—Coolies fording a mountain river.

country is not too rough, the two-wheeled cart is the usual conveyance for merchandise. Over the mountain passes, however, and in many of the smaller valleys, roads are so narrow that carts can not be used, and so here pack animals, particularly horses and mules, are substituted. The traveler in this part of China is often reminded of his proximity to Mongolia by the frequent sight of camels. They are nevertheless not indigenous beasts of burden and the inhabitants themselves do not use them.

In consequence of the swampy state which prevailed in this part of China far back in the carboniferous period, thick deposits of coal were formed. These are now exposed in the deep valley slopes between beds of limestone and sandstone, and the circumstance has made Shansi Province the principal coal-producing district of China. The coal is mined by very primitive methods and as there is still no adequate system of railroads in this or any other part of the empire, the product can be transported only in carts or on pack animals. Either of these modes of carriage is so expensive that it becomes unprofitable to transport the coal more than 60 to 100 miles from the mine, and so the denizens of a great part of northern China, where fuel is scarce and the winters are severe, are no more able to obtain it than as if the United States contained the only coal fields in the world. The advantages that will accrue from the building of railroads in northern China are many, but one of the greatest will be the wide distribution of this essential fuel.

In going south by west from the plateau country, one enters a region of warmer climate and more generous rainfall, which, for want of a more distinctive name, I have called the Central Ranges. This is the part of China which was particularly affected by the rock-folding movements of the Jurassic period, and which in a much more recent time has been reelevated and therefore newly attacked by the streams and other erosive agencies. Broadly regarded, it is a complex of sharp mountain ridges and spurs with narrow intervening valleys. The ridges are not so high, however, but that they are clad with vegetation, and the scenery is therefore not alpine. The surface is nevertheless very rugged and its internal relief averages at least 3,000 feet. The roughest parts of our Carolinas resemble it in a measure. In such a region obviously there is no room for a dense population. Wherever there is a little widening of the bottom of the valley there is a farm or occasionally a small village, and even the scattered benches high up the mountain sides are reached by steep trails and diligently cultivated. But even when all of these are combined, the total area of land under settlement is relatively small.

In this region there are no railroads whatever, and although wagon roads could be built in some places, they would be expensive, and the Chinese have not yet attempted to make them. All travel and commerce, therefore, depend on the agency of pack animals or coolies, and the roads they follow are mere trails winding around the steep mountain sides or threading the bottoms of narrow valleys, where swift streams must be forded at frequent intervals. Under such circumstances it is evident that there can be but little effective traffic. Only comparatively light and expensive articles can be transported long distances. Around the edges of the mountain mass where the populous cities of the adjoining plains can be reached with one or two days' travel there has been for centuries an important trade in lumber. The mountains have now been so largely deforested, however, that it is necessary to go farther and farther back into the heads of the valleys to find large trees. Hence only the more expensive kinds of lumber such as coffin boards—which are absolutely indispensable, even to the poorer classes—can profitably be brought out. These are often carried for 20 or 30 miles on the backs of coolies—a costly mode of transportation. The smaller trees and brush the mountaineers convert into charcoal, which they carry on their own backs down to the towns along the foothills.

Lack of transportation facilities is doubtless the chief reason why the opium poppy has in the past been widely cultivated in this part of China, although the practice has lately been prohibited by the Government. The advantage in poppy culture was that it could be carried on in small scattered fields and the product was so valuable for unit of weight that it would pay for long-distance transportation across the mountains. The inhabitants of the region themselves were not, however, generally addicted to the use of the drug.

The rainfall of the central mountain region is sufficient to supply the many springs and tributary brooks of which the people have made use in irrigation. The mildness of the climate here permits the growing of rice, and by terracing the hillsides they are able to make a succession of narrow curved basins, in which the aquatic crop may be grown. For the cultivation of rice it is necessary that the fields be completely submerged during part of the season, and so there must be a plentiful supply of water.

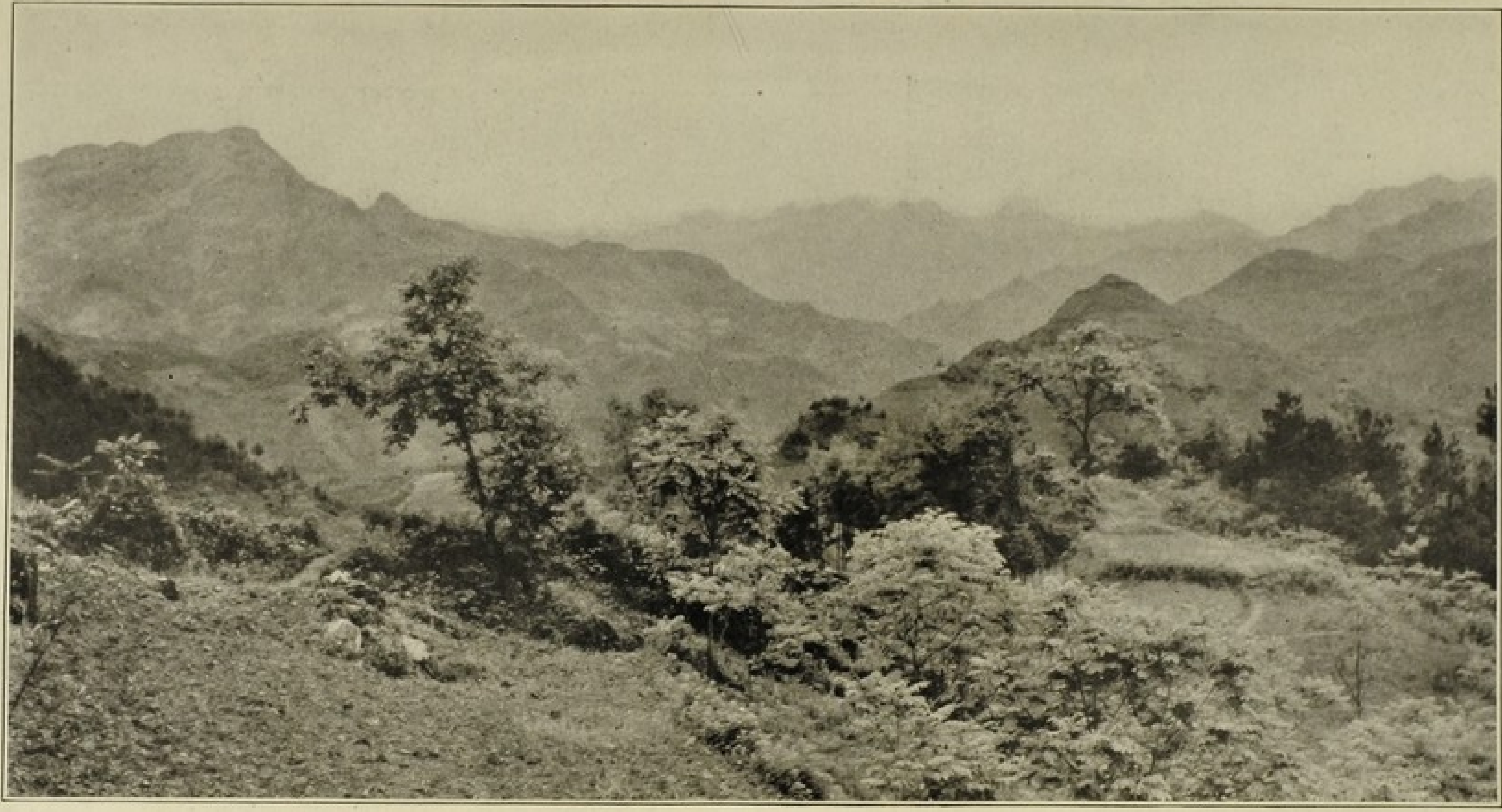
On the larger rivers, such as the Han and the Yangtze and their chief tributaries boats are successfully used. In fact, the Chinese river boatmen are so skillful in the handling of their high-prowed skiffs that they navigate canyons full of rapids which most of us would consider too dangerous to attempt. The descent of one of these rivers is an easy although exciting experience. The return trip, however, is slow and laborious, for the boats must be dragged upstream by coolies harnessed to a long bamboo rope, which has the advantage of being very light as well as strong. In the many places where the river banks are so precipitous that it is impossible to walk

A VALLEY IN THE TSIN-LING MOUNTAINS OF CENTRAL CHINA.

Small cultivated fields may be seen on benches high above the river.

FIG. 1.—COOLIES CARRYING FREIGHT ALONG A MOUNTAIN TRAIL WHICH HAS BEEN PARTLY WASHED OUT BY A TURBULENT STREAM.

FIG. 2.—RIVER SKIFFS IN ONE OF THE LIMESTONE GORGES OF THE CENTRAL RANGES.



AN OPEN VIEW IN THE MOUNTAINS BORDERING THE BASIN OF SZECHWAN.

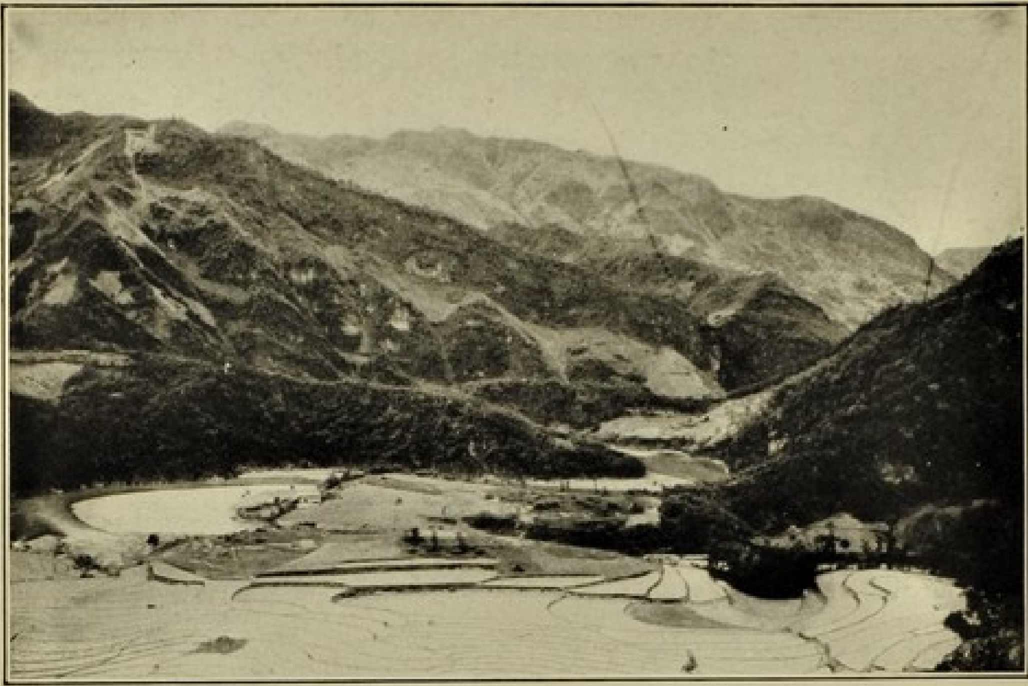


FIG. 1.—A VALLEY IN THE CENTRAL RANGES.

In the foreground are a series of terraced rice fields now filled with water.

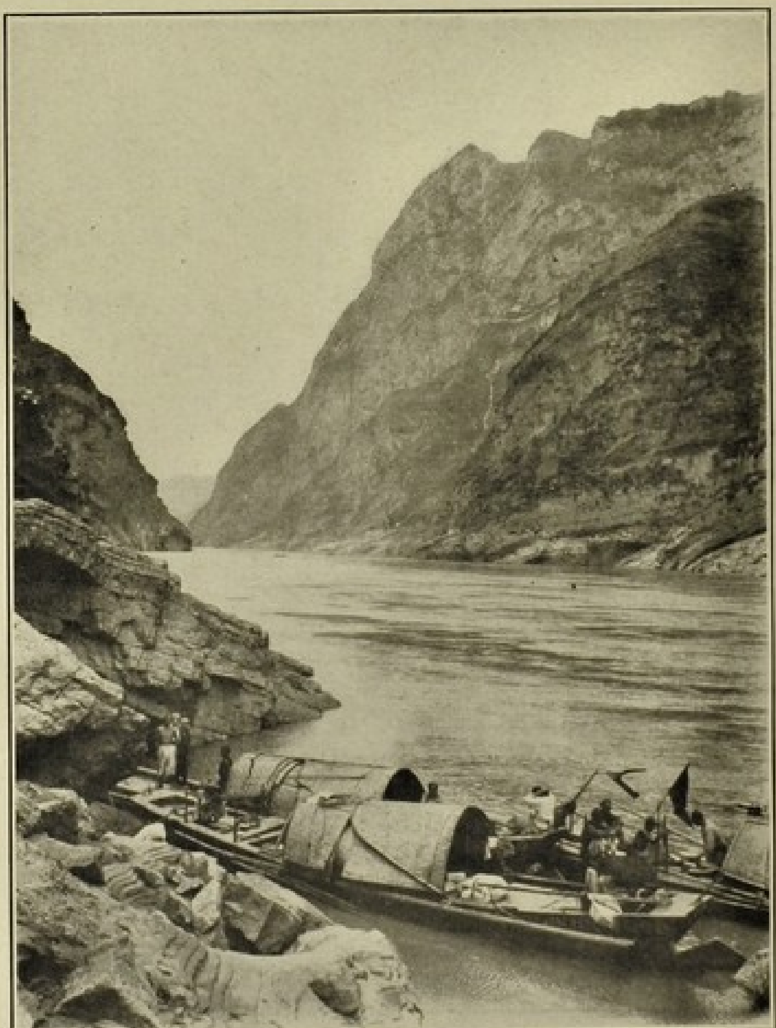


FIG. 2.—ONE OF THE GREAT LIMESTONE GORGES THROUGH WHICH THE YANG-TZE-KIANG PIERCES THE CENTRAL RANGES.

along them it becomes necessary for the boatmen to pole around the cliff or to zigzag from one side of the river to the other to take advantage of every foothold.

Through the central part of this mountain uplift the great Yangtze River, which in its lower course readily accommodates large ocean-going vessels, has carved a succession of superb gorges. In many places the gray limestone walls rise from 3,000 to 4,000 feet above the river, and the stream is compressed into less than a tenth of its usual width. Difficult and dangerous as are these canyons, beset with rapids and whirlpools, they afford the only ready means of communication between eastern China and the fertile basin of Szechwan, which lies west of the Central Ranges.

Without the highway of the Yangtze this great Province, four times are large as Illinois and with more people than all of our States east of the Mississippi River, would be unable to export its many rich products or to enjoy the commerce of outside Provinces and nations. It has been effectually barred off from India and Burma by the succession of high ranges and deep canyons which appear to be due primarily to the great epoch of folding in the Miocene period. Szechwan is a broad basin which has never been depressed low enough to force the streams to level its bottom with alluvial deposits, as in the Yellow River plain to the east; nor does it seem to have been elevated into a high plateau which would have been carved by many streams into a rugged mountain country. The soft red sandstone beds which underlie it have therefore been sculptured into a network of valleys with intervening red hills or buttes. With a climate as mild and moist as that of Alabama, and a diversified topography, there is opportunity for many industries and for the cultivation of a great variety of crops. Szechwan leads all the Provinces in the exportation of silk. Here grow the lacquer and oil nut trees and a wide range of field and garden fruits, grains, and vegetables. Ample water for irrigation and especially for rice culture is supplied by the many perennial streams which descend from the encircling mountains. These uplifted and now mountainous tracts have also served as a barrier to invaders from all directions, so that this has been less subject to wars than almost any other part of China, and hence has been more stable in development. Its inhabitants are among the most substantial and progressive components of the Chinese nation.

We now come to the last of the geologic divisions which were laid out for consideration. From the Szechwan Basin southwest to the confines of India there extends a series of high mountain ranges separated by deep and narrow valleys, all trending in a south or southeasterly direction. Although not so high above sea-level as the mountains north and south of Tibet, these ranges are an even more effective barrier to travel because they are so continuous and the relief is so great. Not only is there no waterway but there are no wagon roads, and the building of a railroad would be a stupendous and expensive engineering task. Such a road would necessarily involve the making of a succession of long bridges and tunnels. Here, as in the central ranges, settlements are limited to the rare open spots in the bottoms of valleys, and so the population is sparse indeed. The total commerce is very small in volume, because goods must be carried almost entirely on the backs of coolies. The rugged characteristics of the region are evidently the direct result of the recency of the compressive movement which produced the tremendous mountain folds, and perhaps are still more due to the renewed uplifts which have permitted the streams to continue the carving of their deep gorges. This part of China is geologically very young, and to quote the words of the distinguished old geologist of California, Joseph Le Conte, "the wildness of youth (here) has not yet been tempered by the mellowness of age."

Alloys of Copper. The most valuable of the alloys of copper are those with tin and zinc, the tin-copper alloys forming the important family of the *bronzes*, and the zinc-copper alloys giving us *brass*, both of which we shall consider at some length. With gold and silver, aluminium, nickel, and antimony, copper also alloys well [see page 1323 and JEWELLERY], but with lead and iron it is unsatisfactory.

Successful alloys of copper depend greatly upon the absence of deleterious ingredients in the copper used. Cuprous oxide makes the metal red-short and cold-short, and the higher the proportion of cuprous oxide the more pronounced are these faults. It also causes castings of the metal with which it may be mixed to contract considerably. Sulphur in copper makes blown castings; silicon affects the ductility, pales the colour, and gives brittleness; nickel and antimony, singly or in combination, decrease the malleability; phosphorus increases the hardness and the fusibility.

Copper Alloyed with Gold and Silver. The British gold coinage is an alloy of gold and copper [see page 1189]. The colour of a gold-copper alloy shades into red, and green gold is an alloy of gold, silver, and copper. Silver-copper alloys are hard, strong, and tough, and give out a clear, penetrating sound when struck. Copper may be added to silver up to almost 50 per cent. of the alloy without changing the colour of the silver. Care must be taken in casting a silver-copper alloy, or "liquation"—that is, separation, may take place. In working articles of silver-copper, the frequent annealing necessary causes the copper to oxidise, giving the alloy a steel-grey colour. This colour is removed by the process of "blanching," so-called—that is, boiling the articles in dilute sulphuric acid (1 in 40). This process dissolves the surface copper and gives a surface of pure silver.

Bronze. Bronze is an alloy of copper and tin. It has been in use from prehistoric times, and in the early days it was more nearly a pure binary alloy than it became during the mediæval ages, when its value was usually impaired by a percentage of lead. Although tin is a soft metal by itself, it forms a very hard metal when alloyed with copper. If bronze is to be rolled into sheets, the percentage of tin must be small—not more than from 4 per cent. to 6 per cent.

Most of the bronze of commerce is not a mixture of pure copper and tin, especially when it is made with an admixture of old bronze, which usually contains other metals as impurities.

A small quantity of zinc in the alloy makes bronze castings sharp and tends to prevent blow-holes, but the zinc should not constitute more than 2 per cent. of the whole, or the appearance will tend towards that of brass. Lead in bronze is detrimental, especially when the alloy is to be cast; it increases the liability to oxidation, and as the lead tends to liquate from the bronze, the castings are unequal. Iron hardens bronze and gives a whitish colour; it is often introduced when the bronze is to be used for axle bearings. Nickel makes bronze harder, and decreases the toughness.

Properties of Bronze. The colour of bronze may be varied within wide limits by the different proportions of the constituent metals. Bronze with over 90 per cent. of copper is of a pure red colour. As the copper decreases, the colour passes through orange yellow to pure yellow at 85 per cent. of copper. A copper proportion between 50 per cent. and 35 per cent. gives a pure white bronze, and below this proportion the colour is steel grey, but as the copper becomes very low, the white colour reappears.

Tin reduces the ductility of bronze very much, and as low a percentage as 15 makes it impossible to hammer the alloy without fracture, even when it is hot. The maximum hardness of pure bronze is when it is made of 72·8 per cent. of copper and 27·2 per cent. of tin. As the tin increases above this proportion, the hardness diminishes, until, when the tin is two-thirds of the whole, the alloy is as soft as pure copper. Bronze, very rich in copper, is made very hard and very brittle by repeated forging. Cooling red-hot bronze rapidly makes it much less brittle and less dense, so that bronze bells rapidly cooled are deepened in tone. The higher the proportion of copper in bronze the higher is the point of fusion. Thus, bronze with 95 per cent. of copper melts at 2,520° F., while, when the copper is only 80 per cent., the melting point is only 1,868° F.

Bronze for Various Purposes. The general rules which should guide in the manufacture of bronze for various purposes have been given, but we may tabulate common formulæ of bronzes for various industrial purposes:

COMPOSITION OF BRONZES

Purpose.	Copper.	Tin.	Zinc.	Lead.
Rail waggon axles	75	20	2	
Piston rings	84	2·9	8·3	4·3
Stamped articles	64	5·5	30·5	
Small castings	94	6·0		
Cocks..	88	10	2	
Steam whistles	80	17	2	
Articles to be hard soldered ..	87	12	1 part antimony.	
To resist atmospheric action ..	93	7		
Speculum for telescopes	66·6	23·3		
Very tough	32	3	1	
Valves and fittings (Admiralty mixture)	90	10	2·5	
Soft gun metal	16	1		
Gun metal for casting	9	1		
Maximum hardness for bearing metal	5	1		
Bell metal..	4	1		
Ordnance metal	91·6	8·3		

For bronze statuary, the composition of the alloy depends upon the colour desired. The following proportions are recommended by Brannt to give the shades indicated:

COMPOSITION OF STATUE BRONZES

Colour.	Percentages.		
	Copper.	Tin.	Zinc.
Red yellow	84·42	4·30	11·28
Orange-red	83·05	3·92	13·03
Orange yellow	81	4	15
Pale orange	73	4	23
Pale yellow	70	3	27

Another authority states that the best statue bronze has the following composition: copper, 78·5 per cent.; tin, 2·9 per cent.; zinc, 17·2 per cent.; and lead, 1·4 per cent. If the proportion of zinc be too high in a statue bronze, the object loses the warm colour desired in statues, and when the zinc is too high the natural green tone, termed *genuine patina*, which a statue of the proper composition gains from exposure to the air, is not acquired, but one shading into black.

In making alloys into which tin enters, it is usual to put in one-half of 1 per cent. more tin than the final alloy is desired to carry, this quantity being lost by oxidation during the period of fusion.

Bell Metal. Bell metal is a variety of bronze, as it is essentially a copper-tin alloy. Occasionally, other metals are introduced in order to modify the tone. Common cheap bells are frequently made of brass or of steel. The low-priced bicycle bells are of this order, but gongs and house bells, clock bells, and sleigh bells, tower and church bells, are made from the bronze alloy known for centuries as bell metal. We refer under Manganese Bronze [see below] to claims for that alloy as a material for bells. It was formerly considered that a small percentage of silver improved the tone of a bell, but this view is no longer held, and the use of silver in bells is now discarded. The usual bell metal contains about 20 per cent. to 25 per cent. of tin. The following table gives the recognised formulæ for some bell metals.

COMPOSITION OF BELL METALS

	Copper.	Tin.	Zinc.	Silver.	Lead.	Bismuth
House bells	80	20				
Do. smaller ..	75	25				
Small hand bells ..	40	60				
French clock bells ..	72	26·56		1·44		
German do.	73	24·3	2·7			
Swiss do.	74·5	25			0·5	
Sleigh bells	84·5	15·4				
Gongs	82	18				
White table bells ..	17	80				3

A good bell metal is grey white in colour. In practice, the fracture determines the quality of the metal for the bell founder. If too coarse, the alloy must be made richer in tin; and if too fine, the tin is already too high, and copper must be added. Bells made from metals that have been frequently melted are not pure toned, this being caused by the oxide solution which has come into the alloy. But the art of the bell-founder embraces more than merely making a suitable alloy. The size, shape, and diameter of a bell, and the relation of its height to its diameter, have much to do with the sound that it gives out. Small bells are often cast in iron moulds, but large ones are always cast in the sand.

Phosphor Bronze. *Phosphor bronze* possesses very great strength, and can be rolled and hammered in a cold state. The name would indicate that it is a bronze carrying a certain percentage of phosphorus, but it is not always so. A more appropriate name would be *deoxidised bronze.* Phosphorus is used in the preparation of bronze, although the final metal may contain no phosphorus. Copper usually contains cuprous oxide in solution, and this oxide reduces the strength of any alloy made from copper containing it. By the introduction of phosphorus when the alloy is in a state of fusion, a complete reduction of the cuprous oxide is effected. The quantity of phosphorus can be gauged accurately in accordance with the cuprous oxide present in the metal. No phosphorus may remain in the alloy. A practice in making phosphor bronze is to introduce the phosphorus as phosphor copper or phosphor tin, or sometimes as both, these alloys having been prepared beforehand. To make phosphor copper heat four parts of superphosphate of lime, two parts of granulated copper, and one part of finely powdered coal in a crucible. Phosphor copper with 14 per cent. of copper will separate at the bottom of the crucible. Phosphor tin may be made by heating together three parts of anhydrous phosphoric acid, one part of carbon, and six parts of tin. Then, to make the phosphor bronze, 10 ounces to 12 ounces of this phosphor bronze or phosphor tin is added to each cwt. of molten bronze. The field of phosphor bronze is in articles such as hydraulic presses and propeller blades, where great strength is required. Sometimes lead or aluminium is introduced into phosphor bronze for specific purposes.

Silicon Bronze. *Silicon bronze,* which is an alloy of copper, tin, and silicon, or of copper and silicon only, has very high tensile strength, and has been much used for telegraph and telephone wires. Such wires have been erected with stretches of 1,000 ft. with no intermediate supports. Phosphor bronze has, however, largely taken its place. A formula recommended for silicon bronze specifies copper 97·12 per cent., tin 1·14 per cent., zinc 1·10; and silicon 0·05 per cent. The tensile strength of this alloy is said to be 600 lb. for 0·001 square inch section. Silicon bronze owes its properties to the fact that silicon, while reducing the cuprous oxide in the copper just as phosphorus does, seems to have a greater affinity for the copper than phosphorus has.

Manganese Bronze. *Manganese bronze* is, properly, not a bronze at all, but a brass; yet, on account of its name, we refer to it here. The following mixture is frequently used: copper 51 per cent., manganese copper (containing 20 per cent. of manganese and 8 per cent. of zinc) 40 per cent., and aluminium 1 per cent. The manganese copper, besides containing manganese, usually contains from 2 per cent. to 4 per cent. of iron. Manganese bronze possesses very high tensile strength. The alloy of the composition given above has a tensile strength of 36 tons per square inch and an elongation of 20 per cent. A higher percentage of zinc increases the hardness and tensile strength and diminishes the elongation, while a lower percentage has the opposite effect. The sphere of manganese bronze is in the manufacture of ordnance, propellers, pinions, and bearings, where its qualities make it desirable. As the tin constituent in the true bronze alloys is replaced by the cheaper zinc in manganese bronze, it is cheaper than the other special bronzes without showing inferior qualities as a special metal.

Manganese bronze finds some use as a bell metal instead of the usual copper and tin alloy generally used for the purpose. The advantages claimed by the advocates of manganese bronze for this purpose are that in comparison with the older composition it is more sonorous, has a mellower tone, and is not liable to be cracked. The usual bell metal is made very hard and brittle in order to improve the quality of the tone.

Aluminium Bronze. *Aluminium bronze* is an alloy of copper and aluminium, and contains no tin, hence the use of the word bronze is not quite accurate, although it has come to be accepted. The content in aluminium is never usefully higher than 10 per cent., but even up to this modest proportion colour and physical properties vary a good deal. With 5 per cent. of aluminium the colour is golden, at 7½ per cent. it partakes of a green-gold hue, and at 10 per cent. it is a bright golden colour. These alloys have great tensile strength, are exceedingly malleable in both the hot and the cold states, give sharp, clean castings, and admit a fine polish. The highest qualities of aluminium bronze are brought out by remelting it three or four times, and its strength may be further increased by hammering so that it may be made equal to steel. In casting aluminium bronze experience is necessary to good work. Its shrinkage is about twice as much as that of brass [see also page 1462].

Aluminium Brass. *Aluminium brass* is properly so termed, being an alloy of copper, zinc, and aluminium. Here also the percentage of aluminium is invariably low; if it be higher than 15 per cent. the alloy becomes red short and hard. An alloy containing 60 parts of copper, 30 parts of zinc, and 2 parts of aluminium can be worked mechanically by rolling, stamping, or forging, and has a valuable use for cartridge shells, because the aluminium imparts the property of resisting corrosion by the gases of the powder. It has been claimed that aluminium brass with from 1 per cent. to 3 per cent. of aluminium has much similar properties to aluminium bronze with from 5 per cent. to 10 per cent. of aluminium, and, of course, it is much the cheaper; but we question the evidence for this claim. Certainly aluminium brass is heavier and oxidises more easily. But the aluminium and zinc seem to form an intimate combination, and to develop properties even superior to the aluminium-copper alloys. The field for aluminium brass is in machinery parts and fittings in which exceptional strength is desired, such as valve seats, hydraulic and mining machinery, and propellers.

Bronze Powders. Most of the bronze powders used to coat metal, paper, wood, and other materials are made in Austria. A large number of different shades are procurable. Zinc and not tin is alloyed with copper to form the material from which they are made, so that the term *bronze* is technically incorrect. Powders which incline to white in colour have a high zinc content, and those that incline to red are high in copper.

Brannt gives the following compositions for some representative colours:

ALLOYS FOR BRONZE POWDERS			
Colour.	Copper.	Zinc.	Iron.
Yellow	82·33	16·69	0·16
Pale green	84·32	15·02	0·63
Lemon	84·50	15·30	0·07
Copper red	99·90		
Orange	98·93	0·73	
Pale yellow	90·00	9·60	
Crimson	98·22	0·50	0·56

All the variety of shades are not, however, obtained by varying the composition of the alloy so much as by heating the alloy (after it has been finely pulverised), until a layer of oxide of the desired shade surrounds each individual particle.

In making the bronze powders the alloy is beaten into fine leaves by power hammers. These leaves are then forced through a fine sieve with the assistance of a scratch brush, oil being added at the same time, and the oil and powder passes through a grinding machine, which consists of one steel plate mounted with fine needles having blunt points revolving against another steel plate. The metal is here reduced to a very fine powder, and the oil is removed, first by putting the mass into water, where the oil floats off, and then by pressure.

Brass. Although the alloys of copper and tin—the bronzes—can claim antiquity, the alloys of copper and zinc, generally known as *brass*, can claim a much wider use industrially. Brass is properly a binary alloy, and should contain only copper and zinc; but pure brass is seldom made. The alloy is usually associated with tin, iron, lead and arsenic, those metals sometimes being present as impurities in one or both of the constituent metals, and sometimes again being added so as to modify the properties of the alloy. The two metals, copper and zinc, alloy within very wide limits. The higher the percentage of copper the more does the colour of the alloy tend towards gold, and copper also increases the softness and the malleability. As the proportion of zinc increases the colour becomes paler until it is a pale grey, and zinc increases the brittleness, hardness, and fusibility. A proportion of zinc up to 7 per cent. does not change the colour of the copper to an appreciable extent, but when the proportion comes above this quantity the tone is red-yellow. Then at 14 per cent. the colour has modified into pure yellow, and above 16 per cent. it goes into a mixed yellow, while at over 30 per cent. the red colour returns, and is at about its maximum when the two metals are present in equal proportion. As the zinc exceeds 50 per cent. the colour rapidly pales, passing through reddish white at 53 per cent., yellowish white at 56 per cent., bluish white at 64 per cent. and into lead colour as the zinc exceeds this limit.

Colours of Brass. The various phases through which the colour of brass passes as the proportions of the constituent metals vary may be given in the form of a table.

COLOURS OF BRASS		
Colours.	Composition.	
	Copper. Per cent.	Zinc. Per cent.
Red	95	5
Reddish brown	90	10
Red-yellow	85	15
Reddish yellow	80	20
Light yellow	75	25
Yellow	70	30
Dark yellow	65	35
Reddish yellow	60	40
Golden yellow	50	50
Light grey	40	60
Lead grey	30	70
Darker lead grey	20	80
	10	90

The physical properties of brass, other than colour, are also much influenced by the proportions of the metals alloyed. A small proportion of zinc increases the fusibility without affecting the hardness; a high proportion increases the malleability when cold, but makes forging when hot impossible. Lead causes brittleness if it be present in brass in large quantities, but small quantities increase the ductility, making it better for turning and filing. A small proportion of phosphorus makes sounder brass castings, by increasing the fluidity and tenacity, and helps the alloy to resist atmospheric action. It also permits of tempering to some extent. The composition of commercial brass for many specific purposes is given in the following table [see also the table of bronzes which is given on page 1721].

COMPOSITION OF BRASS				
Purpose.	Copper.	Zinc.	Tin.	Lead.
Gas fittings	40	20	..	1
Sheet brass for stamping and turning	3	1		
Brass wire	67	33		
Soft brass for hammering ..	7	3		
Tough brass for engine work	100	15	15	
Brass for soldering	8	3		
Sheathing brass	3	2		
Nails for sheathing	87	4	9	
Yellow brass	2	1		
White brass	10	80	10	
Red brass	16	2		
Brass for forging hot	33	25		
Pinchbeck	88	12		
Tombac	86	14		

The common quality of brass used in the foundry is termed in the trade *ash metal*. This is a general mixture suitable for cheap work, and is very wide in its quality. It is made by melting together scrap brass, borings and filings, sweepings and skimmings. These materials are riddled so as to free them from unnecessary dirt, and are washed, melted, and poured into ingots so as to be ready for use. Remelting improves brass, although there is loss of weight in any remelting, so that to remelt brass is more expensive than the mere cost of fuel and labour which it entails.

Standard yellow brass, so called, is an alloy containing two parts of copper to one part of brass. It is common to use this mixture already made as an ingredient in brass mixtures for casting, particularly for *red metal*, as it is called. A cheap red metal is made by alloying 36 parts of yellow brass (standard) with 46 parts of copper, 14 parts of lead, and 4 parts of tin. For highly polished red metal plumbers' fittings a common formula is 4 parts yellow brass, 16 parts copper, and one part each of lead and tin. For red metal to stand riveting the proportions of lead and of yellow brass are usually increased and the proportion of tin lowered. Thus, a good formula frequently followed takes 26 parts of yellow brass, 66 parts of copper, 5 parts of lead, and 3 parts of tin.

Brazing Metal. For the coppersmith the most commonly used alloy of copper is called *brazing metal*. Whatever may be the composition of the brazing metal—and this depends upon its purpose—it is always desired to retain to a great extent the malleability, fusibility, and colour of copper. If the zinc be higher than 20 per cent. of the alloy the red colour of copper is replaced by the yellow colour of brass. The chief use of brazing metal is in the manufacture of brass and other tubes. Brazing metal may be made from copper and zinc only, but very small additions of lead and tin make the alloy more easily worked in the sheet. A common mixture is eight parts of copper to from one to two parts of zinc. The best qualities have only 6 per cent. of zinc. Sometimes 2 per cent. of aluminium is incorporated, and is, indeed, specified in some Government work, but although tubes made to this formula give a more rigid joint than ordinary brazing metal, the aluminium makes the alloy less easy to work. A special article on engineers' coppersmithing is given in later pages in MECHANICAL ENGINEERING.

German Silver. German silver is brass with a proportion of nickel, the amount of which ranges from 15 per cent. to 25 per cent. according to the quality of the alloy. A formula frequently used prescribes three parts of copper to one part each of zinc and nickel. German silver ought to be of silver whiteness and almost untarnishable if made from pure metals, but the presence of impurities such as arsenic and antimony in the constituent metals detracts from this result. A small proportion of tin—up to 3 per cent.—permits German silver to take on a high polish; lead or manganese in a similar proportion increases the fluidity and gives good castings, while iron increases the hardness and helps the whiteness. The usual method of making German silver is to make an alloy of nickel and copper, and another alloy of nickel and zinc, the latter being added to the former while both are in the molten state [see also page 1323].

Copper Amalgam. Copper amalgam is an alloy of copper and mercury; it has a wide field of industrial use. Its chief sphere is in the recovery of gold from the crushed quartz by the use of amalgamated copper plates [see page 1184]. The alloy is not obtained by the direct method—that is, by uniting the fused metals. There are several methods of preparing copper amalgam, and we may notice one of them. Zinc strips are immersed in a sulphate of copper solution and shaken vigorously. The copper, which deposits as a fine powder, is washed and triturated with a solution of nitrate of mercury. Hot water is poured on the copper, and mercury (seven parts to three of the zinc) is added. The mass is kneaded into combination, and a longer kneading makes it more intimate. Then the water is discarded, and the paste remaining can be shaped to any desired form. Copper amalgam has the curious property of becoming soft when placed in boiling water. It is also used to a limited extent in cementing metals together. The metals to be joined must be heated to just under 200° F., after which the amalgam, usually in the shape of wire, is applied and the parts pressed together.

Manufacture of Brass. The earliest method of manufacturing brass was to fuse copper with zinc-bearing ores, usually calamine [see page 1588]. The results of this method were by no means uniform, owing to the varying properties of the ores used, even with ores from the same bed. Thus, as with all rule-of-thumb methods, the men who practised this method had to be expert in their judgment, able to tell by colour and fracture that the desired point in alloying had been reached. This method has not yet quite disappeared, but it has almost done so, and its death knell has long sounded in the best modern practice.

The present day practice of the brass-founder is to heat the metals in crucibles placed in furnaces. Many attempts have been made to dispense with the need for crucibles in brass making, but all attempts to fuse the metals direct in special furnaces have been unsatisfactory and have resulted in a return to the crucible. The types of furnace vary with the kind of fuel used, and with the size and regularity of the output. We may consider a furnace of small size heated with coke, and taking one crucible, capable of making about 80 lb. of brass. The furnace is about 28 in. deep with a horizontal section about 15 in. square. The chimney must be not less than 15 ft. high, and is usually 10 in. square, the flue connecting it with the furnace being, say, 7 in. by 10 in. The crucible rests on a firebrick placed on the firebars. It is heated, usually, by being placed upside down in the furnace. Then it is placed upright and packed around outside with coke. The copper and zinc have meantime been weighed in their proper proportions, but not mixed. The copper, in small pieces, is placed in the hot crucible and melted. Then the zinc, or spelter, broken into small pieces and warmed, is added gradually and stirred. Zinc volatilises, so that the proportion of zinc in the final alloy is never so high as it was in the weighed metal. Every time brass is remelted the zinc content becomes less. The brass-maker allows for this loss by using more zinc, in a definite proportion, than he wishes the alloy to show. As the metals fuse, the surface is sprinkled with powdered charcoal, borax, or broken glass, so as to prevent oxidation. After all the zinc has been melted the crucible is covered over for a few minutes before being poured. If part of the charge is old brass, this is melted first, then the copper is added, and when the latter is fused the zinc is put in as already described.

Brass Furnaces. There are many so-called improved furnaces, each with specific claims to merit, offered for the use of brass founders, but the common furnace has too strong a hold to be easily displaced. Tendencies during recent years have been towards liquid fuel instead of hard coke, and the value of many patent furnaces offered has consisted in their ability to utilise cheap oils as fuel. Gas is also used for brass melting, and may be the most economical fuel with a very small plant and where the work is intermittent.

Patterns for Brass Castings. Patterns are discussed at length in articles on Patterns and Castings under MECHANICAL ENGINEERING, and reference should be made there for general instructions. The small size of most brass castings causes the use of metal patterns to a far greater extent than for iron castings. Metal patterns, generally, give cleaner castings than wood patterns, and brass castings often carry some finely cut ornamentation for which wood would be unsuitable as a material upon which to work. Metal patterns for brasswork are usually made of brass, primarily because it is more convenient to make them of brass in a brass foundry, and also because brass patterns require no preliminary preparation, such as rusting and varnishing, as iron patterns do, an application of a black-lead brush being all the treatment required.

Moulds for Casting Brass. The condition of the sand is of great importance in brass casting. If the moulds are made of loam they must be thoroughly dried before use. Good moulding sand is better than loam, however. If the sand is too meagre it will give a rough surface, occasioning labour and expense in finishing. The addition of a little flour paste to the sand will obviate this trouble, and if the sand be too "fat," the addition of powdered charcoal will prevent bad effects. The pouring temperature must be carefully gauged. If the metal is not hot enough, sharp castings cannot be secured ; and if it is too hot, porous castings will result, and there will be loss of zinc by oxidation. Casting from the bottom is desirable, as the air cannot rise through the casting and cause blow-holes.

Brass-founding. In brass-founding, the ordinary iron-founding practice is generally followed, but there are a few points where variation is required. The contraction of brass in cooling is greater than that of iron, therefore the patterns have to bear a different relation to the work. Small castings of brass—say, under 12 in. long—shrink $\frac{1}{8}$ in. in each foot, and over this size the contraction is $\frac{3}{16}$ in. Brass sets more quickly than iron, therefore the molten metal must reach home more quickly, and to secure this the gates and runners are usually made larger. The sand used for brass is generally more porous than it is for iron, and there is not so much venting. Much brasswork is poured through the ends of the mould boxes instead of by the top, the boxes in the end pouring being made to be at an angle in a trough, the object being that spilt metal may be recovered from the trough instead of being lost in the sand. Vertical pouring, which is common with iron castings, is infrequent with brass, there being no risk of scabbing and of blow-holes in the latter case.

Casting Bronze on to Iron. Sometimes it is desirable that a piece of mechanism should be of iron or steel inside and of brass or bronze outside. We may take as a typical instance of such work the pump plunger, which may be wanted with an iron or steel centre and with the working part of bronze which will withstand corrosion. The bronze part could be cast separately and fitted on, but this method entails much labour and expense. A cheaper and thoroughly satisfactory job may be made by casting the bronze upon the iron as a centre if proper precautions be taken. Brass or bronze cast upon iron is more or less spongy or porous, and would, in most cases, be unsatisfactory as the working surface of a piece of mechanism. The method of overcoming this objection is by casting upon the iron or steel a layer or brass or bronze only half of the desired ultimate thickness of the brass or bronze. The centre, of iron and steel, should for preference be tinned, as the copper alloy will unite with the tin easily, but tinning is not essential. Its absence may cause a little spluttering as the metal is poured, but it will give as good a result as when tinning is practised. If the iron or steel be not tinned, it should be cleaned and polished. In casting, this iron or steel is used as a core, and the porous coating of brass or bronze forms a good surface upon which to cast a second and final layer of brass or bronze, which will not in this case have the tendency to be spongy. The second pouring is made when the first cast is cold and when, of course, the second mould has been prepared for it. The second cast should be given under a good head of metal so as to get a good dense casting. The two castings of brass or bronze should unite solid, and can be machined in the usual way for the finished mechanism.

Modelling. In brass castings, especially those of an ornamental nature, modelling in clay is practised in the preparation of patterns to a considerable extent. The clay model is reproduced in plaster of Paris, and from the latter tin sections are cast, or rather sections made with an alloy of three parts of lead to one part of tin. These sections, when built up together, form the working pattern for the moulder. Modelling is used in ornamental ironwork also, but we give it an extended notice in this section on account of its application in the brass foundry and because most textbooks neglect it.

Modelling is chiefly suitable for light and ornamental castings. The actual task of modelling in clay is the work where, more than in any other which falls to his lot, the workman may give expression to any artistic feeling he may possess. The general work of clay modelling is fully discussed in another course [see SCULPTURE in Group 3], and the technical details there given permit us to be brief upon that part of the subject. The clay must be soft and pliable. It is prepared by grinding, and all stones and grit are removed. The tools necessary are few and simple. The most important are the ten fingers of the workman, and he supplements these by a few boxwood modelling tools and floats. The chief work is done with the fingers, which press and knead the clay into the form desired. The tools are used to impart the finer lines, to remove any excess of material, and generally to give the finshing touches. The work is nearly always in low relief, as high relief would be impossible without undercutting, which would not allow the article to leave the mould.

The work is usually done on a modelling board, stiffened at the back and coated on its surface with a few applications of shellac varnish. Thus the moisture of the clay does not penetrate into the board. This board is placed on trestles or on a bench, and the clay is placed on it and manipulated as already stated, the operator working to his drawing. If the work cannot be completed at one sitting, a damp cloth thrown over the clay will cause it to remain soft and pliable. The work finished, the clay is allowed to get somewhat firm, after which it is removed from the board, which may be helped by pulling a piece of thin wire right down the board, meantime holding it across the full width of the board under the clay. If the impression of the clay model is to be taken in plaster of Paris, this is generally done before the clay leaves the board. The tin alloy pattern is cast from the clay on the plaster of Paris counterpart in the ordinary way, and the material, while hard enough for ordinary handling, is pliable enough to be bent and modified in shape and to have the ornamentation cut or deepened with ease and good result.

Brass Burning. In casting brass, it may be that the casting desired is too large for the capacity of the crucibles or of the furnace. The difficulty is overcome by *burning* or autogenous soldering [see following article]. The process consists in making the full-sized casting in two or more pieces; then, by placing these in their proper positions in a sand mould and by pouring molten brass so that it flows around the surfaces it is desired to join, a homogeneous casting as strong as if it had been cast in one piece is obtained. In preparing the brass castings for burning, the surfaces where the join is to take place are filed or scraped, so as to free them from scale. It is desirable that the new metal should be hot, therefore an excess of metal is allowed, the first part of the pouring flowing out through a gate and heating the surfaces as they pass over them; then the metal that remains finally comes upon the heated surfaces and the union is made.

Plate Brass. Brass which has to be subsequently rolled into sheets or cut into strips to be drawn into wire [see WIREWORK] must retain its ductility, hence special precautions are necessary in casting the thin plates which are to be subject to this special treatment. Sometimes iron moulds have been tried, but have never had extended favour due to the fact that the brass cools off too rapidly, although this defect might be overcome by heating the moulds before casting, and by allowing them to cool off gradually by the application of external heat.

In many places loam moulds and sand moulds are used, but granite moulds are also in extended use, and give good results if properly manipulated. A granite mould is made of two granite slabs, the lower one a little wider than the upper. Both have an even coating of clay covered with cow dung, and are kept at the proper distance apart by iron bars placed between them at their ends. The slabs are bound together with iron bands. Their normal position for pouring is at an angle of 45° from the horizontal, and as soon as the poured plate has solidified, it is removed and another poured, so that the mould remains warm. The plates removed from the mould are cleaned with wire brushes. Then they are rolled and sometimes hammered. Sometimes they are rolled hot only, and sometimes the hot rolling is finished by cold rolling. This depends upon the nature of the brass. The composition may be capable of extension by rolling only if hot. Between each rolling the sheets are annealed to give back the ductility which the previous rolling has taken from them, and before passing between the rolls they are coated with oil. If the final sheet be required soft, the last process is one of heating and quenching in water, while if a hard sheet be required, this heating is omitted.

The sheet at this stage does not resemble brass. It is black, and must be pickled—that is, dipped into a bath made of water with 10 per cent. of sulphuric acid. This may complete the preparation for the market, or another bath of nitric acid in water or a mixture of nitric and sulphuric acids in water may be given. Nitric acid dissolves zinc more quickly than it dissolves copper, so that a sheet that has come from a nitric acid bath has a surface richer in copper than the body of the sheet; hence a redder shade of brass.

Casting Bronze Statues. France is the headquarters of statue-founding in bronze. In that country the appliances and methods are the best, and the results unexcelled, and seldom equalled. The old process of statue-founding was by what is known as the *cire perdu* process [see BRONZE CASTING IN ARTS], and this is still practised. By this process a rough model of the object is first made in sand or porous cement, and this is coated with wax to the same thickness as the metal which is to form the statue. Then the artist works upon this wax surface, giving the final form by delicate touches. Then several pieces of wire are pushed through the wax into the core. Now the wax is carefully coated with liquid sand, and is placed in an iron frame, which is filled up with sand. The frame is taken to a warm place, where the moisture escapes from the sand, which becomes firm. Holes are now pierced through to the wax coating, and the frame is then placed in a hot oven, where the wax melts and runs out, leaving the core supported in position by the wires which were inserted for the purpose. Bronze is now poured in by the holes through which the wax escaped, and the statue is cast. If this process produce a perfect statue, all is well, but this result is by no means certain. The operation is delicate, flaws are frequent, and if the statue be imperfect, the work of the artist has gone for nothing, because his wax model has been destroyed in the process. For this reason the *cire perdu* process has been superseded in the best French practice by a less risky process, which leaves the work of the artist uninjured if the casting be bad, so that subsequent attempts may be made without the necessity of beginning the work again *de novo*.

Piece Moulding. By this newer method the sculptor makes his design in plaster, and the rest of the work is mechanical, albeit demanding a high degree of skill on the part of the founder. The plaster statue is placed in a bed of sand, so that it may rest solid and still be comparatively safe from injury. Then the moulder begins the operation of *piece moulding*, so-called. Selecting a small section of the statue, he presses sand into every crevice in it, and obtains thereby a mould giving an exact impression of that section to which he has been devoting attention. He does the same with another section of the statue, and so on until he has the whole surface of the plaster statue impressed upon the several moulds that he has made. The plaster statue itself may now be put aside, and may not again be required. The small impressions that have been taken in sand are carefully fitted together in their proper places in the mould-box—a task requiring high skill. A rough facsimile is now made, a little smaller than the original statue, and this does duty as a core, the space between the two faces representing the thickness of metal of which the statue is to be. The mould and core are then dried in an oven to remove moisture, and to harden the sand. Vents and runners are made, and when all is ready the casting is poured. Should it be faulty for any reason the operation must be repeated; but this is not the serious matter it is by the *cire perdu* process, because the plaster statue remains upon which to work.

In statue-founding great care is taken in selecting the metal. Colour and homogeneity depend upon the bronze alloy, and no metal of which the exact composition is not known is allowed to enter. No old brass and copper are used, and the ingot copper employed is usually purified by liquidation before the actual process of founding. Good work is possible only by having a highly finished mould capable of producing a sharp casting which will require only very little chasing. The sand employed is also important. It must be carefully selected; it is usually blended to suit the nature of the work in hand, and is then passed between cast-iron rollers to give it uniformity. The moulding boxes must be accurately fitted, and their edges are usually planed.

Dressing Castings. Castings which come from the mould must be *dressed* or *fettled* before being ready for the more delicate operations of finishing. The nature of the dressing depends upon the metal under consideration, the perfection or, rather, imperfection of the casting, and upon the subsequent finishing processes, if any, to which it is going to be made subject. The processes of dressing castings are similar whatever metal may be employed, and we shall describe briefly the appliances used, having special regard to the fact that we are considering castings of brass and bronze.

The usual extraneous metal upon a casting as it emerges from the sand takes the form of ragged edges, fins and spurs. Cores are removed from castings usually in the foundry, and if they be large this is usually done before the casting is quite cold. A casting is *trimmed*, the first process entailing the removal of prominent spurs, by being *chipped*, by the hammer only, or, if necessary, with the assistance of a cold chisel. Sometimes pneumatic hammers [see Machine Tools] are used. Then fins, which are not sufficiently prominent to be properly removed by this means, are rubbed, generally with old files, which have served their first usefulness in the fitting or machine shop. Sometimes cast-iron files are used. For brass there are not the same reasons of economy for the use of old files, and good files may be employed, the brass being softer. Then the castings are usually ground. Grindstones used to be employed, but the better practice is to use emery wheels [see Machine Tools]. They are better than grindstones. They should not be "forced"—that is, the work should not be pressed against them with too great force, as this is bad for both the work and the tool. For large castings, which cannot be moved about over the periphery of the wheel, an emery wheel fitted to the end of a flexible driving shaft may be used. It can be applied to any accessible part of a stationary casting, but brass castings are seldom of so large size as to demand treatment by this method. But a wire brush mounted upon a flexible shaft in this manner is often used, and is valuable as an instrument for removing adhering sand.

Dressing by Sand-blasting. Another process often employed for small castings is that of "rumbling"—that is, placing them in a cylindrical chamber which is made to revolve upon a horizontal axis. As this process wears the edges chiefly, it is not suitable for small castings of an ornamental nature. A similar process is employed in pin manufacture, and also in tinning. Sharp sand, small star-shaped castings, known as "stars," and sometimes sawdust are placed inside the rumbling cylinders, and made to revolve with the castings under treatment. But perhaps the best method of cleaning cast surfaces is by a sand-blast machine. This ingenious invention—similar to that used for decorating glass [see Glass] —is a vessel in which a supply of sand is contained in a chamber with an aperture at the bottom, this aperture being capable of regulation as to size, and as a thin stream of sand falls through the aperture it encounters an air blast—usually from 5 lb. to 15 lb. per square inch—which carries it through a flexible tube to a nozzle, whence it is blown upon the surface of the casting. The workman guides the nozzle, and its value over the tumbling process already described is that the work can be directed to the points where it is most required, and not to prominent points only.

Brass Spinning. The die press and the draw press have modified the practice of working sheet metals considerably, not only by doing away with the need for much of the hand or "piece" work formerly undertaken, but also by making possible many forms of work formerly unattainable. The process of spinning sheet-metal is usually subsequent to the work of the press, which is an economical means of securing a blank suitable for spinning. Spinning is an operation whereby an object such as a reeded curtain-pole end, a brass bed-knob, or a berry pan is given its shape. The operation is simple, but clever. It can be carried out upon work in the flat state which has been cut out by hand or by press, but it is economical in most cases to put the work through the draw press before spinning. For spinning, a "former" is required. This former must be of the shape which it is desired the final form of the article shall have. The widest part of the former must never be larger than the narrowest neck of the spun article, else the former could not be withdrawn after the article had been spun.

The Spinning Lathe. The lathe, in which the work is performed, is a machine with a bed and fixed headstock having a chucking arrangement suitable for holding the articles, usually of cylindrical or cup shape, or something approaching thereto. The article is held in position on the formers by a movable tail stock, and special burnishing or friction rollers carried upon a compound slide-rest are made to press against the work, and cause the metal to "flow" into the required shape, the form being given by applying the pressure at the proper points. It is possible to give by spinning not only plain ridges and grooves but ornamental patterns, such as milled, beaded, and spiral edges, such forms being attainable by the use of pressing rollers and formers carrying the particular pattern it is desired to impress upon the work. For spinning work, the result depends upon the high speed at which the work is made to revolve. The operation we have described utilises burnishing or friction rollers attached to the slide-rest. This is the modern practice, and is the best for cheap work where thousands of one article are being made; but for some work other than brass, such as spun Sheffield ware, it is common to use burnishers, held by hand and pressed against the work without mechanical aid other than the strength of the workman.

Spinning is possible by reason of the malleability of the material employed. The effect is to cause hardening just as in the operations of drawing and raising metals, and therefore annealing is necessary when the work of spinning is of a prolonged character. Besides the brasses, Britannia metal is used, and in a lesser degree zinc and aluminium. The "forms" or chucks are of hard wood usually, attached to the mandrel nose. Only when large numbers of similar pieces are required are forms of metal employed.

Articles of Partnership. Interest and Division of Profits. Admission of Partner. Dissolution of Firm. Division of Ledger. Balancing by Sections.

PARTNERSHIP ACCOUNTS

Use has been made in the preceding pages of the words "partners" and "firm," but the general question of partnership has not hitherto been considered. Sir Frederick Pollock, in his work on the subject, defines partnership as "the relation which subsists between persons who have agreed to share the profits of a business carried on by all or any of them on behalf of all of them," and it is difficult to imagine a more comprehensive definition in few words. The legal relations between partners and the outside world are defined by the Partnership Act, 1890, which codified the law on the subject, and that statute contains the regulations under which partnerships are carried on in the absence of any special agreements between the members of a firm. It is usual, however, in practice for a formal agreement defining their rights and liabilities to be drawn up and executed by partners in a business.

Articles of Partnership. This document is entitled "The Articles of Partnership," and deals, amongst other matters, with the amount of capital to be contributed by each partner, the limit up to which each may draw money from the business on account of his share of the profits, the way profits and losses are to be divided, the question whether interest is to be allowed on the capital introduced or charged on the amounts withdrawn, and the method of arriving at a partner's share of the property in the event of dissolution of the partnership. The manner in which these matters are dealt with varies in different firms, and is a matter which concerns the partners only.

The principal points of difference between the accounts of single traders and partnership are three in number:

1. Each partner has a separate capital account, which is divided into (*a*) capital account; and (*b*) drawings account;
2. Interest on drawings and capital;
3. Division of profits and losses.

There is no hard and fast rule for any of these matters; they are the subject of agreement between the partners themselves.

Separate Capital Accounts. A separate account for each partner is absolutely necessary, as each individual member of a firm is entitled to his own share of the partnership property and no more. The amounts contributed by the partners are in the majority of cases unequal, and it would clearly be inequitable to amalgamate the capitals and give each partner equal rights irrespective of the amount he had brought in or of the work he was to perform. The sum contributed by each partner is therefore debited to cash and credited to him on a separate capital account opened in his name. If a partner should bring into the business any property other than cash, an account is opened and debited with such property, the partner being credited with the value as agreed with the other members of the firm.

It is expedient also to have a separate account for recording the drawings of the partners from the business. The amounts drawn may be numerous, and it is very undesirable to have a large number of small items of cash and goods debited to the capital account proper. As already explained, when a partner draws cash on account of his share of the profits he is debited with the amount, cash being credited. At the end of the financial year, when the accounts are balanced, his share of the profits is ascertained in accordance with the provisions of the partnership articles, and he is credited on his drawing account with the amount. The excess of his share over his drawings is then transferred to the credit of his capital account.

Interest on Capital and Drawings. The question of interest is one entirely within the discretion of the partners when settling the terms of the partnership. In the absence of any arrangement to the contrary interest is not allowed, and it is therefore usual, where capitals are unequal and profits are not shared in proportion to the respective capitals, to stipulate that interest at an agreed rate, usually five per cent., shall be charged to the business for the use of the money and credited to each partner according to the amount of his capital. On the other hand, it is frequently arranged that interest shall be charged against the partners on their drawings, this, of course, forming a credit to the business. The entries necessary to record these charges are (1) a debit to the profit and loss account and a credit to each partner on his drawings account of the amount of the interest on his capital, and (2) a debit to each drawing account and a credit to profit and loss of the amount of the interest on the drawings, this being calculated from the dates on which the drawings take place to the date up to which the accounts are prepared. It may be pointed out that when profits are divided in proportion to the partners' capitals there is no object in charging interest on capital, as the net result will be the same as if no charge were made.

Division of Profits. The manner in which the profits and losses of the business are to be shared depends, as a rule, upon two things: firstly, the amount of each partner's capital; secondly, upon the share which each takes in the management of the concern. It sometimes happens that a considerably greater amount of work is done by one partner than by another, and this is equalised by the working partner being allowed either a partner's salary or else a larger share of the profits than he would be entitled to having regard to the amount of his capital.

In order to show clearly the working of the drawings and capital accounts a specific case will be considered. Grey and Green are partners with capitals of £3,000 and £1,000 respectively. The business is managed by Green, for which he is allowed a salary of £200 per annum. Profits are shared in proportion to their capitals, interest at 5 per cent. being allowed on the latter and charged at the same rate on drawings. Grey's drawings were £50 on 31st March, £75 on 30th June, and £40 on 30th September. Green's only drawing, with the exception of his salary, which he received quarterly, was £30 on 30th June. The profits of the business, after charging and allowing interest in the profit and loss account, was £600. [See Tables below.]

In preparing the balance-sheet of a firm it is usual to show the capital accounts of the partners in detail. The capital accounts of Grey and Green would therefore appear in their balance-sheet.

LIABILITIES		
Sundry Creditors, viz. :		
On Bills Payable	685 7 0	
On Open Accounts	1,819 15 6	2,505 2 6
Capital Accounts :		
Grey balance, Jan. 1st	3,000 0 0	
Add Interest	150 0 0	
Share of Profits	450 0 0	
	3,600 0 0	
Less Drawings and Interest ..	169 5 0	3,430 15 0
Green balance, Jan. 1st ..	1,000 0 0	
Add Interest	50 0 0	
Share of Profits	150 0 0	
	1,200 0 0	
Less Drawings and Interest ..	30 15 0	1,169 5 0
		£7,105 2 6

Admission of a Partner. From a variety of causes, such as retirement of a partner, increased business, or want of further capital, a new partner is frequently introduced to a firm. The terms upon which he is admited are matters for arrangement, and usually include the investment by him of a fixed sum in the business and

GREY'S DRAWINGS ACCOUNT

Dr.					Cr.
Mar. 31	To Cash	50 0 0	Dec. 31	By Interest on Capital ..	150 0 0
June 30	,, Cash	75 0 0	,,	,, Profit and Loss Account, being ¾ of profits	450 0 0
Sept. 30	,, Cash	40 0 0			
Dec. 31	,, Interest on Drawings	4 5 0			
,,	,, Transfer to Capital a/c	430 15 0			
		£600 0 0			£600 0 0

GREY'S CAPITAL ACCOUNT

Dr.					Cr.
			Jan. 1	By Cash	3,000 0 0
			Dec. 31	,, Transfer from Drawings Account ..	430 15 0

GREEN'S DRAWINGS ACCOUNT

Dr.					Cr.
Mar. 31	To Cash	50 0 0	Dec. 31	By Salary as Managing Partner	200 0 0
June 30	,, Cash	80 0 0	,,	,, Interest on Capital ..	50 0 0
Sept. 30	,, Cash	50 0 0	,,	,, Share of Profit	150 0 0
Dec. 31	,, Cash	50 0 0			
,,	,, Interest on £30 drawings	15 0			
,,	,, Transfer to Capital a/c	169 5 0			
		£400 0 0			£400 0 0

GREEN'S CAPITAL ACCOUNT

Dr.					Cr.
			Jan. 1	By Cash	1,000 0 0
			Dec. 31	,, Transfer from Drawings Account ..	169 5 0

the payment of a premium to the existing partners. The premium is usually regarded as being in respect of the goodwill of the business, and as it frequently happens that there is no account in the books representing that asset, and it has not been necessary hitherto to arrive at the value of it, the price to be paid in this respect is generally fixed upon the basis of so many years' purchase of the annual profits. Two years' purchase is a very usual price, but it may, of course, be either more or less according to the nature of the business.

The premium may be dealt with in two or three different ways. The cash the new partner introduces as his capital will be debited to cash and credited to his capital account. The premium may perhaps be paid to the old partners direct and not come into the new firm's books at all, or it may be paid into the firm's bank account and credited to the old partners in such proportion as may be agreed between them. It is sometimes arranged that instead of a payment being made by the incoming partner a goodwill account is opened and debited with an agreed amount which is credited to the partners in proportion to their shares in the business.

Dissolution of Partnership. In the absence of any agreement to the contrary, a partnership is indefinite as to its duration, but it is automatically dissolved upon the happening of certain events, two of which are the death or bankruptcy of a partner. It is not unusual for the articles of partnership to provide that upon the death of a partner his share in the business is to be calculated upon a certain basis in order to avoid the necessity of preparing a balance-sheet in the middle of a trading period. One method is to take his capital as at the date of the last balance-sheet and allow the addition of profits at the rate of the average for the three preceding years, providing also for the valuation of the goodwill. It is sometimes further provided, in order that the business shall not be crippled by the sudden withdrawal of a large amount of capital, that payment to a deceased partner's representative shall be made by instalments. In other cases provision is made for such a contingency by an insurance of the lives of the partners being effected at the cost of the firm, which will, of course, receive the sum insured in the event of the death and use the money to pay out the deceased partner's capital.

Final Winding-up. The kind of dissolution, however, which requires further explanation is the complete winding-up of the firm owing either to failure or to the period for which it was entered into having terminated, or to general agreement amongst the partners to discontinue business. In any of these events it is necessary to realise the assets and pay to each partner the amount due to him in respect of his capital. The first step to be taken is to prepare a balance-sheet as at the date of dissolution. An account called the realisation account is then created, and the values of the assets as appearing in the books are transferred to its debit, the various assets accounts being closed by being credited by the amounts so transferred. As the realisation proceeds, cash account will be debited, and the realisation account credited with the sums received.

When the assets are sold the balance of the realisation account will represent the gain or loss on realisation, probably the latter, for assets seldom realise their book values. This balance must be treated in the same manner as if it were the balance of the profit and loss account. If it represents a gain, it will be transferred to the credit of the partners and increase the amount of their capitals, while, on the other hand, if, as is probable, there is a loss, it will be transferred to the debit of the partners and reduce their capitals. Any expenses of realisation will also be debited to the realisation account as they are paid, while cash will be credited with the payments as well as with payments to the creditors. The result will be a balance on the cash account representing the excess of the proceeds of the sale of the assets over the liabilities and the expenses of winding up. As all the assets have been sold and their proceeds received in cash, the balance of the cash account will equal the aggregate of the balances on the partners' capital accounts after the latter have been debited with the loss or credited with the gain on realisation.

Self-balancing Ledgers. We have so far assumed that one ledger only has been used in the businesses with which we have dealt, but it will have been obvious to the observant reader that in undertakings where a large business is carried on the debtors and creditors must be too numerous to allow of all their accounts being kept in one book. Where this is the case, it is necessary to divide the ledger into sections, each set apart for a particular class of transactions. It must be remembered that where separate books are used the ledger as a whole consists of all the different sections, and if it is desired to prove the books at any time by means of a trial balance, it will be necessary to extract the balances of all the accounts in every ledger before agreement can be obtained.

This, in a business where there are hundreds of debtors—and there are many such—is a work of considerable magnitude; and if when all the balances have been extracted the totals do not agree, the bookkeeper is at a loss to know in which ledger to look for the error. In order to obviate the necessity of searching through all the ledgers to find a difference which may exist in only one of them, a method has been devised by which it is possible to localise errors and thus restrict the search to the particular section indicated as being that in which the error has arisen. The system is variously known as sectional balancing, self-balancing ledgers, and balancing by totals, but, subject to very slight modifications, these terms refer to the same system whichever name is employed.

Sectional Principle. The underlying principle is that each ledger must contain *in itself* a complete double entry of all the transactions recorded in it. This is, of course, always the case where only one ledger is used, but when, owing to the increase in the number of accounts, it becomes necessary to have more than one ledger, it is highly probable that while the debit side of a transaction may be posted to one ledger the credit side will be posted to another. Thus, in the case of a sale of goods the debit to the customer would be made in the sold ledger, while the credit to the goods or sales account would be made in the general ledger. If nothing further were done, it would be necessary, in order to obtain a trial balance, to extract the balances of all the ledgers, but if each ledger is so arranged that the total of its debits is equal to the total of its credits, it will be possible at any time to extract a trial balance of each ledger separately, and so ascertain that the work of posting has been correctly performed. This may sound somewhat like duplicating work, but it is not so in fact, and the gain is so enormous in a large concern that the slight amount of extra trouble is fully compensated for by the result achieved.

The system is only necessary in a business where the ledger is divided. The first division which is made is usually into (1) sold ledger, containing the accounts of the debtors; (2) bought ledger, containing the creditors' accounts, and (3) general ledger, set apart for such accounts as stock, purchases, sales, the various revenue and expenditure accounts, the capital and drawings accounts of the partners, and the assets of the concern, other than book debts. The sold ledger is frequently further divided into sections set apart for town and country debtors, or for portions of the alphabet, and sometimes for both.

Separate Sold Ledgers. It will be sufficient for the purpose of explaining the system to take a case where the sold ledger is divided into town and country ledgers, as the principle applied is the same whatever the number of ledgers. There must be either separate books of first entry for each ledger (and this is the better method where the ledgers are numerous), or the books from which the ledgers are posted—*viz.*, the sales, returns inward, cash and bills receivable books—must be ruled with columns for both ledgers, care being taken to enter the items in the column relating to the ledger in which the customer's account is kept. The postings to the debit of customers of the goods sold to them will be carried out in the usual manner, and the gross

Dr. ADJUSTMENT ACCOUNT IN TOWN SOLD LEDGER Cr.

Date	Particulars	£ s. d.	Date	Particulars	£ s. d.
Jan. 31	To Cash received as per Town column of Cash Book	1,208 1 9	Jan. 1	By Balance b/d, being the total of the balances on the customers' accounts	2,743 16 8
	,, Discount (Cash Book)	24 6 3	Jan. 31	,, Sales as per Town column of Sales Book	1,426 18 2
	,, Returns as per Returns Inward Book, Town col.	42 8 6	Feb. 28	,, do. do.	1,107 5 3
Feb. 28	,, Cash and discount as above..	1,124 5 3	Mar. 31	,, do. do.	1,384 12 6
	,, Bad Debt as per analysis of Journal ..	42 8 11		,, Dishonoured bill as per Journal	27 10 0
Mar. 31	,, Cash and discount ..	1,456 8 1			
	,, Bills Receivable as per Town col. of Bills Receivable Book ..	84 2 6			
	,, Balance c/d, agreeing with aggregate of debtors' balances ..	2,708 1 4			
		£6,690 2 7			£6,690 2 7
			April 1	By Balance b/d	2,708 1 4

Dr. TOWN SOLD LEDGER ADJUSTMENT ACCOUNT IN GENERAL LEDGER Cr.

Date	Particulars	£ s. d.	Date	Particulars	£ s. d.
Jan. 1	To Balance b/f, being total of balances on customers' accounts ..	2,743 16 8	Jan. 31	By Cash received as per Town column of Cash Book	1,208 1 9
Jan. 31	,, Sales as per Sales Book, Town column	1,426 18 2		,, Discount do. do. ..	24 6 3
Feb. 28	,, do. do. ..	1,107 5 3		,, Returns as per Returns Inward Book, Town column	42 8 6
Mar. 31	,, do. do. ..	1,384 12 6	Feb. 28	,, Cash and discount ..	1,124 5 3
	,, Dishonoured bill as per Journal	27 10 0		,, Bad debt as per Journal	42 8 11
			Mar. 31	,, Cash and discount ..	1,456 8 1
				,, Bills receivable as per Town column of Bills Receivable Book ..	84 2 6
				,, Balance c/d, agreeing with total of debtors' balances	2,708 1 4
		£6,690 2 7			£6,690 2 7
April 1	To Balance b/d	2,708 1 4			

total of the sales, both town and country, posted to the credit of the sales account in the general ledger. The cash, bills receivable, discount, and the returns inward—*i.e.*, from customers—will be posted to the credit of the customers' accounts, while the gross totals will be posted to the debit of the respective accounts in the general ledger relating to bills, returns, etc. This would complete the ordinary double entry of the various transactions, and the accuracy of the work could be tested by extracting a trial balance covering all the ledgers. But in order to obtain the desired result of balancing each ledger separately, we must obtain from the books of first entry the totals of the postings made to the debit and credit of customers in the two ledgers respectively. This is done by means of the town and country columns in each book, which are totalled at the end of the month, and the amounts posted to accounts opened at the end of each sold ledger, entitled General Ledger Adjustment Account.

The effect of this operation will be that each sold ledger will balance in itself, for, taking the case of the town ledger, the sales to town customers will have been separately posted to the debit of individuals, while the total of the town column in the sales book will be posted to the credit of the adjustment account. The cash, bills received, and discount, will have been posted to the credit of the customers individually, and the totals of the town columns in the cash and bills receivable books will be posted to the debit of the adjustment account. Returns inward will be posted to the credit of customers, and the total of the town column to the debit of the adjustment account. It will be apparent that if these entries have been correctly made the town ledger will balance in itself, for care has been taken to debit and credit to the adjustment account in total the items that have been credited and debited to the customers separately. It will be necessary to dissect the journal for any items affecting the town ledger in order that the totals may be entered on the adjustment account on the opposite side from that on which they were entered in the case of the customer. These items may consist of dishonoured bills, bad debts, special allowances, etc. The result will be, if the work has been accurately carried out, that the balance of the adjustment account will equal the aggregate of the balances of the other accounts in the ledger—*viz.*, those of the town customers. This balance is carried down at balancing time and shows at a glance the total of the customers' balances then owing.

General Ledger Adjustment. In order that the balancing of the books as a whole may be preserved, an adjustment account is raised in the general ledger for each of the other ledgers, and the entries made on these accounts will naturally be the reverse of those made in the adjustment accounts in those ledgers. In order that the working of the system may be thoroughly understood, specimens of the adjustment accounts in a town sold ledger and in a general ledger respectively are shown on the previous page.

In the case of a small business, with only three ledgers—*viz.*, sold, bought, and general ledgers—it might be more convenient to prepare monthly summaries by analysing or dissecting the books of first entry and showing in the form of an account the totals of the postings to the three ledgers. Thus, in the case of the bought ledger, the credit side of the cash book would be analysed, and the amounts which had been posted to the debit of persons whose accounts were kept in the bought ledger would be extracted, totalled, and entered on the credit side of the summary. The purchases book would give the total of the postings to their credit, and this would be entered on the debit side of the summary. Any returns outward would be taken from the returns book, and as these would have been posted in detail to the debit of the sellers, the total would be entered on the credit side of the summary. Any bills given to the creditors which have been posted to their debit would be entered in total on the credit side of the summary, which would then appear as below. J. F. G. PRICE

Dr. SUMMARY OF BOUGHT LEDGER Cr.

		£	s.	d.			£	s.	d.
Jan. 1	To Balance b/f, being total of the balances of the creditors' accounts	283	5	4	Jan. 31	By Cash paid to creditors, as per analysis of Cash Book	148	6	9
Jan. 31	,, Purchases as per Purchases Book	195	6	0		,, Discount allowed by creditors	5	6	0
						,, Returns outward ..	18	10	0
						,, Bills payable	50	0	0
						,, Balance c/d, agreeing with total of creditors' balances ..	256	8	7
		£478	11	4			£478	11	4
Feb. 1	To balance b/d	256	8	7					

A special Dictionary, explaining Commercial Terms and Phrases, appears at the end of the Self-Educator

Methods of Extracting Square Root and Cube Root. Measurement of Surface.

SQUARE ROOT AND CUBE ROOT

POWERS AND ROOTS

138. When a product consists of the same factor repeated any number of times it is called a *power* of that factor.

7×7 is the *second power*, or the *square* of 7.

$7 \times 7 \times 7$ is the *third power*, or the *cube* of 7.

A power of a number is generally expressed by writing the number only once, and placing after it, above the line, a small figure to show how many factors are to be taken. The small figure is called an *index*.

Thus, $7^2 = 49$; $7^3 = 343$; $7^4 = 2401$.

139. A number is called the *square root* of its square. Since $7^2 = 49$, the square root of 49 is 7.

The "square root of 49" is written $\sqrt{49}$.

Again, a number is called the *cube root* of its cube. $7^3 = 343$. Therefore, the cube root of 343 is 7.

The "cube root of 343" is written $\sqrt[3]{343}$.

A *perfect square* is a number whose square root is a whole number. A *perfect cube* is a number whose cube root is a whole number.

SQUARE ROOT

140. If a number can be put into prime factors, its square root can be written down by inspection.

EXAMPLE. Find the square root of 27225.

Since $27225 = 3^2 \times 5^2 \times 11^2$.

$\therefore \sqrt{27225} = 3 \times 5 \times 11 = \underline{165\ \textit{Ans.}}$

141. We know that $\sqrt{1} = 1$, and $\sqrt{100} = 10$. Therefore, the square root of any number which lies between 1 and 100 lies between 1 and 10; *i.e.*, if a number contains *one* or *two* digits, its square root consists of *one* digit.

Similarly, since $\sqrt{100} = 10$ and $\sqrt{10000} = 100$, the square root of a number between 100 and 10000 lies between 10 and 100. That is, if a number contains *three* or *four* digits, its square root consists of *two* digits.

Proceeding in this way, we obtain a general result—viz., the square of a number has either twice as many digits as the number, or one less than twice as many.

Hence, to ascertain the number of digits in the square root of a perfect square, mark off the digits in pairs, beginning from the right. Each pair marked off gives a digit in the square root; and, if there is an odd digit remaining, that digit also gives a digit in the square root.

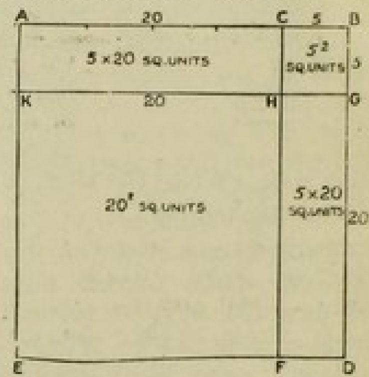
EXAMPLES. There are *three* digits in the square root of 546121, and *four* in the square root of 5774409.

For, marking off the digits from the right, we get in the first case 54̦61̦21, giving three digits in the square root, and in the second case 5̦77̦44̦09, the odd digit giving the fourth in the square root.

The method of finding the square root of a given number depends on the *form* of the square of the sum of two numbers.

Consider the number 25, *i.e.*, $20 + 5$. In the figure, let AB measure 25 units and BC 5 units. Then $AC = 20$ units. Draw the square ABDE, and draw CF parallel to BD.

Make $BG = 5$ units, and draw GK parallel to AB. Then it is easily seen that (1) ABDE contains 25^2 square units; (2) BCHG contains 5^2 square units; (3) each of the figures ACHK, GHFD, contains 5×20 square units; (4) HKEF contains 20^2 square units.



It follows that

$$25^2 = (20 + 5)^2 = 20^2 + \text{twice } 20^2 \times 5 + 5^2.$$

The result may be written in the form

$$25^2 = 20^2 + (\text{twice } 20 + 5) \times 5.$$

142. Suppose we are required to find the square root of 625. By Art. **141**, there will be two digits in the square root The greatest perfect square which is not greater than 6 is 4—*i.e.*, 2^2. Hence, 2 is the first, or tens, figure of the root. Subtract this 20^2 from 625. The remainder is 225. Now, by Art. **141**, if 625 is a perfect square, this remainder must be equal to (twice 20 + digit required) × that digit. Twice 20, or 40, is therefore a *trial divisor*. Now, 40 divided into 225 gives 5 for quotient. We therefore try whether $(40 + 5) \times 5$ is equal to 225; and, finding this to be the case, we know that 5 is the digit we wanted, and that the square root of 625 is 25.

Example 1. Find the square root of 74529.

$$\begin{array}{rl} & 7\,45\,29\,(200 + 70 + 3 \\ 200^2 = & \underline{4\,00\,00} \\ & 3\,45\,29 \\ 70 \times (\text{twice } 200 + 70) = & \underline{3\,29\,00} \\ & 16\,29 \\ 3 \times (\text{twice } 270 + 3) = & \underline{16\,29} \end{array}$$

EXPLANATION. There will be three digits in the root. The greatest square number below 7 is 4, *i.e.*, 2^2. Hence, 2 is the hundreds figure of the root. We subtract 200^2, and obtain a remainder, 34529. We now have twice 200, *i.e.*, 400, for a trial divisior; and 400 divided into 34529 gives 80. By trial, we find 80 is too large, since

$80 \times (400 + 80)$ is greater than 34529. We therefore try 70. This gives $70 \times (400 + 70) = 32900$, and this, when subtracted from 34529, leaves 1629.

We have now completed the subtraction of 270^2 from the original number, and found a remainder 1629.

Next, use twice 270, *i.e.*, 540, for a trial divisor. 540 into 1629 gives 3. And $3 \times (540 + 3) = 1629$, so that, after subtraction, there is no remainder.

Also, since [Art. **141**] $273^2 = 270^2 + (\text{twice } 270 + 3) \times 3$, we have now subtracted 273^2 from the given number 74529. Hence, as there was no remainder, we know that $273^2 = 74529$, so that the required square root is 273.

The working is abbreviated as follows:

```
    7,45,29(273 Ans.
 47)3 45
54 3)16 29
```

Explanation. As above, we find the first digit of the answer is 2. Square 2, and subtract from 7, in one process. Remainder is 3. Write the next pair of digits, 45, after the 3, giving 345.

Double the digit of the answer, which has already been found, obtaining 4 as a trial divisor. 4 into 34 gives 8, which, as we saw above, is too large. Try 7. This proves small enough, so we write the 7 after the 4 of our trial divisor, and put 7 into the answer. Multiply 47 by 7 and subtract from 345. Remainder is 16. Bring down the remaining two digits, 29, of the given number. Double the 27 of the answer, obtaining 54 as trial divisor. 54 into 162 gives 3. Write 3 after the 54 and 3 in the answer. Multiply 543 by 3 and subtract from 1629. There is no remainder, and 273 is the required square root.

Example **2**. Find the square root of 2310·7249

```
      23,10·72,49,(48·07 Ans.
  88  ) 7 10
9607  )  6 72 49
```

Mark off the digits in pairs *from the decimal point*. Proceed as in Example 1. After obtaining the first two figures of the square root, 48, we reach the decimal point in the given number. We therefore put a decimal point in the answer, and bring down the next two figures, 72. The trial divisor is 96, and 96 into 67 gives 0. Put 0 in the answer, and bring down 49. The trial divisor is now 960, and this gives 7 for the remaining digit.

143. In the case of a number which is not a perfect square, the process of finding the square root can be continued to as many decimal places as we please, but never terminates.

The square root will not be a recurring decimal, for a recurring decimal can be expressed as a vulgar fraction in its lowest terms; and, if we square such a fraction, the numerator and denominator will still be prime to one another—*i.e.*, the square is a *fraction*, and so, of course, cannot be equal to the given number.

Example. Find the value of $\sqrt{2}$ to four places of decimals.

```
      2    (1·4142 Ans.
   24)100
  281 ) 400
 2824)11900
28282 ) 60400
         3836
```

We consider that 2 is 2·0000... and bring down 00 at each stage of the work.

A number such as $\sqrt{2}$, or $\sqrt{5}$, which cannot be exactly expressed as a decimal is called an *Incommensurable Number*, or a *Surd*.

144. To obtain the square root of a vulgar fraction we take the square root of the numerator and the square root of the denominator.

For, the square of $\frac{3}{4}$ is $\frac{3}{4} \times \frac{3}{4}$, *i.e.*, $\frac{9}{16}$. Therefore,

$$\sqrt{\frac{9}{16}} = \frac{3}{4} \text{ or } \frac{\sqrt{9}}{\sqrt{16}}.$$

In the case of a mixed number, we reduce it to an improper fraction and proceed in the same way.

Example **1**. Find the square root of $19\frac{30}{49}$.

$$19\tfrac{30}{49} = \tfrac{961}{49}.$$

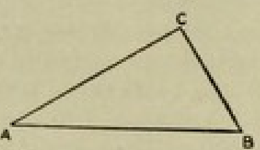
$$\therefore \text{ Square root} = \frac{\sqrt{961}}{\sqrt{49}} = \frac{31}{7} = 4\tfrac{3}{7} \textit{ Ans.}$$

If the denominator is not a perfect square, we multiply both numerator and denominator by such a number as will make the denominator a perfect square.

Example **2**. Find the square root of $\frac{3}{5}$, to three places of decimals.

$$\sqrt{\frac{3}{5}} = \sqrt{\frac{3 \times 5}{5 \times 5}} = \sqrt{\frac{15}{25}} = \frac{\sqrt{15}}{5} = \frac{3\cdot872\ldots}{5}$$
$$= \cdot774 \ldots \textit{ Ans.}$$

145. Applications of Square Root. In the course on GEOMETRY it will be proved that if one angle of a triangle is a right angle then the square on the side opposite the right angle is equal to the sum of the squares on the other two sides. This property enables us to find the length of the third side of a right-angled triangle when we know the lengths of the other two sides.



Thus, if the angle C is a right angle, and we know that BC = 3 and CA = 4, then

$$AB^2 = 3^2 + 4^2 = 9 + 16 = 25.$$
$$\therefore AB = \sqrt{25} = 5.$$

Or, if we know that AB = 37 and AC = 35, then

$$BC^2 = AB^2 - AC^2 = 37^2 - 35^2 = 144.$$
$$\therefore BC = \sqrt{144} = 12.$$

Example. How long is the diagonal of a rectangular field whose length is 153 yd. and breadth 104 yd.?

The square of the diagonal $= 153^2 + 104^2$
$= 23409 + 10816$
$= 34225.$

$\therefore$ Diagonal $= \sqrt{34225} = 185$ yd. *Ans.*

146. The following is a common type of problem in square root.

Example. The members of a club each subscribed as many sixpences as there were members of the club. The total sum was £455 12s. 6d. How many members were there ?

```
          £   s.  d.
         455  12   6
          20
        9112 s.
           2
       1,82,25 sixpences (135 members Ans.
  23)   82
 265)  13 25
```

Explanation. Evidently the number of sixpences subscribed is the square of the number of members. We therefore reduce the given sum to sixpences, and find the square root.

Other problems will be met with after the chapter on Areas and Volumes.

CUBE ROOT

147. If we can find the prime factors of any perfect cube, we can write down its cube root by inspection.

Example. Find the cube root of 74088.

```
8|74088
9| 9261
3| 1029
7|  343
7|   49
      7
```

$\therefore\ 74088 = 8 \times 9 \times 3 \times 7 \times 7 \times 7$
$= 2^3 \times 3^3 \times 7^3$

$\therefore\ \sqrt[3]{74088} = 2 \times 3 \times 7$
$= 42$ *Ans.*

148. Since $1^3 = 1$ and $10^3 = 1000$, therefore, the cube of a number which lies between 1 and 10 lies between 1 and 1000, *i.e.*, the cube of a number of one digit contains either one, two, or three digits.

Again, since $10^3 = 1000$ and $100^3 = 1000000$, the cube of a number of two digits contains either four, five, or six digits.

Proceeding in this way, we see that *the cube of a number contains three times, or one less or two less than three times, as many digits as the number.*

Hence, to find the number of digits in the cube root of a given number, we mark off the digits in sets of three, beginning at the decimal point, and marking both to the right and to the left.

149. The simplest method of finding the cube root of numbers whose prime factors are not known is analogous to the method of finding square root, being based upon the form of the cube of the sum of two numbers.

The student can easily verify for himself that

$$67^3 = 60^3 + 3 \times 60^2 \times 7 + 3 \times 60 \times 7^2 + 7^3$$
$$= 60^3 + (3 \times 60^2 + 3 \times 60 \times 7 + 7^2) \times 7.$$

If, then, from some given number, we first subtract 60^3, and then subtract $(3 \times 60^2 + 3 \times 60 \times 7 + 7^2) \times 7$, we shall, altogether, have subtracted 67^3. If we now have no remainder we conclude that the given number is 67^3, *i.e.*, that its cube root is 67.

It should be noticed that 3×60^2 is the same thing as $6^2 \times 300$, and that $3 \times 60 \times 7$ is the same as $6 \times 30 \times 7$. In working examples we shall use the second of these forms, as there is possibly less chance of the student making any mistake in forming the "trial divisors."

By multiplication we know that $67^3 = 300763$. Let us consider how, when we are only given the number 300763, we find that its cube root is 67.

```
                    300,763(67
        6³ =        216
  6² × 300 = 10800|  84 763
  6 × 30 × 7 = 1260|
        7² =    49|
             12109|  84 763
```

We first mark off the digits in threes, beginning at the decimal point—*i.e.*, in this case, at the right-hand digit. Next, we know that $6^3 = 216$, and $7^3 = 343$. Hence, since 300 lies between these numbers, we know that the first digit of our answer is 6. Write the 216 under the 300, and subtract. In reality, of course, we are subtracting 60^3 from 300763. The remainder is 84763. We now form our trial divisor, by squaring the digit already found and multiplying by 300 [see above]. Thus, $6^2 \times 300 = 10800$. Now 10800 into 84763 appears to give 7 for the next digit of our answer. We try 7, forming the rest of our divisor by taking $6 \times 30 \times 7 = 1260$, and $7^2 = 49$, and adding the three lines. This gives 12109, and, on subtracting 7 times 12109 from 84763, there is no remainder. Hence, 67 is the required cube root.

Example. Find the cube root of 14706·125.

```
                      14,706·125,(24·5 Ans.
          2³ =          8
    2² × 300 =  1200|  6 706
  2 × 30 × 4 =   240|
          4² =    16|
                1456|  5 824
   24² × 300 = 172800| 882 125
 24 × 30 × 5 =   3600|
          5² =     25|
               176425| 882 125
```

Explanation. Mark off the digits in threes. By inspection, the first digit of the answer is 2. Subtract 2^3 from 14, obtaining remainder 6. Bring down the next set of digits, making 6706. Form the next divisor by taking $2^2 \times 300 = 1200$. This, divided into 6706, would appear to make the next digit of the answer be 5. If, however, we use 5, and complete the divisor, we find that 5 is too big. Try 4, *viz.*, $2 \times 30 \times 4 = 240$, and $4^2 = 16$. Adding, the divisor is 1456. Subtract 4 times 1456 from 6706. The remainder is 882. Bring down the next set of digits, 125, and, since these digits form the decimal part of the given number, we put a decimal point in the answer. Proceed as before—*i.e.*, square the part of the answer already found, and multiply by 300. Thus, $24^2 \times 300 = 172800$. Dividing this into 882125 gives 5 for quotient, and we complete the divisor by taking $24 \times 30 \times 5 = 3600$, and $5^2 = 25$, which, on addition, makes 176425. Subtract 5 times 176425 from 882125, and there is no remainder. Hence the required cube root is 24·5.

150. A great amount of labour can be saved in forming the trial divisors, after the first. Thus, in the previous example, the second trial divisor, 172800, can be found without working out the value of $24^2 \times 300$.

$2 \times 30 \times 4 = 240$
$4^2 = 16$
1456
Repeat $4^2 = 16$
$24^2 \times 300 = 172800$

The rule is as follows: In the first divisor, already obtained, repeat the $4^2 = 16$, and add together everything but the first trial divisor, 1200. This gives 1728. *If we now add two noughts we obtain the value of* $24^2 \times 300$.

In actual work, we repeat the 16 mentally, and write down nothing more than was shown in the working of the example.

151. The cube root of a number which is not an exact cube can be found to any required number of decimal places. If the decimal part of the given number does not contain an exact number of sets of three digits, we simply put on ciphers to make up the set, and, of course, use three ciphers for each succeeding set.

Example. Find the cube root of 4·9590954051 to four places of decimals.

4·959,095 405,100 (1·7053... *Ans.*
1
$1^2 \times 300 = 300$ | 3 959
$1 \times 30 \times 7^2 = 210$
$7^2 = 49$
559 | 3 913
$170^2 \times 300 = 8670000$ | 46 095 405
$170 \times 30 \times 5 = 25500$
$5^2 = 25$
8695525 | 43 477 625
$1705^2 \times 300 = 872107500$ | 2617 780 100
$1705 \times 30 \times 3 = 153450$
$3^2 = 9$
872260959 | 2616 782 877
997 223

Explanation. After obtaining the first two figures, 17, of the answer, the remainder is 46. Bringing down the next three figures we obtain 46095. Our trial divisor (obtained, as already explained, by adding together 210, 49, 559, and 49, and affixing two noughts) is 86700. This, divided into 46095, evidently gives 0 for the next figure of the answer. Therefore, after putting 0 in the answer, we bring down the next three figures, and obtain 46095405. The trial divisor is now $170^2 \times 300$, which means we have simply to put two more noughts on to the 86700 already obtained. We then proceed as before.

EXAMPLES 18

By the method of factors, find the value of

1. $\sqrt{74529}$.
2. $\sqrt{4624}$.
3. $\sqrt{27300625}$.
4. $\sqrt[3]{456533}$.
5. $\sqrt[3]{18399744}$.
6. $\sqrt[3]{1520875}$.
7. Find the square root of 98765·6329.
8. Find the square root of $3\frac{1}{4}$ correct to three places of decimals.
9. Find the cube root of 30959144, and of 9269337·400720047.
10. Find the cube root of $13\frac{203}{512}$.
11. The side of a square is 5 ft. Find, to three places of decimals, the length of the diagonal.
12. A man spent £19 5s. 4d. in buying books. On the average, each book cost as many pence as there were books. How many books did he buy ?
13. On a tour, a man spent each day 5 times as many sixpences as the number of days the tour lasted. If he spent, in all, £6 2s. 6d., how long did the tour last ?
14. The foot of a ladder 50 ft. long is 14 ft. from the wall of a house, and its other end just reaches the top of a window. When the foot of the ladder is moved to a distance of 30 ft. from the wall, the other end just reaches the bottom of the window. What does the window measure from top to bottom ?

MEASUREMENT OF SURFACE

152. The chief surface with which we are conerned in arithmetic is the *rectangle*

A rectangle is a four-sided figure in which each side is equal in length to the opposite side, and each of the angles is a right angle.

The length and breadth of a rectangle are called its *dimensions.*

If the length and breadth of a rectangle are equal, the figure is called a *square.* We see, then, that the unit of surface, the *square yard* in the tables on page 415, means a square surface, each of whose sides measures a linear yard.

153. The number of square feet (or inches, or yards) in the area of a rectangle is equal to the number of linear feet (or inches, or yards) in the length multiplied by the number of linear feet (or inches, or yards) in the breadth.

This statement is usually abbreviated into

$$\text{Length} \times \text{Breadth} = \text{Area}.$$

154. Since, Length × Breadth = Area, it follows that Length = Area ÷ Breadth, and Breadth = Area ÷ Length.

Example 1. A plot of ground containing 1 acre is 44 yd. wide. What is its length ?

$$\text{Length} = \frac{4840}{44}\text{ yd.} = \underline{110\text{ yd.}}\ \textit{Ans.}$$

Example 2. It costs £5 10s. 3d. to carpet a floor 21 ft. long with carpet at 3s. a square yard, Find the breadth of the floor.

Here, the number of square yards in the floor is equal to the number of times 3s. is contained in £5 10s. 3d.

We must then be careful to divide the number of square *yards* in the floor by the number of *yards* in the length, and not by the number of *feet.* Hence,

$$\text{Area of floor} = \frac{£5\ 10\text{s.}\ 3\text{d.}}{3\text{s.}}\text{ square yd.}$$

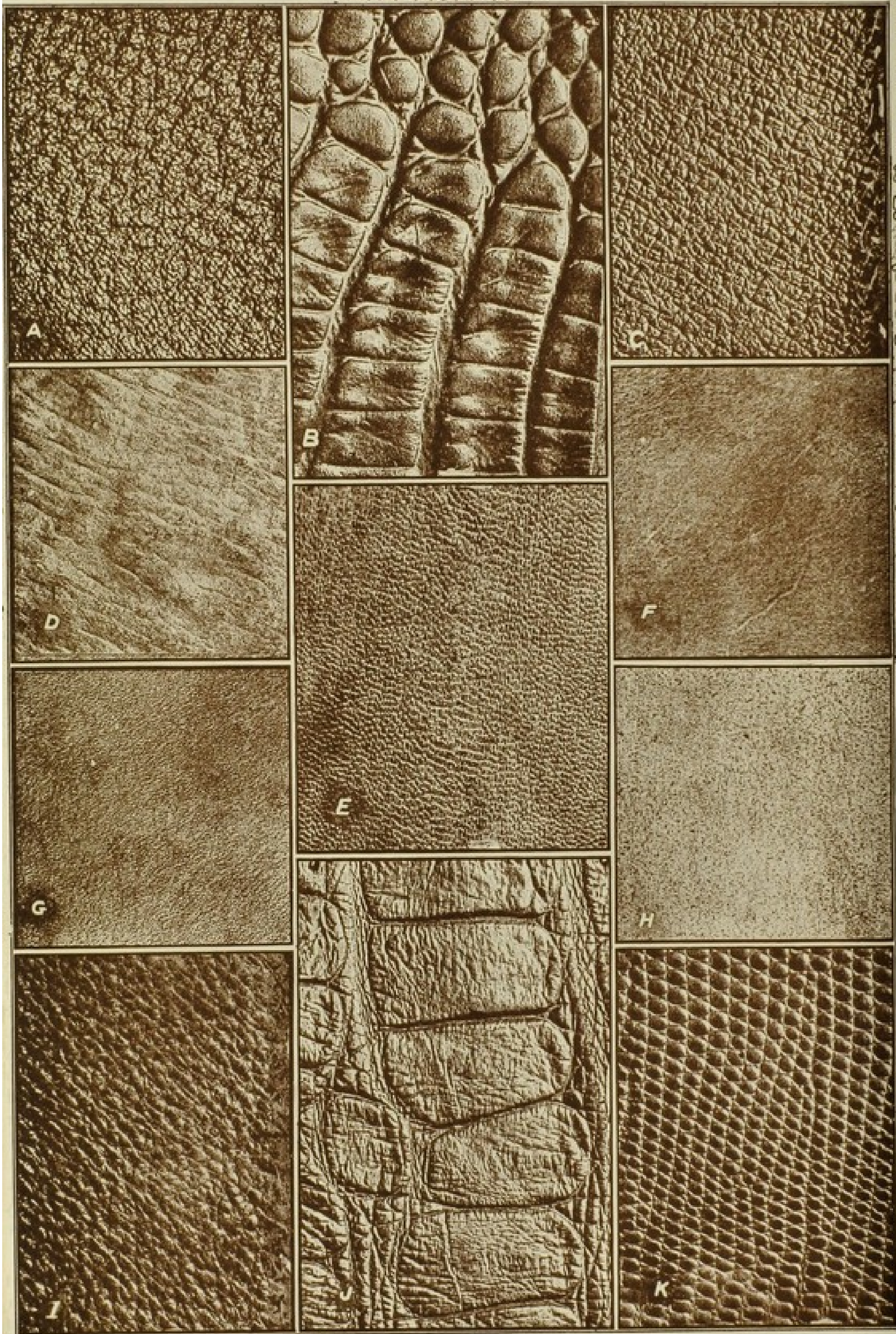
$$= \frac{110\frac{1}{4}}{3}\text{ square yd.}$$

$$\text{Length of floor} = 21\text{ ft.} = 7\text{ yd.}$$

$$\therefore \text{Breadth of floor} = \frac{110\frac{1}{4}}{3 \times 7}\text{ yd.} = \frac{21}{4}\text{ yd.}$$

$$= 5\tfrac{1}{4}\text{ yd.} = \underline{15\text{ ft. } 9\text{ in.}}\ \textit{An.}$$

H. J. ALLPORT



TYPICAL LEATHERS, SHOWING VARIOUS GRAINS

A. Printed grain on goat-skin—morocco. B. Calf-skin printed to imitate crocodile. C. Printed grain to imitate pig-skin. D. Grain side of calf-skin in the "crust"—*i.e.*, as taken from the tan-pit. E. Grain of goat-skin in the "crust." F. Grain side of calf-skin after buffing or scraping. G. Grain side of calf-skin after buffing, smoothing, dyeing, and finishing. H. Split flesh side of same piece as G. I. Grain of kip, boarded to increase markings. J. Grain of crocodile or alligator. K. Printed grain to imitate serpent.

The Nile and its Value to Egypt. The Suez Canal and Railways. Abyssinia. British and German East Africa. The Niger and West Africa.

NORTHERN AFRICA

The Source of the Nile. The true source of the Nile is the Kagera River, which rises considerably south of the equator at a height of over 6000 ft. in the highlands overlooking Lake Tanganyika. In 370 miles it falls over 2000 ft. to Lake Victoria Nyanza, round the northern half of which lies Uganda. The great lake is set among hills, and above its waters rise many wooded islands. Its reedy banks are the home of the hippopotamus. Where it leaves the lake, forming Ripon Falls, the Victoria Nile is half a mile wide. It descends the northern slopes of the Central Highlands, gently at first, but afterwards in a series of cataracts and rapids, to Lake Albert, 1500 ft. below. The length to Lake Albert, including 135 miles of Lake Victoria, is 744 miles. Lake Albert is also fed by the Semliki, which has risen in Lake Edward 1000 ft. above, and flowed down beneath the snows of Ruwenzori.

The Nile in the Sudan. Shortly after leaving Lake Albert, the Bahr-el-Jebel, or Albert Nile, rushes over foaming cataracts, and near Lado enters the vast plains of the Sudan, where its character changes. It begins to wind, and to broaden out into swamps which form immense lakes when the river is high. In this part of its course it divides into two branches, the Albert Nile, and a right-hand branch, the Bahr Zeraf, which later reunite. Both are liable to be choked by sudd, or blocks of living vegetation. "These blocks are formed of papyrus, weeds, and water-grasses, which grow on the half-sandy, half-peaty banks of the lagoons and marshes traversed by the river, and, under the action of a rising flood and strong winds, are torn up and driven into the channels wherever these are confined in width, and there jammed into solid masses of floating weeds, filling the whole width of the river, and very nearly the whole depth." Navigation is, of course, impossible. Since Britain held the Sudan, most of the obstructive sudd has been cut away, but it tends to re-form. An endeavour is being made to use sudd as fuel. Across similar country comes in the Bahr Ghazal from the west, in appearance resembling a swamp rather than a river. Below the junction of the Sobat from the east, the river is known as the White Nile. It is 1318 miles from Lake Albert to Khartum.

The Sudan. The Sudan extends from the confines of Egypt southward into the tropical forest area, which covers much of the Bahr Ghazal basin, supplying rubber and other products. The forests are replaced to the north by grass lands, which extend on either side of the Nile swamps, passing gradually into poor grass-lands covered with tall, coarse grass, and still farther north into desert. Khartum, the capita[l] of the Sudan, is on the margin of the deser[t] region. The cultivated land lies round the rivers. Millet and pulses are the staple crops.

The Blue Nile. At Khartum the Whit[e] Nile unites with a tributary of very differen[t] character, the Blue Nile, the main source o[f] that fertilising mud out of which Egypt has bee[n] built up. It rises in Lake Tsana, about 900[0] feet above the sea, in the volcanic highlands o[f] Abyssinia, the scourings of which are swept dow[n] to the main stream by the tropical rains of sum[-]mer, and whirled along by the foaming river, t[o] be spread out over the plains of Egypt, thousand[s] of feet below. After leaving the forested high[-]lands of Abyssinia, the Blue Nile enters th[e] plains of the Sudan, of which it drains the mos[t] fertile part. Millet, cotton, and wheat ar[e] grown, and the region will doubtless become [a] great wheat-land.

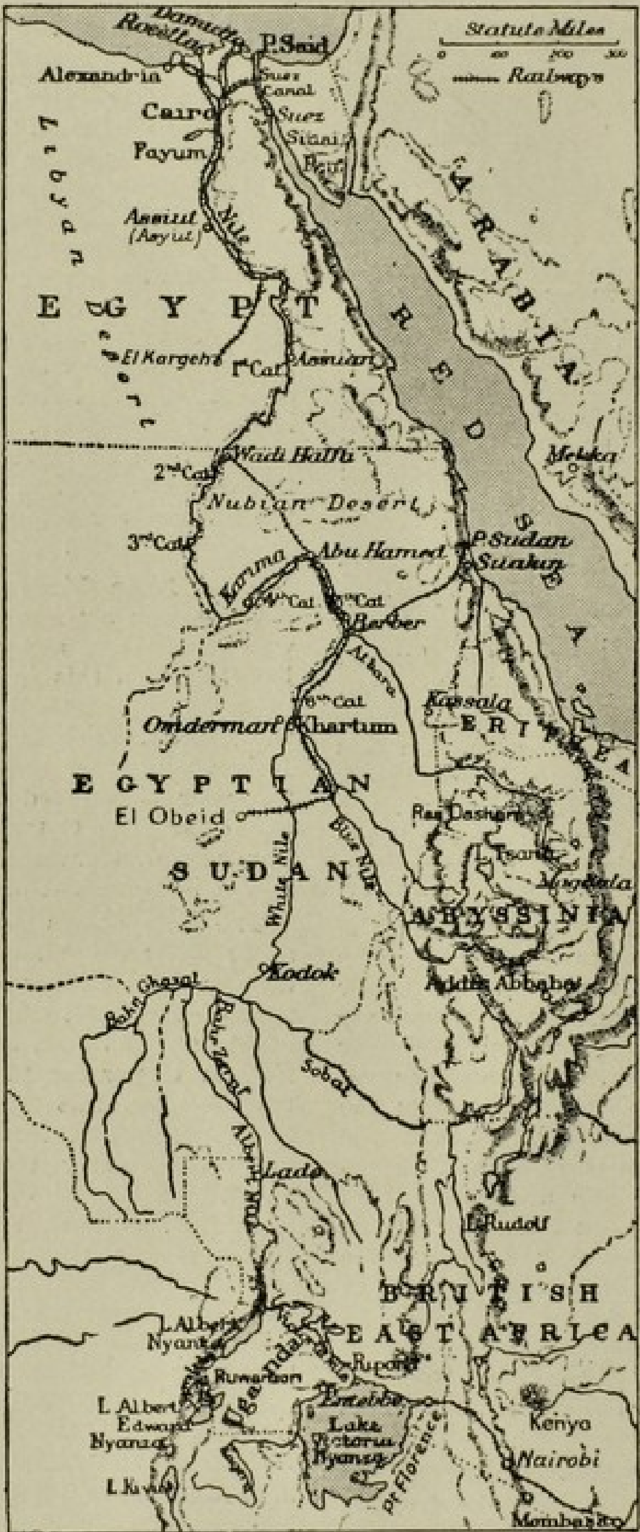
The Nile Valley. Below Khartum th[e] Nile flows in a gorge cut in the Sahara plateau, which is highest along the western shores of th[e] Red Sea. In this part of its course it forms si[x] cataracts. Between the sixth and fifth it receive[s] the Atbara, which has risen near the Blue Nile. It is a wild river in flood, but for two-thirds o[f] the year is reduced to a string of pools. Jus[t] above the Fifth Cataract is Berber, with a line t[o] Port Sudan, near Suakin, on the Red Sea, makin[g] Egypt independent of the Suez Canal in war.

The Nile enters Egypt near Wadi Halfa, [a] short distance above which is the Secon[d] Cataract, extending over 124 miles. At th[e] foot of the First Cataract is Assuan, where [a] great dam has been built across the river. Th[e] Nile in Upper Egypt flows in a narrow valley bordered by cliffs or hills, formed by the edg[e] of the Sahara plateau. Where these approach the river closely the scenery is picturesque. Cairo, the capital of Egypt, near the famous Pyramids, is built at the apex of the delta. Below it the river divides into the Rosetta and Damietta branches, with dams across both for irrigation purposes. Along the Mediterranean are a number of lagoons, some entirely land-locked. The surrounding country is marshy and unhealthy. The port of the Nile is Alexandria, 35 miles west of the Rosetta branch, founded by Alexander the Great. The length from Khartum is 1913 miles, and the total length, 3975 miles.

The Nile Floods. All through the hot months the river falls, and its waters become green and offensive. The coming flood is felt first far up the river, where the Abyssinian tributaries begin to pour in their mud-laden waters. At Assuan the Nile begins to rise in May, but the brown muddy waters do not reach Cairo till the beginning of June. The Nile is highest at Assuan in the middle of September, and at Cairo early in October. The Atbara has run dry by the end of September, the Blue Nile is falling rapidly, and the main stream falls slowly but steadily till the anxious season of low Nile comes round again. A tardy rise of the river causes almost as much anxiety in Egypt as a delayed monsoon in India, so close is the connection between water and fertility in these hot lands.

Methods of Irrigation. Egyptian irrigation is of two kinds—seasonal and perennial. The former utilises the flood waters of the Nile, the latter its permanent flow. The basin system of irrigation has been in use for 7,000 years. In the narrow valley of Upper Egypt dykes about 10 ft. high are built parallel to the river, with cross dykes to subdivide the enclosed area. At high Nile water is admitted to these basins by shallow canals, allowing 4 ft. or 5 ft. of water to cover them. The villages, built on mounds, stand above the level of the flooded country. After six weeks the surplus water is drained off by escape canals, and the saturated soil, covered with newly-deposited fertile mud, is fit for cultivation by the end of November. This is a simpler method than perennial irrigation, but land so irrigated produces only winter crops.

Perennial irrigation is a modern system. The river is dammed back at suitable points till it becomes very deep, and water is drawn off above the dam to fill great canals, which feed a network of smaller ones. One dam has been built below Cairo, enabling the delta to be permanently irrigated, and another at Asyut, to irrigate Upper Egypt. They are fitted with sluices, which are opened in flood, when water is abundant, but shut down as the river begins to fall. The gigantic dam at Assuan, $1\frac{1}{4}$ miles long, with 100 sluices, was built to regulate the supply of water to the lower reaches of the Nile. It forms an immense reservoir, which is fed out as the Nile falls, keeping the river level high enough to supply the perennial canals of Upper Egypt and the Delta. The extension of permanently irrigated and therefore permanently fertile land by these engineering works is one of the great boons which British rule has conferred on Egypt.



THE BASIN OF THE NILE

Besides these elaborate methods, primitive ones are also used, especially in high lands near the river. Water is raised by steam pumps, by the sakieh, a water mill of cogged wheels turned by an ox, and working up a series of pitchers which empty into a trough, or by the hand-worked shadoof—a simple contrivance for raising and lowering a bucket.

Cause of the Nile Floods. The cause of the periodic rise and fall was long a mystery. The explanation is simple. The equatorial lakes and the rivers which discharge them provide the permanent flow of the river as we have it at low Nile. The flood waters are brought by the Abyssinian tributaries, and especially the Blue Nile, after the tropical summer rains on the Abyssinian plateau.

Egyptian Crops. Egypt is often said to have three seasons, summer, flood, and winter. In summer the Nile is low, and cultivation is confined to the perennially irrigated lands, on which are grown cotton, sugar-cane, millet, rice, fruit and vegetables. In flood the basin lands are submerged, and all the canals are full. The crops are millet, maize and flood rice. Early winter sees the basins uncovered and the earth everywhere abundantly moist. Nearly all the country is now under cultivation. The crops—cereals, clover in the basins, pulses and vegetables—are sown in October or November, and reaped the following spring.

Of Egyptian crops cotton is the most important. Egypt is third among cotton-producing lands. And the crop is a summer one, grown both in Upper and Lower Egypt. There are many ginning mills, but few cotton mills as yet. Sugar is grown in Upper Egypt, where sugar factories are numerous. The cultivation of cereals will doubtless increase with irrigation. Egyptian lentils are famous.

Oases of Egypt. In a sense Egypt is itself one great oasis. West of the Nile valley are several oases in the desert, resembling Tafilet in general character. The Fayum, a depression in the Libyan hills, anciently received the surplus waters of the high Nile through a natural channel. It is thus formed of Nile mud. It is sometimes classed as an oasis, but it is irrigated from the Nile, and not, like the others, from springs.

The Suez Canal. The Suez Canal across the isthmus is 87 miles long, of which 21 miles consist of natural depressions, now lakes. The Mediterranean port is Port Said, with long sea-walls to prevent it silting up from the Nile. In the centre is Ismailia, the railway junction for Cairo, supplied with fresh water from the Nile by canal. Suez is the Red Sea port. The tolls for passing through the Canal, which reduces the distance to Bombay by 5000 miles, may amount to thousands of pounds. Britain is a large holder of Canal shares. East of the Canal is the mountainous peninsula of Sinai, cut off from Egypt by the Gulf of Suez, and from Arabia by the Gulf of Akabah.

The railway from Cairo to Khartum, forming part of the Cape-to-Cairo project, is now extended some 400 miles farther south, to El Obeid, the capital of Kordofan. From Port Sudan a line runs, via Suakin, to the mouth of the Atbara river just south of Berber, and takes much of the trade which formerly passed northwards. Farther north, Karima and Abu Hamed are linked by rail, and a branch extends from the Assuan line to El Kargeh.

Abyssinia. Abyssinia is a volcanic plateau averaging 8000 ft. in height. The surface is diversified with isolated peaks and ranges of fantastical shapes, and in many parts rent by great ravines, which make it very inaccessible. The climate and products are as varied as the surface. At one part of the day travel is along the bottom of some gigantic crack in the earth's surface with a nearly tropical heat; at another over some wind-swept plateau with a climate like that of England in winter. Every sort of vegetation is met with, the warm, low valleys growing tropical plants, while on the wind-swept uplands the flowers and grains will be of an Alpine nature. Within a few hours' march are found the banana, grape, orange, pomegranate, peach, apricot, and blackberry, the dhurra, maize, wheat, barley, pears, and the chili, pumpkin, tomato, and potato. The villages

ON THE DESERT WASTES OF TUNIS

are generally on heights, and the keeping of animals is important. Minerals, including gold, are known to be abundant. The capital shifts as the supply of firewood becomes exhausted. The trade centre is Harrar, near the Somali frontier.

Eritrea, the Horn of Africa This is occupied by the Italian colony of Eritrea to the south-west of the Red Sea, and by French, Italian, and British Somaliland. All consist of coastal plain, behind which rises the plateau. The inhabitants depend chiefly on their camels and other animals. Jibuti, in French, and Berbera and Zeila, in British Somaliland, are the chief settlements.

British East Africa. British East Africa ascends by a series of steep terraces to the plateau, much of which consists of boundless grassy plains occupied by pastoral tribes. It is crossed by the Eastern Rift valley, with its chain of lakes, and contains the great cone of Kenya. The railway from Mombasa, on the hot, fertile, malarial coast, passes through Nairobi, near the great cone of Kenya, crosses the Eastern Rift, and descends to Port Florence on Lake Victoria. Steamers cross to Entebbe, the capital of Uganda, which lies to the north of the lake. Zanzibar, consisting of the islands of Zanzibar and Pemba, is British territory governed by a native sultan. Cloves are the chief product. Zanzibar is the most important port and commercial centre of East Africa.

German East Africa resembles British East Africa, but is drier. It extends from Lake Tanganyika to the coast, and from Lake Victoria to Lake Nyasa. The chief port is Dar-es-Salaam.

West Africa. Between the Western Sahara and the Gulf of Guinea lies a vast region drained to the Atlantic by the Senegal (950 miles) and the Gambia (600 miles), and to the Gulf of Guinea by the great Niger (2600 miles). The northern part of this region, a plateau of moderate elevation, is a savana land forming a transition between the arid desert to the north and the densely forested coastal lowlands of the Gulf of Guinea. This savana land, the Sudan, extends as far east as the Nile. The Nile provinces of the Sudan have already been described. The Senegal and Gambia rivers rise in the forested Futa Jallon highlands, and flow north-west, forming falls in their descent from the plateau to the lowlands, which are less densely forested than those of the Gulf of Guinea. The exports are ground nuts and rubber.

Difficulties of West African Trade. Two great difficulties hinder trade—the want of harbours and the want of roads. Freetown has a good harbour, but from there to Old Calabar, a distance of 1500 miles, the coast is beaten by the heaviest surf of the world. "Off every beach is a fringe of parallel thundering rollers, white-crested and steep-sided, smiting the sand with tremendous force." Every river has its thundering bar, "which it is almost certain death to cross except in boats constructed for the peculiar work, or in native canoes." Every pound of goods has to be shipped or landed through this fringe of breakers, and ships ride at anchor a mile or so from the shore. Roads in the forest country are mere tracks, unfit for wheeled carriage. Human carriers are employed at a cost of time and money which is prohibitive to trade on a large scale. The cost of carriage in Northern Nigeria is 2s. a ton a mile.

Swamps of the Niger Delta. Between Lagos and the mouth of the Old Calabar River lies a waste some 400 miles long "of festering mud and slime, out of which the leather-leaved mangroves grow. Through this desolation of rottenness the waters of the Niger find their way to the sea by innumerable channels, the whole bound together by a network of tangled waterways." Of several hundred mouths only eight or nine are navigable by large vessels, though a steam-launch might travel through 500 miles of swamp and forest. The chief entrance is at Forçados for Akassa, at the main mouth, which has a dangerous bar.

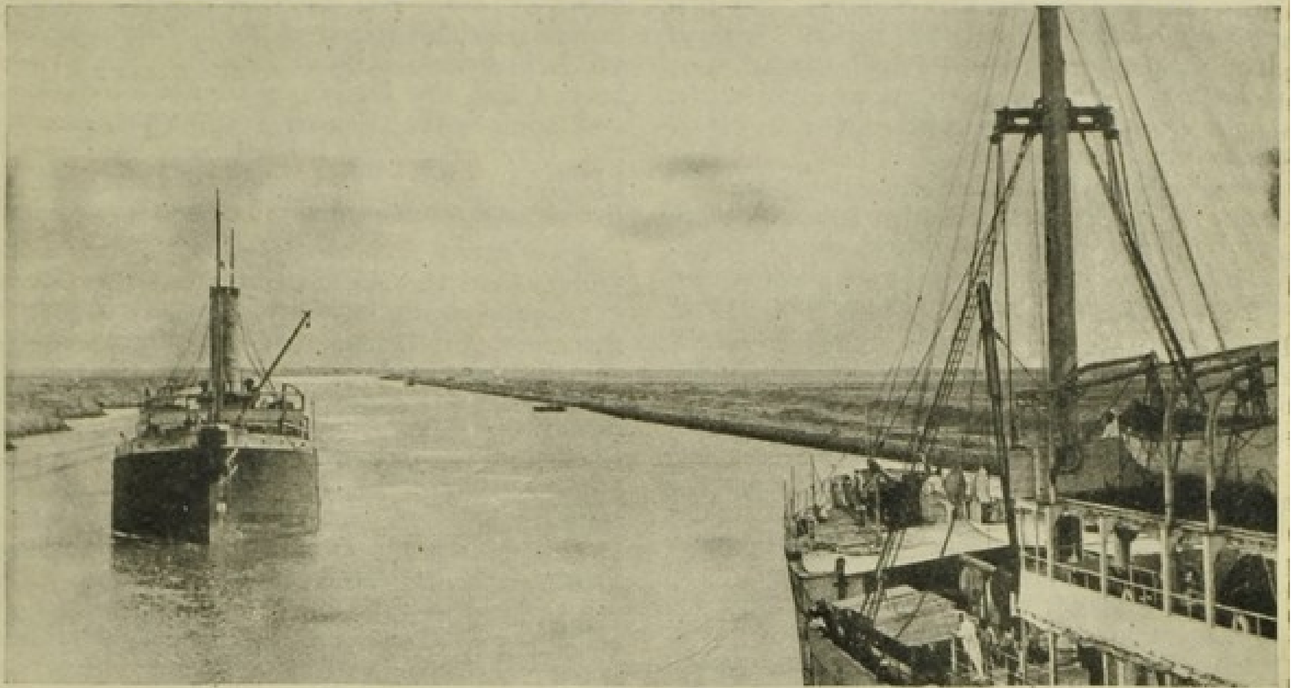
An important deep inlet farther east, with a high bank suitable for a harbour, has been called Port Harcourt, and a railway is to be built northwards from it. Away from the fringe of forest along the creek the traveller sinks deep in the evil-smelling, slimy ooze, above which rise the distorted, stilt-like roots of the mangroves. Towards the apex the abundance of oil-palms tempts the almost fever-proof native to brave the diseases of this uninviting region, which is yearly inundated by the flooded river.

The oil-palm will not grow more than a certain distance from the sea, and loves a swampy soil. Its fruit resembles a fir-cone or a pineapple, and contains many nuts, each something like a yellow plum. The nut contains a mass of fibre and yellow grease, and when boiled down produces the palm-oil of commerce. The natives use it as we use butter. Enormous quantities are exported to Europe for soap and candle making, and to lubricate railway-carriage wheels.

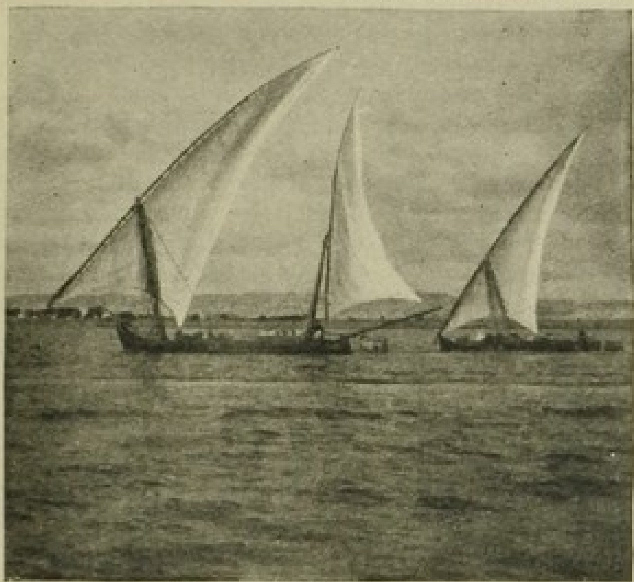
The Lower Niger. Not till Abo, 100 miles from the sea, is the Niger confined to a single channel. Above Abo it is a noble river, flowing between forests which contrast agreeably with the horrible swamps of the delta. Crocodiles and hippopotami disport themselves in the sun, and the banks are dotted with many palm-shaded villages, each with its thatched garden of yams, which form the staple food. The forest native tribes have many cruel tribal feuds and many savage religious practices.

The Ascent to the Plateau. Some 200 or 300 miles from the coast the country begins to rise into hills, which are the southern margin of the plateau from which the Niger comes down. The river flows between flat-topped mountains, rugged and bare, its fierce current swirling round the islands and rocky barriers which impede its descent to the forested lowlands. The navigation of this part of the Niger is beset with dangers until Lokoja, where the great Benue enters from the east, is safely reached, and then Baro, where a railway runs to Kano, with a branch at Zaria to Bauchi.

THE NEW AND THE OLD IN NORTHERN AFRICA



STEAMERS PASSING THROUGH THE SUEZ CANAL



NATIVE BOATS ON THE NILE

A STREET SCENE IN TUNIS

NATIVES OF NIGERIA AROUND AN ENCAMPMENT ON AN ISLAND NEAR BARO

The Sudan from the South. By this ngerous barrier we enter the Sudan. Instead the primeval forest, with its enervating climate d its unprogressive, superstitious inhabitants, e have an open plateau, with a drier, healthier imate, and that possibility of free movement n which the spread of civilisation depends. The eople—Fulas, Hausas, and other tribes—though ere is much diversity of blood, are civilised. hey are clever traders, skilful agriculturists and aftsmen, devout Mohammedans, and possess e power of self-government. Till recently the gion was divided into independent states, okoto being the most powerful. Much of it now rms the British colony of Northern Nigeria.

In the Sudan the palm-oil tree disappears, but is replaced by the equally useful shea butter-ee. Sorghum, a kind of millet, and maize place the yams of the Niger forest, and domes-cated animals are once more numerous. The ountry is covered with villages, and there are lso important walled cities, some with nearly 00,000 inhabitants, the centres of trade between he Guinea coast and the Mediterranean. The rgest are Bida, near the Niger, and Kano, much rther north, and better placed for the caravan rade across the desert. Blue Kano cloth, made om local cotton, is famous through half Africa, nd can be bought at places as far apart as lexandria, Tunis, and Lagos. Kano is also the reat market for kola nuts. These are so valued the Sudan for their feeding and stimulating roperties that in times of drought a slave is ften given in exchange for a single nut. The ruit resembles a large chestnut, and grows in ong pods containing several nuts. Bauchi, vith tin ores, is the chief centre in the east. The eat of government in Northern Nigeria is Zungeru, on the Kaduna river.

The Resources of Nigeria. Very little f Northern Nigeria lies in the densely forested oastal plain which forms Southern Nigeria. here are valuable forests in the south, pro-ucing mahogany, ebony, oil-palms, kola nuts, nd rubber. Agriculture is important every-here in the plateau region. Around the rivers re rich alluvial lands, over which the water preads when swollen by the summer rains, and ver which it deposits a mud hardly less fertile han that of the Nile. Fine crops of rice, tobacco, and cotton are grown on these alluvial lands. Cotton is a native of the Sudan, and will probably become as important as in Egypt. Wheat may also become a valuable product. Towards the north, on the margin of the desert, a different vegetation appears, among which gum-bearing acacias may be noted.

The Powers in West Africa. The predominant Power in West Africa is France, whose sway extends from the Mediterranean across the desert and the French Sudan to the shores of the Gulf of Guinea. Along the coast between the mouth of the Gambia in the west and that of the Niger in the east, other Powers have established colonies. The narrow Gambia valley forms the British colony of Gambia. A little farther south is Portuguese Guinea, separated by some 200 miles of French territory from the British colony of Sierra Leone, beyond which is the republic of Liberia. The French Ivory Coast, the British colonies of Gold Coast and Ashanti, the German Togo, which recently has been seized by Britain, and the French Dahomey bring us to Southern Nigeria, a British possession in the basin of the lower Niger.

The West African Coast. Between the Gambia and the Niger mouths one may steam for days along the coast without any change in the scenery. "Imagine a sunlit sea, running in mile-long undulations, which pile themselves up on end and smite the yellow beach with a thundering crash. Beyond the beach a row of mud huts nestles beneath the shade of an immense palm, whose green fronds form a feathery lacework over them. Beyond these are cottonwood forests, while a steamy haze hangs over the whole." Railways are built across the forest belt to the interior from the chief ports. Freetown, the capital of Sierra Leone, the second town of West Africa, has white houses set in orange gardens along the slopes of Tower Hill, and the forested heights of the Sierra Leone, or Lion Mountains, behind. Fifteen hundred miles farther east is Lagos, the most important town in West Africa. "Glancing shorewards you see the inevitable line of yellow beach, but no forest behind. On a low island in a wide lagoon stands what is really a handsome town, and not the conglomeration of galvanised sheds and mud huts which form so many West African settlements." Lagos commands the shortest routes to the most fertile parts of the Niger basin, and a railway is built across the Niger through Zungeru to the Baro-Kano line.

The Niger in French Territory. Nearly all the rest of the Niger basin is French. The river makes a great bend to the north, separating the desert from the savana lands to the south. The most important town is Timbuktu, a few miles north of the river, but connected with it by a winding channel. Timbuktu is the terminal point of two important routes across the desert, and a great trade centre.

The Niger rises among forested mountains some 5000 ft. high at no very great distance from the Senegal and Gambia. At its source it is less than 150 miles from the sea, but owing to the configuration of the country it flows inland in a north-easterly direction for several hundred miles before it finally turns south to the Gulf of Guinea. It is the third in length and the second in volume among the rivers of Africa. Between the Niger, the Nile, and the Congo is the Lake Chad basin of inland drainage which receives the Shari river. Lake Chad lies in a depression surrounded by higher ground, so that it has no outlet to the sea. It is a shallow, marshy lake, studded with many islands, and varies in size from 6000 to 30,000 square miles, according to season.

In the French Sudan the same general characteristics are found.

A. J. and F. D. HERBERTSON

Explanation of Terms. Networks. Borders. Enclosed Ornament for Panels. Arches and Mouldings.

GEOMETRICAL DESIGN

ALTHOUGH geometrical ornament is more abstract than that founded on natural forms, yet it is the oldest, as is shown by the primitive art of savage races of past and present times. No doubt this is so because geometrical ornament is easier and requires less artistic skill than conventional arrangements of natural forms. Probably sewing with a thread suggested the zigzag line, and the wave the wavy line; and woven work may have suggested reticulated patterns, plaited hair the plaited band. The revolution of a fork gave the circle, the combination of dots at regular intervals suggested the polygons or pointed stars. The gradual development of these original geometrical forms, due to the growth of culture and knowledge, led finally to such geometrical artistic forms as are seen in Moorish panelled ceilings, in Gothic tracery, in the guilloche and other patterns.

Application of Geometrical Design. The laws of geometry appear to have controlled the beautiful artistic designs of the ancient Greeks, and the decline of art in the different ages can be traced to neglect. Few workers seem to realise how universal are the applications of geometry to artistic ornament, such as is used in architecture, wall decoration, mosaics, parquetry and marquetry, tiles, floorcloths, carpets, pottery, metal-work, and jewellery.

Groups of Geometrical Ornament. Geometrical ornament may be generally divided into three groups: First, when the ornament is in bands or borders, as in **528** to **560**; secondly, when it is repeated in patterns over an unlimited space, as in diapers [**510** to **527**]; and thirdly, when the ornament fills an enclosed space, as in panels of various shapes.

The designs here given are not by any means exhaustive, but are suggestive of the many variations that can be made in geometrical forms. The student, after copying them as exercises, should test his skill by endeavouring to design suitable variations in order to develop his ingenuity and taste.

Explanation of Terms Used. *Repetition* is a succession of the same form. This becomes monotonous if not varied, and for this reason the curves are introduced among the interlacing straight lines in **553**. In **547** the nailhead shape is *repeated*. When the same shape is repeated in an opposite direction, it is said to be *reversed* or *contrasted*, as in **527**, where the left-hand half of the repeat is reversed in the right-hand half of the same repeat.

Symmetry is the repetition of any form on its axis, as in **527**, where the central vertical line in each repeat is the axis. This principle of symmetry is one of the most important in producing ornament.

The *unit of design*, or *unit of repetition*, is the whole ornament in each repeat, as in **547**, where each nailhead is the unit of design.

Kinds of Network. The construction lines used in setting out geometrical patterns are arranged to form a *network* in order to secure accuracy of construction and repetition. This network is of various kinds. The most frequent is quadrangular reticulation, as in **504** to **507**, in which **505** is the *diamond* or *lozenge* net, and **507** is a combination of the square and diamond, while **508** and **509** illustrate the equilateral triangular network.

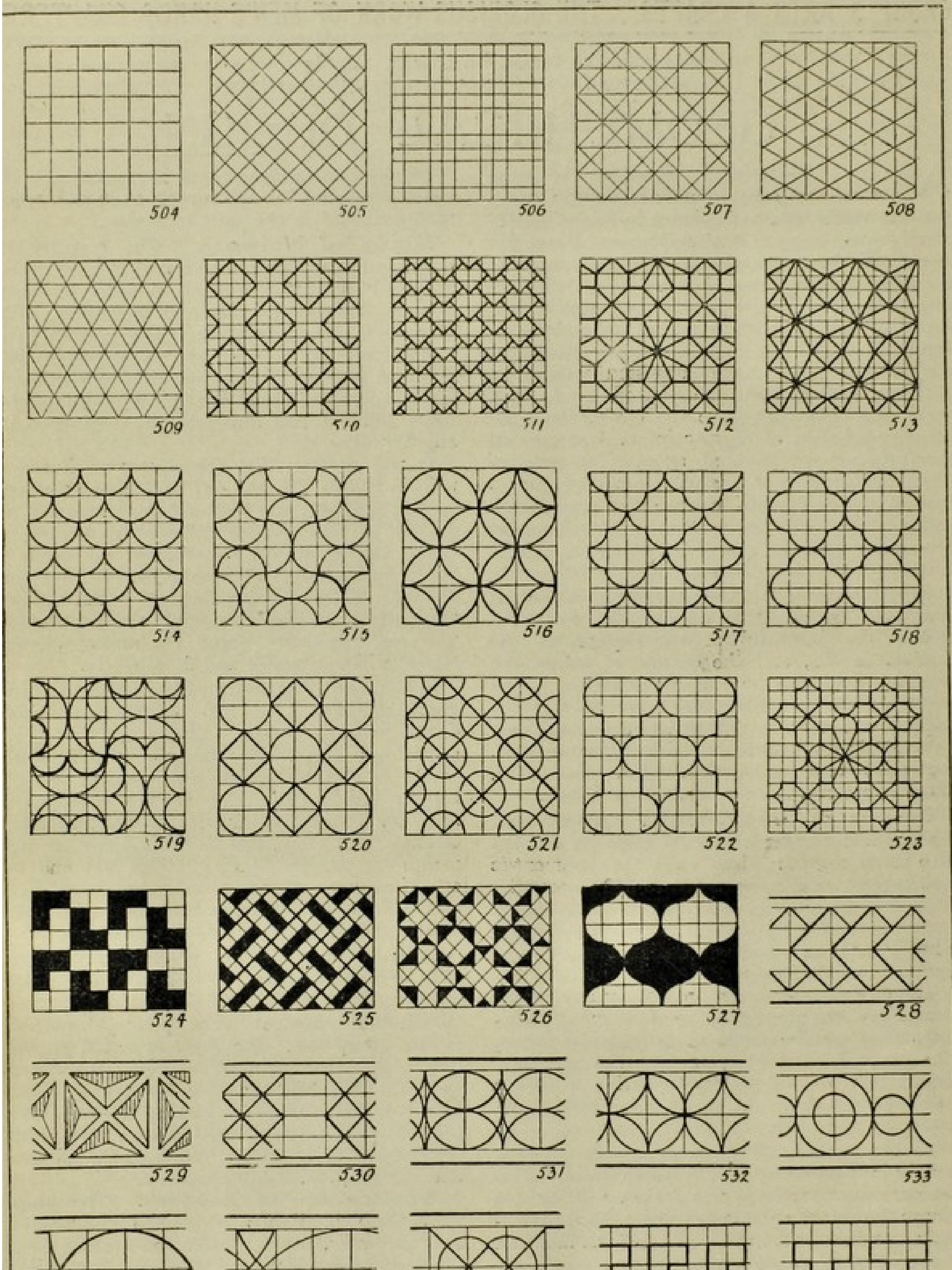
It will be seen that the square net has been used in **510** to **524**, and **527** to **545**, the diamond in **525**, **526**, **546**, and **548**, and the triangular net in **561** to **574**. These different nets may be easily and accurately constructed by means of the T-square and set-squares of 45 deg. and 60 deg. It is, of course, essential that the network should be very accurately made, otherwise patterns, especially those containing circular forms, will not repeat and fit properly.

All-over Patterns Founded on the Square Net. In **510** to **527** are shown examples of "*all-over*" patterns, as they are sometimes called. The designs in **510** to **52**[illegible] would be suitable for window glazing, without further enrichment. They are also construction lines for richer patterns for carpets, tapestry, ceilings, etc. Figs. **524** to **526** suggest arrangements for parquet flooring. Figs. **511** and **51**[illegible] are similar to tiling arrangements for roofs and are "*scale*" designs. In **527** the black and white forms are the "*ogee*" pattern.

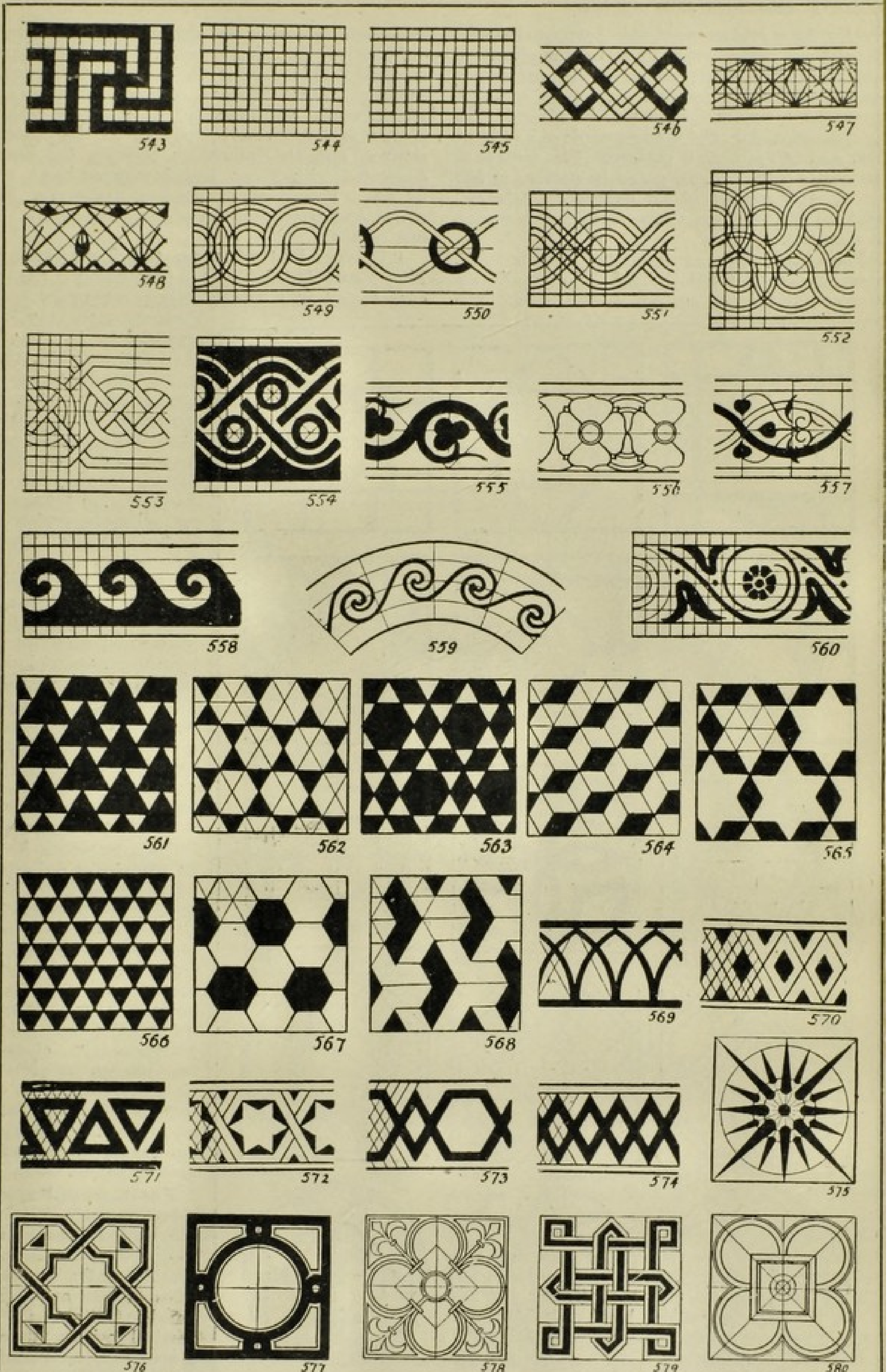
Bands or Borders with the Square Net Foundations. These are not limited with regard to length, and are generally narrow ribbon-like ornament. The principal patterns in this group are: The Fret, as in **537** to **545**; Chain, as in **546** and **550**; Interlaced patterns, as in **531**, **536**, **550**, and **553**; the Guilloche, as in **549**, **551**, **552**, and **554**; and Foliated Bands in the forms of Rosette [**556**], Flower, Leaf, Scroll [**555** and **557**], the Greek Wave scroll, the Leaf and the Egg and Tongue pattern.

Application of Borders. The proper application of Bands is to the enclosing of ceilings, walls, floors, panels, on certain architectural constructions, on the abacus and plinth of columns, and as a running ornament round the shaft of the latter. They are also used as the hem or border of garments, carpets, and other textiles, on the rims of plates, in typography, etc.

The Fret is specifically Greek ornament, and no doubt of textile origin. It was Greek vase painting and architecture which gave rise to the variations of the pattern. Among the Romans the fret was used for mosaics on floors. The



504–509. NETWORKS. 510–527. ALL-OVER PATTERNS ON SQUARE FOUNDATIONS. 528–542. BORDERS



543–560 AND 569–574. BORDER PATTERNS OF VARIOUS TYPES. 561–568. ALL-OVER PATTERNS ON TRIANGULAR FOUNDATIONS. 575–580. ENCLOSED ORNAMENT FOR SQUARES

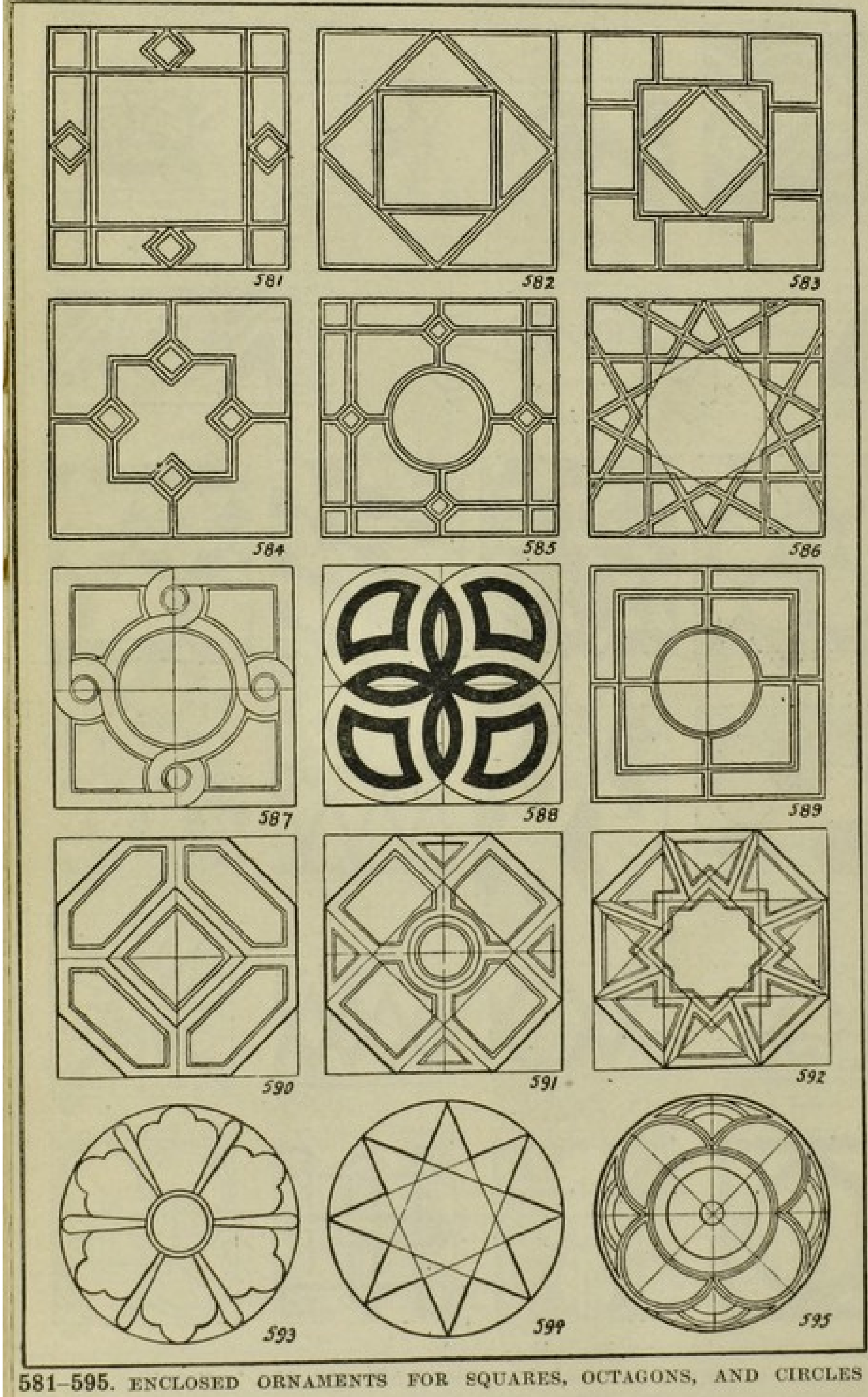
Middle Ages seldom used this pattern, but the Renaissance revived it in its ancient application, and made new combinations. The pattern is sometimes carried round a circle, an arrangement, however, which is not in accord with its character. Fig. **539** is an example of a Chinese fret, and **540** is a plait pattern. The centres of the circles in the double guilloche pattern in **552** are at the corners of an equilateral triangle, while in **554** they are at the corners of a square or diamond.

The Greek wave *scroll*, or the evolute-spiral band, is shown in **558** to **560**. The line of this pattern divides the surface of the border into two parts, which in flat ornament are coloured differently. In plastic work the lower part projects. This border is suitable for robes, shields, plates, friezes, cornices, tablets in architecture, and for other purposes. The rosette is sometimes introduced at the volute centres, and the interstices between the lines decorated with leaves and flowers or buds, as in **560**. Examples of borders drawn on an equilateral triangular foundation are shown in **569** to **574**.

All-over Patterns on the Triangular Net Foundation. This foundation is easily constructed with the 60-degree set-square and T-square, and may be arranged in two ways, as in **508** and **509**. It is the readiest basis upon which the designer can form " drop " patterns. Many different shapes, such as the triangle, the rhombus or diamond, the hexagon, etc., all make perfectly fitting diapers upon this net, as shown in **561** to **568**. Many designs for parquetry and marquetry may be founded on these lines, and the ornament indicated by the various coloured tiles, stones, or pieces of wood used.

Enclosed Ornament. This is ornament designed to fill a definite bounded space, such as a square, an oblong, a circle, etc., according to artistic rules, so that it fits exactly into this space alone. The space is sometimes called a " panel." Besides the square, oblong, and circle, other shapes, consisting of the regular polygons, the ellipse, the lunette or semicircle, various forms of the spandrel, the lozenge, and the triangle, are most commonly used as panels.

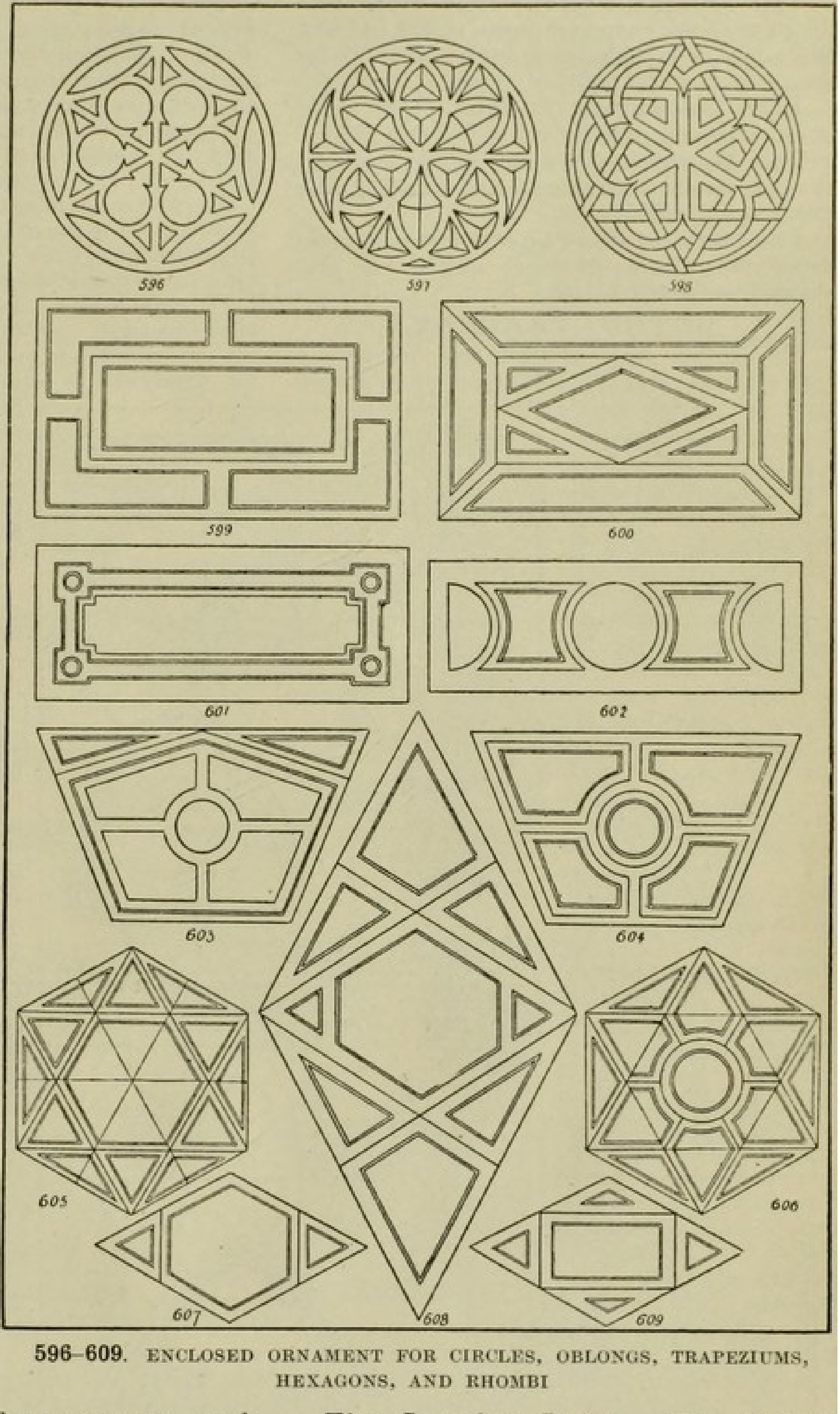
Position of Panel Ornament. When the enclosed space has the design arranged symmetrically on both sides of one axis, the panel is suitable for a vertical position. When it is developed regularly in all directions from the centre of the shape,



581–595. ENCLOSED ORNAMENTS FOR SQUARES, OCTAGONS, AND CIRCLES and is symmetrical to two or more axes (multi-symmetrical), the panel is suitable for a horizontal position, as in **575** to **595**.

The Square Panel. The two diagonals and the two diameters are the lines on which the decoration of the square may naturally be based, and they form an eight-rayed star, with rays alternately of unequal lengths, dividing the figure into eight equal spaces. Numerically, this mode of planning the decoration is predominant. The design shown in **575** is the Uraniscus, an ornament used in the coffers of Greek ceilings; the rays were gold on a blue ground. The patterns in **576** and **579** are examples of inlaid work of the fourteenth and fifteenth centuries. Fig. **578** is an arrangement suitable for ironwork, while **580** is the planning out for a tile design used in mediæval times, but trefoliated forms were also added to this linework.

Another kind of decoration for squares is that in which it is subdivided into separate spaces, as in **581** to **589**, and each space may receive independent ornament. It will be noticed that these are much used for panels in ceilings. The panelling in **586** is constructed by dividing the square into sixteen smaller squares, and then drawing lines from the middle points of the sides of the large square at an angle of 60 degrees.



596–609. ENCLOSED ORNAMENT FOR CIRCLES, OBLONGS, TRAPEZIUMS, HEXAGONS, AND RHOMBI

The Octagonal Panel. This may be easily constructed within the square as shown in **590** to **592**, or within a circle. The diagonals and diameters intersecting again give a great variety of subdivisions.

The Hexagonal Panel. This is best constructed within a circle, and may be subdivided in a similar manner to the octagon. Many variations of the six-pointed star may thus be obtained.

The Circular Panel. This shape is usually subdivided into 3, 4, 5, 6, 8, 10, 12, or 16 similar parts, by lines radiating from the centre; or it may be divided into zones, with each belt-like band decorated independently. The subdivision formed by means of arcs, as in **593** and **595**, is very suitable for this shape, especially when required for tracery.

Fig. **596** is a mediæval design for a wrought-iron key handle; **597** is a Gothic design for chip-carving; and **598** is taken from a Romanesque portal designed in the twelfth century.

The Oblong Panel. The usual subdivisions of this shape are shown in **599** and **600**, while **601** is suitable for a tablet, and **602** for door panels or the soffits of arches.

The Trapezium Panel. This shape may be divided as indicated in **603** and **604**.

The Hexagonal Panel. Two examples of the usual subdivisions for panelling are given in **605** and **606**.

The Rhombus Panel. This is often called the "lozenge" shape, and may be subdivided as in **607** to **609**.

GOTHIC TRACERY

The Gothic style evolved and brought to perfection a characteristic decoration known as Tracery, by means of arcs of circles. These designs possess great originality and richness of form, although they are somewhat stiff and mechanical when compared with designs founded on Nature in other styles.

Tracery is chiefly applied to stone and wood used in architecture, for galleries, windows, panels, etc., and for furniture.

Fig. **610** is the necessary construction for **611**, a design for a square panel; **612** shows three foliations for a circle; and **613** is the planning for a rose window, or for a circular panel.

Fig. **614** is the foundation for **615**, a curvilinear triangle, and **616** is a design for tracery for an equilateral triangular panel, suitable for woodwork or stone. In **617** is given the construction for **618**, the tracery which might be used for a window or a screen. Fig. **619** contains the foundation lines for **620**, a design for the head of a four-light window.

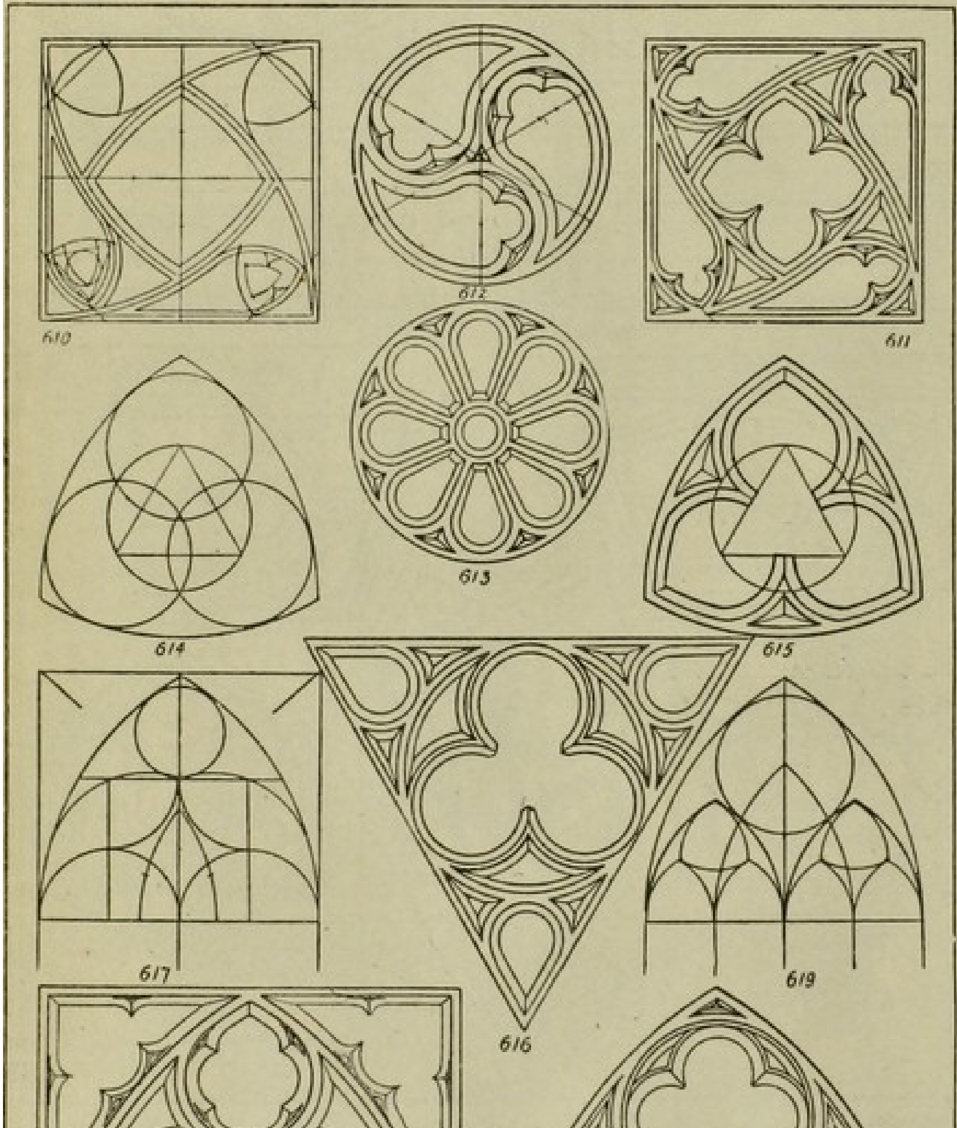
Many other beautiful examples of tracery can be found in good textbooks on architecture.

ARCHES

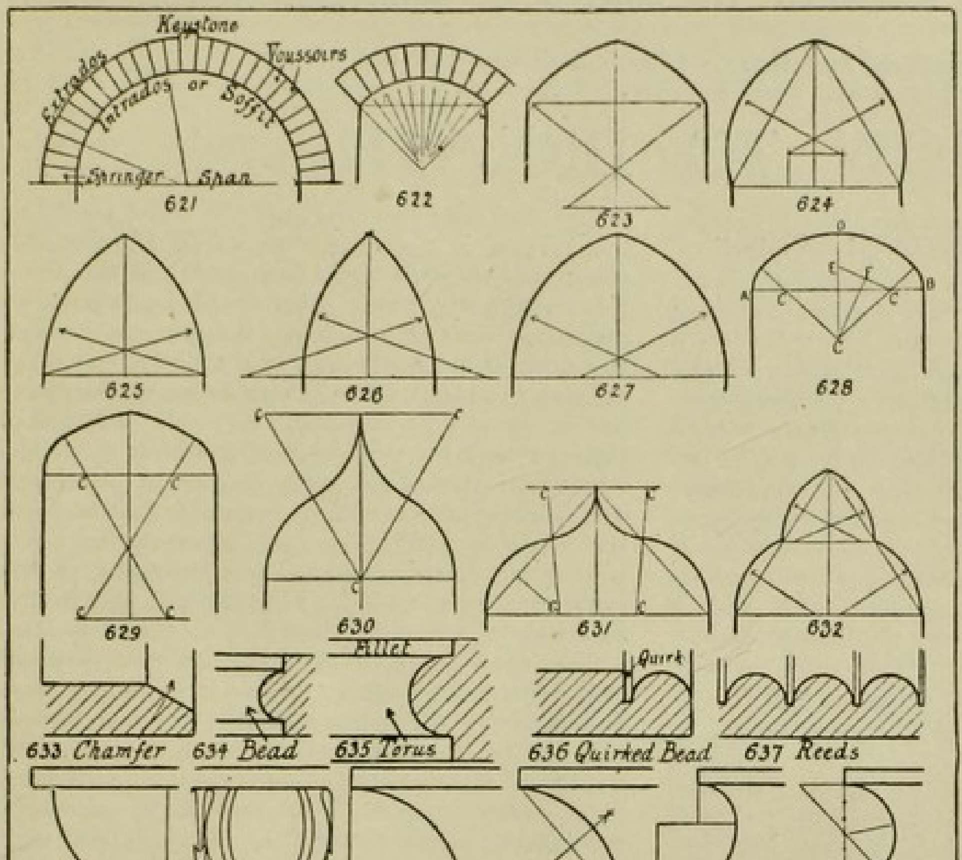
The arch is a very ancient construction, and has appeared in many forms from the classic periods. The Romans were the first to use the arch extensively in architecture, even if they were not the originators of this form. The earliest shape of the arch was semicircular [**621**], and this was in succeeding centuries changed to the various forms shown in **622** to **632**. The latter are only typical examples, which illustrate the arches in general use; and although the centres are shown from which the curves are struck, these centres, in most cases, may be varied in position.

The names of the individual parts of an arch are given in **621**.

Various Forms of Arches. The *segmental* arch may be struck from one centre as in **622**, or from two centres as in **623**. Fig. **624** is one form of the *horseshoe* or *Moorish* arch. The *equilateral* arch, much used in Gothic architecture in the thirteenth century, is shown in **625**. In the twelfth century the *lancet* arch [**626**] was very common, as also was the *obtuse* arch [**627**].



610–620. EXAMPLES OF GOTHIC TRACERY



621–649. ARCHES AND MOULDINGS

The *three-centred* arch given in **628** is constructed by first determining the height and the span; then make AC, BC, and DE all equal. Join EC and bisect in F. The intersection C of the bisecting line FC with DE produced is the third centre. Describe arcs from C, C, C, as centres.

The *depressed Tudor* arch [**629**] is described from four centres. The *ogee* arch, or so-called ass's back, has either three [**630**] or four centres [**631**]. The *pointed trefoil* opening has the centres placed as shown in **632**. The parabola and ellipse may also be used for arch forms.

MOULDINGS

In architecture mouldings form a constituent part of an order, and were used in eight forms by the Romans and the Greeks. These forms are named: the *fillet*, a narrow flat band used to separate and combine curved mouldings; the *astragal* or *bead*, a narrow or small convex cylindrical moulding [**634**]; the *torus* [**635**], which is really a large form of the astragal, and is often used at the base of columns; the *ovolo*, or *echinus* (meaning "*egg-formed*"), a convex moulding [**638** and **644**], which appears to have originated in the capital of the Doric column; the *cavetto* [**639** and **645**], which is the reverse of the ovolo; the *scotia* [**640** and **646**], a concave moulding which gives a deep shadow on itself and is very effective when used on bases of columns; the *cyma recta* [**641**, **642**, **647**, and **648**], a moulding with the concave above the convex portion; and the *cyma reversa* [**643** and **649**], which has the convex part uppermost.

Besides the above, the *chamfer* [**633**], the *reeds* [**637**], and the *flute*, a concave channel used to ornament the shaft of a column, are often used.

The characteristic difference between Greek and Roman mouldings is that the former are described with parabolic, hyperbolic, and elliptical curves, and the latter with arcs of a circle, but the Greek are more graceful in contour. Figs. **638–643** are Roman, and **644–649** Greek mouldings.

The mouldings were often decorated with carving or colour, a particular design being used for each moulding, as in **638** and **649**.

A thorough knowledge of the principles of design given in this chapter is essential if the student contemplates taking up COMMERCIAL DESIGN, which is dealt with later in this course. He should always carry his sketchbook in readiness to note a characteristic piece of design or a beautiful detail of ornament. The patterns and schemes of decoration in use at different periods for buildings, furniture, domestic utensils, personal ornaments, and so forth, should form subjects for observation.

WILLIAM R. COPE

The Breathing Apparatus. Chemical Changes in the Breath. Chest Expansion and Mobility. Methods of Breathing.

HOW TO BREATHE

We will now briefly consider the muscular and chemical aspects of respiration. Respiration is essentially a chemical combination of oxygen with the tissues, resulting in oxidation, followed by the surrender of a volume of carbon dioxide about equal to the volume of the oxygen combined. In the lowest and smallest organisms the oxygen is taken in all over the general surface of the body, but in the higher and larger organisms there is a specialised apparatus to facilitate the intake of oxygen and the output of carbon dioxide. A small unicellular organism can absorb oxygen from its general surface. A fish requires gills and a system of canals, while the mammals require lungs, thoracic muscles, and a system of canals.

The Breathing Apparatus. The breathing apparatus in man consists briefly of mouth, nose, pharynx, larynx, trachea, lungs, thoracic muscles, and the whole vascular system. The larynx, or voice-box, leads into the trachea, or windpipe, and the windpipe divides into two big branches called the right bronchus and the left bronchus, which go to the right and left lung respectively. The bronchi, in turn, bifurcate into smaller and smaller branches, and when the branches have reached almost microscopic dimensions they expand into little, elongated sacs known as infundibula, which are dimpled with little depressions known as air-cells. Looked at from the exterior, the infundibula, with their little, bulging air-cells, look like bunches of grapes. Over the air-cells are fine blood-vessels, and the infundibula with their blood-vessels are bound together by a fine elastic stringy substance into the lobules of the lungs. The lungs therefore consist mainly of fine branching tubes, terminating in air-cells, together with a meshwork of arteries, veins, and capillaries. The object of all this branching is to provide a large surface where the oxygen of the air inspired into the air-cells may come into close contact with the red blood-cells of the blood. It has been calculated that there are over seven hundred million air-cells in the average lungs, with a total surface of about 90 square metres.

The lungs are contained in the case of bone and muscle known as the chest, or thorax. The walls of the thorax are formed by the breast-bone and ribs with intercostal and other muscles, and its floor is formed of a strong sheet of muscle and fibrous tissue known as the diaphragm, which separates the cavity of the chest from the cavity of the abdomen. Between the lungs is the heart. This, as briefly as possible, is the respiratory apparatus, and now we will glance at its mode of work.

How the Lungs are Inflated. It is quite commonly believed that we inflate the lungs, and that the lungs lift the chest wall, but the reverse is the case. In slang, the chest is often spoken of as the "bellows," and the slang has truth in it, for it enlarges like a bellows or accordion, and as it enlarges it sucks air through the nose and mouth into the air-cells and thus inflates the lung. The enlargement of the chest cavity is effected partly by the intercostal muscles and by other muscles which raise the ribs and breast-bone, and partly by the strong diaphragm muscle. The muscles that expand the thoracic cavity relax, and the chest cavity is contracted again owing to the elasticity of the lungs, the weight of the ribs, and the contractile influence of a few muscles.

The movement of the muscles that expand and contract the chest cavity is usually reflex, and is under the command of a nerve centre at the top of the spinal cord; and the rate and depth of the breathing is regulated according to the requirements of the system by messages sent to the nerve centre from the lung and skin and other parts. Thus a cold douche may take our breath away, and a little excess of carbon dioxide in the blood may quicken respiration, but the will, as we know, has also a certain amount of control over the breathing.

Chemical Changes Made by Breathing. The air, then, in this manner is inspired and expired. In the inspired air is the oxygen, and the oxygen, according to certain laws, is taken up by the blood and red blood-cells, and carried round the body, to be added to various tissues and unlock their energy. In the expired air is a large quantity of carbon dioxide which has been formed by the oxidation of tissues all over the body, and has been carried to the lungs by the circulation. The breathing thus brings oxygen to the tissues and helps to remove the débris of tissues. Hence, during active exercise the breathing is quicker, so as to provide more oxygen and remove more carbon dioxide.

A Chemical Measure of Energy. It has been found experimentally that a man discharges per minute 161·6 cubic centimetres of carbon dioxide when asleep; 569 cubic centimetres when walking at a rate of two miles an hour; 851·2 cubic centimetres when he is walking at a rate of three miles an hour; and 1581·9 cubic centimetres when walking a treadmill. It has been found, too, that horses discharge twice as much carbon dioxide when trotting as when walking. The amount of carbon dioxide is therefore a measure of energy, and the most active and warm-blooded animals discharge the most carbon dioxide in proportion to their weight. Men, it may be noted, discharge considerably more carbon dioxide than women. The expired breath carries away from the lungs not only carbon dioxide, but also heat and moisture. Unless the air be warmer than the body, it is always warmed during the process of inspiration and expiration, and is expired at about body temperature. Air which is inspired at a temperature of 6° Centigrade below freezing is warmed to 24·5° Centigrade during its passage through the nose alone.

Chest Expansion and Mobility. Many people imagine that a big chest is a good chest, and they devote much time and trouble to the increase of their chest measurement by means of various breathing and muscular exercises. But a big chest is not always a good chest. Mobility, or the power of expansion of a chest, is always more important than mere size, and the methods adopted to increase the size of a chest often impair its mobility. We hear of chests increased so many inches in so many weeks, but the increase often, indeed usually, means merely that the chest is pouted out and the ribs rigidly fixed in a position of forced inspiration. Dr. Harry Campbell found that the champion weight-lifter of the world had a very immobile chest, though its size was tremendous, and he found, on the other hand, the most mobile chest he had ever measured in a man of 6 ft. 4 in. in height, with a small chest measuring only 35 inches.

Many chests have been permanently damaged as organs of respiration by an ignorance of these facts. Up till a few years ago soldiers were made to pout their chests and hold their shoulders stiffly back, and the rigid protuberant chest became in time fixed in that position, and was considered an example of development. It was really an example of ignorant stupidity on the part of the trainer, and considerably reduced the soldiers' breathing and working capacity.

Chest Capacity. Mobility being equal, of course, the capacious chest has more respiratory value than the smaller one, but most of the examples that are brought forth of great increases in chest measurement are instances of muscle increase, together with an unnatural fixation in an elevated position of ribs and collar-bones. An increase in chest measurement, to be a true increase, must be a matter of growth, and this is a matter of food, as well as a matter of exercise, and it must take time. By reasonable and judicious breathing, and by athletic exercises which do not involve fixing the muscles or holding the breath, it is possible to increase the mobility of the chest, and if the chest is fixed—as is sometimes the case—in a position of extreme expiration, it is possible to raise and separate the ribs so as at once to increase its capacity and mobility, but no very rapid increase in either respect is possible or desirable.

In judging the mobility and expansion of a chest by measuring it at full inspiration and at full expiration, one must be careful not to be misled by increase in measurement caused merely by contraction and consequent bulging of the muscles around the chest. A strong, muscular man, by contracting and relaxing the big muscles on his chest and under his arms, can increase his chest measurement by several inches, and instances of twelve or twenty inches expansion are of this fictitious nature. The chest wall is made of bone, not of indiarubber; and the amount it can expand is limited by the attachments and movements of the ribs and breast-bone.

How to Breathe. By suitable breathing exercises the mobility of the chest may be preserved and increased, and there are many professors of breathing ready to teach the public exactly how to breathe. We are told we must inspire through the left nostril and expire through the right, and that we must alternately use our upper and lower ribs, and nonsense of that sort. But the best way to breathe is as Nature makes one breathe, and the best way to develop the chest and increase its mobility is to take such exercises in the open air as automatically deepen respiration.

Breathing, after all, is an automatic reflex action. From birth to death, hour after hour, day after day, year after year, we breathe at the average rate of fifteen or sixteen breaths a minute, and breathing is quickened or slowly rendered deeper or shallower just as the regulating reflexes of the body direct. We have nothing to do with it; it is regulated by the physiological necessities of the case, by many varied and ingenious reflexes. A ten-mile walk, a half-mile run, a set at tennis, a game of football, will do more to develop the breathing capacity of the lungs than many hours of patient and painstaking exercises. And to breathe deeply just as an exercise is like raising and lowering a bucket down an empty well. It is largely waste of time and waste of energy. If we think, because we are breathing more oxygen, that therefore we are giving the tissues of the body more oxygen, we are making a great mistake.

The Demand for Oxygen. When the tissues require more oxygen they ask for it in various ways; and reflex messages sent to the respiratory centre deepen or quicken the breathing and accelerate the circulation. But merely to offer oxygen to the blood in the air-vesicles is vain, and the effort of deep breathing, so far as oxidation is concerned, is almost wholly wasted. Far better take exercise till the tissues themselves require oxygen; then the breathing will rise to the occasion, and the heart and red blood corpuscules will do their part. For it must be understood that respiration is a matter of circulation as well as of respiration. It is no use to bring cargo to the docks unless there are ships to take it, and there is no use bringing oxygen to the lungs unless the little red blood-cells are there ready to load it and carry it to the tissues. Even if ten minutes' deep breathing, by momentarily increasing the blood supply to the lung, do cause a little more oxidation, and in some form or other liberate or store a little more energy, what of that? We take about 25,000 breaths a day, and it is absurd to think that a hundred or two deep breaths can make much difference in the combustion or combustibility of the body.

The Place of Breathing Exercises. Only when for some reason exercise is contra-indicated are breathing exercises of much service, and then their chief service is to conserve or increase the mechanical mobility of the chest-wall so that the lungs may be able to rise to the occasion should occasion arise. In such a case the deeper breathing not only will keep the chest-wall limber, but will, by its suction action, assist the circulation both of blood and lymph. In the case of infants, crying is an excellent respiratory exercise, and in the case of adults singing and public speaking are equally excellent.

In consumption, breathing exercises are often recommended, but if the disease be arrested they are unnecessary, and if the disease be active they are dangerous, for in active disease, as in any other inflammatory process, rest is desirable. As a preventive of consumption, however, breathing exercises may be useful, since they bring by suction more blood to the lung, and thus promote nutrition of the lung. Also in heart disease they be of some service, since they assist the heart to propel the blood.

As life advances, the chest measurement increases. This does not indicate increasing vitality; it indicates a loss of elasticity in the lungs, much as wrinkles indicate a loss of elasticity in the skin. A similar enlargement occurs in a diseased condition called emphysema.

Nose Breathing. There seems little doubt that man is meant to breathe through his nose as a rule, and seldom or never through the mouth. The nose is ingeniously contrived for respiratory purposes. Each nostril has little, warm, moist pads (little, delicate films of bone covered with mucous membrane) in it to warm and moisten the air. Its passage is tortuous and broken, so as to catch dust and microbes. The cells which line it have little whips or hairs that flick dust and microbes back; and finally the sticky mucus it secretes catches the microbes, and not only catches but kills them. However cold the air may be, it is warmed as it passes through the nose. If it be 14° F. below freezing, it is warmed to 77° F., and if it be 65° F. it is warmed to 88° F., a temperature warmer than the air on a hot summer's day. Again, however dusty the air may be, it is filtered free of dust in the nasal passages; and however full of microbes it may be, it is practically free from microbes before it passes down the throat. In one experiment it was found that in the inspired air there were 20,000 microbes, and in the expired only 40. Finally, however dry the air may be, it is always one-third saturated with moisture when it reaches the back of the throat.

The nose is therefore obviously an important part of the respiratory mechanism, and if we do not inspire our breath through it, but breathe through the mouth, we run considerable risks. We breathe, perhaps, air that is too cold, perhaps too dusty or too dry, or too microbic, and get bronchitis, or pneumonia, or consumption. Great care should be taken to teach children to breathe through their noses, and if they have any difficulty in doing so they should be taken at once to a surgeon. Even when one is asleep one should breathe through the nose.

Obstruction by Adenoids. The commonest cause of nasal obstruction in children is *adenoids*, a growth in the nose and throat. It blocks the nose to such an extent that the child cannot breathe adequately through it, and so contracts the habit of constantly keeping its mouth open. Lack of oxygen stunts its growth and dulls its mental faculties. And not only does it suffer from lack of oxygen, but the adenoid tissue blocking the nose allows the accumulation and multiplication of microbes which secrete poisons that are absorbed by the tissues of the child and cause many evil consequences. The nose, in fact, which ought to protect the child from germs, harbours and assists them. Often, as the child grows older, the adenoids disappear, but before they disappear permanent injury may have been done to the child's constitution; and the moment adenoids are discovered they should be removed by surgical operation.

Another cause of nasal obstruction, found both in children and adults, is thickening of the mucous membrane of the little cushions, known as turbinal bones, that assist in catching microbes, and that warm and moisten the air as it passes through the nose. This produces not only obstruction, but also constant catarrh, and should always be dealt with surgically.

Still a third cause of obstruction is a displacement of the partition between the two nostrils. This can be remedied by a simple surgical operation, which should be always done when such a condition is discovered.

Impediments to Breathing. Women often impede their breathing by tight belts and corsets. The nature of the impediment compels them to breathe chiefly with the upper part of the chest; but, even apart from belts and corsets, it will be found that women naturally breathe with the upper parts of their chests. That is an adaptation to the function of child-bearing which, for a time, at least, precludes full abdominal breathing. There can be no doubt at all, however, that in extreme cases of tight corsets and tight belts a woman's breathing capacity is seriously diminished, and all her energies are seriously reduced. The pressure is sometimes so great that it displaces the liver, and interferes with the action not only of the lungs, but also of the heart.

However perfect and vigorous the breathing apparatus may be so far as the lungs and the lung-case and the lung-muscles are concerned, respiration cannot be satisfactory unless the heart and blood be in good condition; and shortness of breath is more often due to disorders of the heart and blood than of the lungs. An anæmic girl may have perfectly good lungs, yet she is unable to climb a few steps without panting, simply because her blood is not able to carry enough oxygen from the lungs to the tissues.

RONALD MACFIE