A

PHYSIOLOGICAL ESSAY

ON

THE THYMUS GLAND.

Quod ad opiniones attinet quæ in solidum meæ sunt, nolo ipsarum novitatem excusare: nec me etiam primum ullarum inventorem esse jacto; sed tantum, me nunquam illas pro meis adoptâsse, vel quod ab aliis prius receptæ fuissent, vel quod non fuissent, verum unicam hanc ob causam, quod mihi eas ratio persuasisset.

CARTESIUS, *de Methodo recte utendi Ratione.*

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THE THYMUS GLAND.

BY

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TO

SIR BENJAMIN COLLINS BRODIE, BART., F.R.S.

SERJEANT-SURGEON TO THE QUEEN,

ETC. ETC. ETC.

PRESIDENT OF THE ROYAL COLLEGE OF SURGEONS OF ENGLAND.

SIR,

As the most suitable acknowledgment in my power, for great obligations incurred during the production of the following Essay, I have begged permission to dedicate it to you, and, through you, to the COUNCIL of the COLLEGE over which you preside.

Whatever claims it may possess on the favourable judgment of the Profession, are mainly due to facilities afforded me by the Council, for exploring the unrivalled collection of which they are the guardians.

Permit me, Sir, to add, that I feel peculiar pride and pleasure in associating your name with my present work. A young surgeon, applying his leisure to physiological pursuits, can need no better justification and encouragement than are furnished in the history of your eminent career,—testifying as it does, wherever science has reached, that successful research and continual interest in Physiology are compatible with the utmost devotion to Practical Surgery, and are essential to its highest triumphs.

I have the honour to be,

SIR,

Your obliged obedient servant,

THE AUTHOR.

London; April, 1845.

PREFACE.

The reader will hardly require to be reminded that the late Sir Astley Cooper bequeathed a large sum of money, for the institution of a triennial prize of 300*l*., to be given—under certain conditions specified in his will—for the encouragement of original investigations in Physiology and Surgery.

It is now almost a year since the appointed judges—the Physicians and Surgeons of Guy's Hospital—made their first award of this munificent prize, and honoured the present Essay by their decision in its favour.

The recent memory of the eminent Surgeon, whose name and whose love for science will be perpetuated in this endowment,—and, indeed, the unusual pecuniary magnitude of the prize itself,—are circumstances which may reflect on the following pages a greater importance, and lend them a more general interest, than they could claim on their own merits. Perhaps, therefore, the Author should apologise for the long interval he has suffered to elapse, before submitting his Essay to the ordeal of public examination. Many personal circumstances have contributed to protract the period—in itself naturally long—which was requisite for the printing of the work, and the preparation of its woodcuts.

The Author has thought it expedient to avail himself of this opportunity for reviewing his Essay, in hopes of rendering it—so far as his abilities might permit—worthy of the honour which it earned in its rougher state. With this view, he has travelled a second time over the ground which he professes to describe, has verified former observations, and, in some cases, obtained additional evidence on points where he formerly hesitated. This task was commenced with the intention of rectifying any errors that further examination might shew: but the Author rejoices to add that his corrections have been almost exclusively in respect of style and arrangement; and that he has found no reason for changing any of those positive statements, on which his theoretical conclusions were originally founded. Sentences—indeed pages—have been rewritten; in some cases new illustrations have been inserted; but the work is substantially that to which the prize was assigned.

The Author now proceeds to acknowledge his various obligations for assistance and materials.

In the historical portion of his Essay, he has been much indebted to Dr. Haugsted's learned work, published at Copenhagen in 1832; it has often directed him to sources of information which he might else have overlooked. Indeed, although he has spared no trouble in the matter, and has endeavoured to give as much completeness and accuracy as possible to this part of his work,—there are comparatively few occasions on which he has been able to improve on Dr. Haugsted's notes and quotations. In making his literary references, the Author has usually contented himself with simply stating the opinions of his predecessors; scarcely endeavouring to answer them. Many of them, when plainly stated, sufficiently refute themselves; others are incidentally disproved in the course of the work. The literature of the subject is by no means valuable in proportion to its extent: its largest share is quite worthless. Few theories for the use of the Gland deserve to be spoken of otherwise than as guesses; some of which are, perhaps, among the most ludicrous in the science of Physiology. Boerhaave's suspicion, that the fœtus-in-utero may be nourished by sucking its own nipples, scarcely matches some of the doctrines referred to. Among the curiosities of science—almost in her jest-book—these *ἄλες θυμῖται* may sustain a rank, which they scarcely merit in the solemn archives of her history.

To the kindness of his able colleague, Dr. Miller, the Author owes the two analyses of the Thymus given at p. 36, as well as much other information on the chemical nature of the gland.

The dissections recorded in the Fourth Chapter are such as it would have been impossible for any private individual to have made, on his own resources, within a limited time; and it is chiefly to the Council of the College of Surgeons that the Author is indebted for the means of rendering this portion of his labours complete. He need scarcely add, that, in availing himself of the privilege they permitted, of the freest access to their collection of store-preparations, he received every assistance and information at the hands of Professor Owen, the distinguished conservator of the Museum, to whom his best acknowledgments are due.

From Mr. Gray of the British Museum, the Author has received every help which that gentleman so willingly gives in furtherance of scientific inquiry. The dissections of reptiles, particularly of the rarer species, have been almost exclusively derived from this source.

Of the wood-engravings scattered through the work, there are two classes. Those which relate to structure and development, the reader will please to consider as mere plans, or diagrams, referring to parallel passages of the text. Those which illustrate the fourth chapter are, on the contrary, exact copies of the objects they profess to represent; they are all (with the single exception of No. 45) of the size of life, as fixed by actual admeasurement. All the engravings have been executed by Messrs. Nicholls, of Paternoster Row.

The original drawings for the fourth chapter were coloured, and they included, in almost every instance, the figure of the entire animal. It has been found expedient to copy for engraving only the essential part of each drawing, — that, namely, which pourtrays the Thymus itself, and the structures next adjoining it. The advantage of the former plan lay in the circumstance, that it exhibited at a glance the relative size of the gland, in its proportion to the whole body; but it would have been too expensive for repetition in print. Among the originals were included a large number of drawings from the human subject, which—as well as a few from the comparative series—it has been thought unnecessary to publish. In compensation, the reader is referred to the original collection of coloured drawings, now in the Library of Guy's Hospital, which were made in every instance from recent dissections, and do infinitely more justice to nature than ordinary wood-engraving can attain.

For these copious illustrations of the subject, the Author has been entirely indebted to his friend William H. Morley, of the Middle Temple; one who, with all the accomplishments that belong to his own laborious profession, and with profound literary attainments, conjoins the rarest enthusiasm and capacity for Art. At the sole actuation of friendship, his pencil accompanied the progress of this Essay, in its first form, with a skill that belongs to few hired artists, and with a warm interest and zeal that could have been found in none.

A large portion of the anatomical results here given, being founded on microscopical observations, it may be necessary to state that these have been conducted with every precaution; that all, on which any stress is laid, have been repeated again and again, and, in every instance, by daylight. The Author is not unaware that there are still some anatomists who regard with jealousy and suspicion all information derived from the microscope; who find it convenient to discountenance various new discoveries as optical illusions, and protest against the treachery of glasses in terms worthy of the seventeenth century: *per dire il vero, non hanno curiosità di legger cotesti libri, nè hanno sin quì prestato molta fede all'occhiale nuovamente introdotto; anzi seguendo le pedate* *de gli altri filosofi Peripatetici, hanno creduto esser fallacie, e inganni dei cristalli quelle, che altri hanno ammirate per operazioni stupende.** Happily, we have well nigh outgrown this indolent traditionalism in science. The microscope is so thoroughly identified with all recent progress in Physiology, that practical men cannot refuse to recognise its value as an instrument of research. It is now pretty generally felt and acknowledged, that—assuming in different observers equal familiarity with the microscope, and equal care in its employment—what one anatomist discovers, another may readily verify. To this test the Author of the present Essay will cheerfully submit the result of his labours; wishing his observations to be received only so far as they are confirmed by others, who may investigate the subject with the same care as he has given to it, and with the same freedom from previous bias.

Mere details of micrometry, and the like, are interesting only in proportion to what flows from them. Fortunately, most of the facts in minute anatomy here recorded are important, both in their analogies, and in the consequences which they involve; their application is, in most instances, so obvious that the reader will hardly complain of them as trivial or unnecessary; οὐκ ἔσθ᾽ ὧδε μετρεῖν τὰ ψυλλῶν ἴχνη. In seeking, as he has sought, to spare all unnecessary detail, the Author hopes he may not have fallen into the opposite error of treating any important point hastily or insufficiently.

Finally, the Author trusts that some allowance will be made for the deficiencies of his present Essay. He is fully conscious that it has not the elaborate completeness of many foreign monographs. But, he would remind the reader, there is a vast difference between the circumstances under which Physiology is cultivated here, and those which favour its prosecution on the Continent,—especially in Germany. There, it is often the single occupation of an industrious life: here, it is the leisure-pursuit of men, whose ordinary engagements are in the busiest of all professions, and who can only prosecute collateral studies under the disadvantages of previous fatigue and frequent interruption.

Undoubtedly great advantage accrues to the more purely medical sciences in this country from the combination just referred to. The coincident cultivation of Physiology renders Medical Practice more thoughtful and more secure. Nor perhaps, on the whole, does Physiology lose so much by the union as at first sight would appear; for great lessons in the laws of life are learned out of the phenomena of disease; and

* Galilei, Dialogo sopra i sistemi: Fior. 1632; p. 328. The parallel is so natural, that the author cannot refrain from transcribing Salviati's reply: "La confidenza che hanno questi tali huomini del proprio loro accorgimento è non meno fuor di ragione, di quel che sia la poca stima, che fanno del giudizio altrui; e è gran cosa, che si stimino atti a poter giudicar meglio d'un tale strumento, senza haverlo mai sperimentato, che quelli, che mille, e mille esperienze ne hanno fatte, e ne fanno ogni giorno."

advances in Physiology, infinitely more precious than any due to mere chamber-speculators, have been made by our Medical Practitioners,—by Bell, and by Hunter, and by Harvey. The opposite system, too, may have its minor evils: there may lurk in it some liability to the errors which infect a loitering course,— some tendency, perhaps, to dreamy speculation and to what Bacon calls " vermiculate questions"; but there is in it at least the supreme advantage of an unhurried leisure; there are the facilities of continuous application to the same subject, and the means of treating all its parts with equal amplitude and minuteness. Conditions like these become indispensable for the perfection of a monograph, in proportion as its topics are remote from practice, and involve detailed investigations.

The present Essay has not been composed under such advantageous circumstances, and the Author fears that, in consequence, many parts of it must appear less complete than he would have wished them to be. For such, once more, he begs the indulgence of his readers. Deficiencies might have been rendered less apparent, though not less real, had he chosen to make bolder assertions, or to transcribe, from the pages of other writers, statements that he has had no means of personally authenticating. But he has preferred the other course. Endeavouring to obey the maxim and example of our greatest physiological discoverer—*non ex libris, sed ex dissectionibus, non ex placitis philosophorum, sed ipsius Naturæ fabricâ Anatomen discere et docere*—he has derived his theory from the careful retrospect of many hundred original dissections, and has admitted no element into its construction, for which he would not wish to be considered individually responsible.

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CHAPTER I.

HISTORICAL INTRODUCTION.

Before entering upon the detail of my own researches in the Anatomy and Physiology of the Thymus gland, I esteem it a duty to review the labors of others as completely as my limits and information will permit.

It is with no intention of long or needless controversy that I am induced to adopt this course, but only in the sincere desire of doing all possible justice to those, whose industry has prepared the field for present investigation.

Moreover, I think it almost indispensable that these historical particulars should be presented to the reader in a separate and preliminary form. The subjects afterwards to be treated abound with contested questions to an extraordinary degree; and if each new proposition were to be encumbered with conflicting quotations, there would be no possibility, amid such interruptions, of maintaining a continuous argument. Accordingly, in the present introductory chapter, I shall endeavour briefly to relate the progress of research in the Physiology of the Thymus; and I shall thus be enabled, in the later portions of my Essay, to avoid historical digressions by a simple retrospective allusion.

The existence of the Thymus gland was probably first noticed in the Museum of Alexandria. First discovery.

Rufus[1], the earliest compiler, whose works comprise the discoveries of that celebrated school, mentions it as having already obtained a Greek name. Hippocrates[2] had pre-

[1] Rufus Ephesius, *περὶ θέσεως καὶ ὀνομασίας τῶν τȢ ἀνθρώπȢ μορίων*, lib. i. cap. 26; Londini, 1726, p. 38. While enumerating the glands, by which he apparently signifies only those of the lymphatic system, he includes it as *ὁ καλȢ́μενος θυμός*; and mentions its occasional absence (*Ȣ̓κ ἐν πᾶσιν ἑωραμένος*), though, of course, without understanding the importance of the fact. The accentuation and etymology of the word are disputed matters: there appears no sufficient authority for the change in accent, whereby modern writers seek to distinguish it from its homonym *θυμὸς*, *animus*; see Stephan. Thesaur. Ling. Græcæ.

[2] Hippocrates, *περὶ ἀδένων*.

viously omitted it in his enumeration of the glands, and Aristotle[1] on several occasions had left it unmentioned.

An interval of nearly five hundred years separates the age of those great founders of medicine and physiology from the times of Trajan, when Rufus composed his work; and it would be impossible to determine the date of the discovery in question, otherwise than within extreme limits, if the scientific productiveness of those days had equalled the fertility of ours. But the interval, we are considering, contracts itself to a span in regard of anatomical discovery; for in its long lapse of years we find but one school of original investigation,—that, namely, which flourished in the capital of Egypt under the munificent rule of the first Ptolemies. Here, during many years, the study of anatomy was prosecuted with eminent diligence and success: Herophilus and Erasistratus elaborately dissected the human body, and their zeal of research had its natural reward in various important discoveries. Among their contributions to science we may be allowed, with some probability, to reckon the first demonstration of the Thymus gland.

Although Aristotle was ignorant of its existence, it seems likely that the earliest opinions on its use were indirectly derived from his writings. He had attributed to all the viscera the merely mechanical function of supporting the blood vessels[2], and the first recorded views concerning the Thymus appear but as a particular application of that general theory.

Galen's theory of its mechanical use.

Galen[3] and Julius Pollux[4] are the next writers, after Rufus, who mention this gland: the latter dismisses it in few words; the former gives a more detailed account, and attributes to it the double office of defending the vena cava from the contact of the sternum, and of staying and supporting this large vessel with its branches. The same genuine physiologist was the first to notice (in a passage which has been generally overlooked) the differences produced by age in the size of the gland.

Repetitions of the same.

Sanctioned by Galen's supreme authority, the above-mentioned opinion of the use of the Thymus received universal assent[5]; it prevailed through the silence of the dark ages,

[1] Aristoteles, *περὶ ζώων μορίων*; especially in lib. iii. cap. 3, 4, 5, 6, 7.

[2] In loc. cit. cap. 7. *Κοινῇ μὲν πάντα τῶν φλεβῶν χάριν, ὅπως οὖσαι μετέωροι, μένωσι τῷ τούτων συνδέσμῳ πρὸς τὸ σῶμα· καθάπερ ἄγκυραι γὰρ βέβληνται πρὸς τὸ σῶμα διὰ τῶν ἀποτεταγμένων μορίων·*

[3] Galenus, *Περὶ χρείας τῶν ἐν ἀνθρώπου σώματι μορίων*, lib. vi. cap. 4. *Τοῦτον γὰρ δὴ τὸν ἀδένα μέγιστόν τε ἅμα καὶ μαλθακώτατον ὑπέτεινεν ἡ φύσις τοῖς ἄνω μέρεσι τοῦ μέσου κατὰ τὸ στῆθος ὀστοῦ τοῦ στέρνου καλουμένου, ὡς μήτε ψαύειν αὐτὸ τῆς κοίλης φλεβὸς καὶ τὰς ἄλλας ἁπάσας ἐκφύσεις αὐτῆς τὰς ἐν τούτῳ τῷ χωρίῳ γινομένας παμπόλλας οὔσας στηρίζεσθαι, καθ' ἃ πρῶτον ἐκφύονται. Πανταχοῦ γὰρ ὅπου μετέωρον ἀγγεῖον ἡ φύσις σχίζει, πάντως ἐνταῦθα μέσον ἀδένα τὴν σχίσιν πληροῦντα κατατίθησιν.* The passage in which Galen refers to the diminution of the gland in course of the animal's growth is contained in his work *περὶ τροφῶν δυνάμεως*, lib. iii. c. 6,—*πάνυ μέγιστος ἐστιν ἐπὶ τῶν νεογενῶν ζώων, αὐξανομένων δὲ, μικρότερος γίνεται.* Etienne is almost the only writer whom I have found quote this important original observation, and he cites it by a wrong reference.

[4] Jul. Pollucis *ὀνοματικόν*, lib. ii. sect. 218, *σὰρξ ἀδένι ἐοικυῖα, ἣ καλεῖται θυμός.*

[5] Theoph. Protospatharius, *Περὶ τῆς τοῦ ἀνθρώπου κατασκευῆς*, Parisiis, 1555. Mundini (Anathomia, p. 40, Lugd. 1528) applies the same language to the upper lobe of the right lung as his contemporaries used in reference to the thymus:—"Dicitur pomum granatum, sive culcitra, quia super ipsam sedet vena chilis et arteria in directo cordis, in loco ubi vena ascendit ad cor."

and was asserted in the early works of the Italian anatomists. Berengario[1] da Carpi, while adopting the common belief, seems to have had some notion of the differences produced in the gland by age. Guinther[2] professedly followed Galen; and Vesalius[3], in this instance, bowed to the authority which he elsewhere successfully opposed. Etienne[4], Valverde[5], Colombo[6], Plater[7] and Bauhin[8], in the same century, with Riolan[9], Vesling[10], de Marchettis[11], Bartholin[12], de Muralto[13] and Bidloo[14], in the next, successively repeated the doctrine, either in its original form, or with some trifling modification.

A different theory, though one ascribing to the gland an equally mechanical use, was first suggested by Bidloo, in the thesis just quoted, and has been supported by Pozzi[15], Modifications of the mechanical theory.

1 A. J. Bereng. Carpi Isagoge brevis, Bonon. 1523, fol. 33,—"certa adenosa caro, quæ est culcitra seu stragulum venæ . . . ab auctoribus *morum* et *timum* vocatur, et a vulgatibus nominatur animella et lacticinium . . . est in cibariis usitatis saporosi gustûs, maximè illa quæ reperitur in vitulis et hœdis lactantibus."

2 Joh. Guintheri Anat. institut. ex Galeni sententiâ. Par. 1536, lib. ii.

3 Vesalii Anat. Basileæ, 1543, p. 382,—"vena cava conscendit membranis thoracem intersepientibus eleganter suffulta molle et glandulosum corpus hic in jugulo passim adstratum obtinens, quod Græci θυμὸν, Latini vero communi glandularum nomine, *glandium* vocant. Est autem glandium in elatissimâ thoracis sede exstructum, ut ab omni noxâ frequentissimas vasorum distributiones hic suspensas immunes servaret."

4 Etienne, La dissection du corps humain. Paris, 1546, pp. 128, 129. He compares its mechanical uses with those of the pancreas; "pour confermer la division des grands vaisseaux;" and he corroborates Galen's observation of the diminished size of the gland in the grown animal. His contemporary Sylvius (Disputat. medic., v. 26) also likened it to the pancreas, but with better reason, namely, on account of its constitution: "ex variis quasi partibus, et minoribus glandulis conglomeratis, et cum aliquâ superficiei suæ inequalitate conglutinatis."

5 G. Valverde, Historia della composicion del cuerpo humano, 1556, lib. vi. c. 4; or his own Italian translation of this work, Rome, 1559.

6 R. Columbus, De re anatomicâ. Venet. 1599, p. 214,—"glandulæ in nobis tenues, crassæ vero in brutis, quæ *lactes* dicuntur et thymus."

7 Fel. Plater, De corp. hum. structurâ et usu. Basil. 1583. (1603, p. 112.)

8 C. Bauhin, Hist. corporis anatomica, Lugd. 1597, p. 92; and Theatr. Anat. lib. ii. c. 15.

9 J. Riolanus fil. Anat. Paris, 1610, sect. v. c. 45; and Anthropographia, 1618, lib. iii. cap. 13.

10 J. Veslingius, Syntagma anat. 1647, p. 121,—"mollis spongiosaq. caro, tutelæ et fulcimenti usum præbens."

11 D. de Marchettis, Anatomia. Hardevici, 1656, p. 91,—"vasa cordis a glanduloso quodam corpore fulciuntur, quod *Thymium* vocant."

12 Th. Bartholinus, Anat. quartum renovata. L. B. 1673, lib. ii. cap. 4. Bartholin believed that (in addition to the uses ascribed by Galen) it must support the thoracic duct, and serve as a diverticulum to the chyle,—"ne copiâ oneretur subclavia vena."

13 J. de Muralto, Exercit. anat. Amst. 1688, p. 467.

14 G. H. Muller, præs. Bidloo, dissertatio de thymo. L. B. 1706. From contemporary writings it appears that in this instance (as is frequently the case with foreign theses) the essay should in fact have been affiliated by its nominal sponsor, Bidloo. In addition to serving as a defence to the thoracic viscera against any possible intrusion of the sternum and ribs, the thymus, according to this author, serves to press back the lungs and hinder their premature development. This opinion subsequently became the basis of Prunelle's theory of hybernation. (Annales du Muséum, tom. xviii.)

15 Pozzi, Orat. duæ et Commerc. Anat. Bonon. 1732.

Senac[1], Lieutaud[2], Malacarne[3] and Kopp[4]; namely, that the Thymus fills, during uterine life, the space afterwards occupied by the lungs, either to prevent their expansion before the proper period, or for the mere sake of hindering the *vacuum horrendum* of certain physical philosophers.

Progress of physiology.

Meanwhile, vast alterations had befallen the science of Anatomy, and enabled men to give sounder judgment than heretofore on the functions of complicated organs. The first great Italian dissectors had almost exhausted their task, so far as related to outward form and connexions; their successors, besides completing the detail of this topographical anatomy, had learned to scrutinize the inward distinctive structure of parts, with a view to determine their uses and modes of action.

Harvey's[5] momentous discovery had produced results which, at this distance of time, we can hardly realize to ourselves; and, besides its direct influence in reforming and enlightening physiology, it stood forth prominently as a lesson in scientific method,—an example of the sound and strict induction, by which alone our knowledge of nature can be advanced.

Aselli's[6] interesting observation had, perhaps, a still greater contemporary effect in stimulating research, for it could easily be verified, admitted of popular exhibition, and required no logic for its communication.

Commencement of structural anatomy.

In yet nearer connexion with our subject stands the long series of structural investigations, which continued till the death of Malpighi, and received such memorable benefits from the zeal and sagacious industry of that great anatomist. Scattered traces of the study may be found in the writings of Riolan, Bauhin, Fabricius and others, as far back as the middle of the previous century, when Eustachius wrote on the kidney. (Venet. 1563.) Glisson's[7] elaborate monograph took the lead in this new field, and was soon followed by the more comprehensive work of Dr. Wharton.[8] This treatise evinces much original inquiry, and is, on the whole, one of high merit; but Wharton was misled

[1] Senac, Traité sur la structure du cœur, tome ii. p. 687. Paris, 1749.

[2] Lieutaud, Essais anatomiques. Paris, 1742,—"une masse spongieuse, molasse, qui n'a peut-être d'autre usage que celui de remplir dans la poitrine un espace que l'air, qui s'introduira dans le poumon, doit occuper dans la suite," p. 218.

[3] V. Malacarne, Memorie della Società Italiana, vol. viii. p. 219. He includes the other glands without ducts in the same theory, and assigns to them all the same structure,—"certi organi che non possono rimaner ospiti nell' adulto di quelle cavità, che pur gli contenevan impunemente nel feto;" their common character being that they are "spongiosi, cavernosi, arrendevoli, acciochè facilmente, o data qualsivoglia minima premitura, il volume se ne diminuisca."

[4] J. H. Kopp, Denkwürdigkeiten in der ärztlichen praxis. 1830, p. 28 et seq.

[5] Exercitatio anatomica de motu cordis et sanguinis circulatione in animalibus. Francof. 1628.

[6] Casp. Asellius, De lactibus, seu lacteis venis, quarto vasorum mesaraicorum genere. Mediolan. 1627.

[7] Franc. Glisson, De anatomiâ hepatis. Lond. 1654.

[8] Th. Wharton, Adenographia. Lond. 1656. It is not easy to measure the respective claims of these two writers, in regard to priority. According to the title-pages of their works, Glisson is clearly the first: but Wharton's views had been announced, in lectures delivered to the College of Physicians, a year before the publication of Glisson's treatise.

by an unfortunate theory of Glisson's[1] respecting the physiological relations of the glands, and fancifully attributed to them the function of removing impurities and acrimony from the material of the nerves. The further progress of minute anatomical investigation is registered in the works of Steno[2], Bellini[3], de Graaf[4], Peyer[5], Lossius[6], Brunner[7] and Nuck[8], which, with Ruysch's[9] injections and Malpighi's[10] fruitful labours, completed the achievements of the seventeenth century. These formed a system to which the succeeding age could add but little, and which has constituted a large share of received anatomical doctrine almost to the present day: a system which, indeed, even now, is but partially displaced by, or rather additionally developed in, the brilliant discoveries of German physiology.

Simultaneous with this general progress in structural anatomy—and indeed forming part of it—was a better knowledge of the Thymus gland.[11] Blasius[12] had dissected it in a variety of animals; Bartholin[13], Horstius[14], Harvey[15], Deusingius[16], de Graaf[17], New observations of the Thymus.

1 "Glandulas omnes inservire nervis."

2 Nic. Stenon, De glandulis oris. Ludg. Bat. 1661.—De musculis et glandulis. Havniæ, 1664.

3 Laurent. Bellinus, De structurâ et usu renum. Flor. 1662.

4 Regn. de Graaf, Hist. anatom. partium generat. inservientium. Leidæ, 1688, 1672.—De succo pancreatico. Leidæ, 1664.

5 J. C. Peyer, De glandulis intestinorum. Scaphus. 1677.

6 Jer. Lossius, De glandulis in genere. Witteb. 1683, in Halleri Coll. diss. anat., vol. ii. This was a valuable contribution towards the new anatomy, and contains sound views on its subject. The author expresses himself discontented, as he well might be—"generali parenchymatis nomine"—and brings forward his own theory in these remarkable words :—"citra censuram et præjudicium dixerim glandulas esse partes corporis organicas ex variâ complicaturâ capillarium vasorum, humores a massâ sanguineâ secernentes ;"—a description, which will creditably bear the test of modern discovery.

7 J. C. Brunner, Experimenta nova circa pancreas. Amst. 1683.—De glandulis in duodeno intestino detectis. Heidelb. 1688.

8 Anton. Nuck, Sialographia, et opera alia. Ludg. Bat. 1695.

9 Vide Fr. Ruyschii Thesaur. anatomic. Amst. 1701.

10 Especially in the following works :—De pulmonibus epist. duæ ad Borellium, Bonon. 1661 ;—De viscerum structurâ exercit., Bonon. 1666 ;—De glandulis conglobatis. Lond. 1689. Among the most interesting of this great naturalist's writings is the vindication of anatomical research contained in his "Risposta alla lettera intitolata—de recentiorum medicorum studio dissertatio epistolaris :" the greater portion of it would as well apply to our own days as to his : for instance, "se l'anatomia porta vantaggio alla più soda medicina, mostrando l'origine, e la sede de' mali, le loro cause, et il modo di generarsi, dalle quali si cavano le indicationi per sciegliere li rimedii, *quanto più sarà veridica et esatta, tanto più sarà utile :* atteso che la medicina anche prattica non consiste nell' esibitione del rimedio, mà nella consideratione de' segni, nel ricercamento delle cause, e nelle indicationi da cavarsi a-priori,—le quali cose ricercano la cognizione dell' economia dell' animale, e conseguentemente un' esatta peritia, per quanto si può, della strottura mecanica delle parti solide, e della natura de' fluidi, che si lavorano nelle viscere nello stato sano."

11 The earliest monograph on the Thymus, which is mentioned by Haller in his Bibl. Anat., has for its title—J. C. Remmelin præside, G. B. Metzger Historia anat. Thymi. Tubingæ, 1679, 4to. I have not been able to meet with this work, and it appears, from the reference made to it in the bibliography of Hildebrandt's Anatomy, that Weber had not seen it ; neither had Haugsted.

12 Ger. Blasius, Anatome animalium. Amst. 1681.

13 Th. Bartholin (in his Anat. quartum renovata, Leidæ, 1673) states, that he observed the fluid in 1652.

14 J. D. Horstius, jun. (Epist. med. decas, Franc. 1656, p. 85) says, that he has seen it so turgid with *milk* (lacte adeo intumescentem) "ut primo intuitu apostematis suspicio oboririetur."

15 Gul. Harveius, Epist. ad Riolanum secundâ.

16 A. Deusingius, Exercit. physico-anatomicæ. Groningæ, 1661.

17 R. de Graaf, De succo pancreatico. L. Bat. 1664, p. 50.

Discovery of its fluid.

Diemerbroeck[1] and Munnicks[2], had noticed its fluid contents: Wharton[3] and his followers had recognized its true structure sufficiently to arrange it with the conglomerate glands, and to compare it especially with the pancreas and parotid; its arteries and veins[4] had been traced with tolerable exactness, and its nerves and lymphatics[5] described, though not always with strict fidelity.

With these additions to positive knowledge, an immense number of crude hypotheses are presented to us, and these have so much extended themselves towards the present time, that it will be convenient in reviewing them to follow each particular theory through its later developments, and to consider in one connected view the statements of its early and more modern supporters.

Theory of its nourishing the fœtus. Glisson. Sir A. Cooper.

Glisson[6] first originated an opinion which is interesting as being nearly the same as Sir Astley Cooper's;—quemadmodum mammæ lac infantulo foris præparant, sic Thymus liquorem nutritium intus suppeditaverit: Dr. Charleton[7] adopted, a few years afterwards, the very words of this suggestion. The same views were taught by the celebrated Dionis[8] in his demonstrations of Anatomy from 1673 to 1680, as also by St. Hilaire[9] at the same period, and by Garengeot[10] thirty years later. Puteus[11] partially adopts the theory, and Ludovico Palliani[12] quotes one of his colleagues as having just held a disputation (1758) concerning the Thymus, in which he maintained—"ei prædictam glandulam muneri inservire, ut ex integrâ sanguinis massâ substantiam quandam lacteam nutriendo fœtui necessariam secerneret."

From this time until the period of Sir Astley's work, the opinion seems to have been forgotten, and the terms in which he advances it lead me to believe that he was

1 Isb. de Diemerbroeck, Anat. corporis humani. Ultraj. 1672, p. 427.

2 Munnicks, De re anat. p. 110. Traj. ad Rhen. 1697.

3 Wharton, in l. c.; see also Malpighi, De hepate, c. iii.; Mylius, De glandulis; in Halleri Coll. disput. anat. tom. ii.; Lossius in loc. cit.

4 Ruysch appears to have injected the thymus with his usual success, for Gaubius, in a letter to him says,—"clare ostendisti quod scilicet vasis sanguiferis non solum gaudeat parte exteriore, sed et interiore, tantâq. insuper copiâ, ut ubiq. summâ rubedine perfusa esset hæc glandula." Ruyschii Op. epist. a Gaubio secundâ.

5 See particularly Bartholin and Wharton, in loc. cit.; Drelincourt in Experim. anat. L. Bat. 1681, p. 19, and other French anatomists.

6 Anat. hepatis, p. 443, c. 45.

7 Gualt. Charleton, Exercit. phys. anat. de œconomiâ animali. Bonon. 1675 (in Exercit. x. c. 16).

8 Dionis, Anatomie de l'homme. Paris, 1716. (5th edition.) "Elle sert au fœtus à separer une humeur chileuse et lactée, pour la verser ensuite dans la véne soû-clavière; et cette humeur dans l'enfant qui est encore enfermé dans la matrice, tient lieu du chyle qui est apporté par le canal thorachique aussitôt qu'il est né.

9 De St. Hilaire, Anatomie. Paris, 1679, liv. ii. c. 13.

10 R. J. C. Garengeot, Splanchnologie. Paris, 1728, p. 356,—"servir à la nourriture du fœtus." See also J. Palfyn, Anat. chirurg. du corps humain. Leide, 1718. About this time it seems to have been a general doctrine.

11 Jos. Puteus, in comm. acad. Bonon. vol. ii.—"Thymum datum esse vel ad subigendum continendumq. chylum a ductu thoracico divertentem, . . . vel ad secernendum lac ad modum mamillæ, et absorbentibus venis largiendum."

12 Epist. ab eruditis viris ad Hallerum, vol. iv. p. 160.

unconscious of agreement with the authorities just quoted. "Is it not probable," he asks, "that the gland is designed to prepare a fluid, well fitted for the fœtal growth and nourishment, from the blood of the mother before the birth of the fœtus, and consequently before chyle is formed from food; and this process continues for a short time after birth, the quantity of fluid secreted from the Thymus gradually declining as that of chylification becomes perfectly established[1]?"—a question which I shall endeavour to answer satisfactorily in another place.

Theory of its use to the nerves. Wharton.

Wharton[2] next proposed an hypothesis which, so far as I know, received no support from contemporaries or followers. Constant to his theory of glandular function, (cerebro magis quam cordi ancillantur) and believing the nerves of glands to be "non tam sensûs causâ quam in alium finem," he urges the following extraordinary doctrine: "Forte liquor nutritius quem præsertim nervi sexti paris (pneumogastrici) imbibunt nonnullâ impuritate aut acrimoniâ nimiâ inquinatur; quam depurandi gratiâ coguntur exspuere in hanc glandulam, ubi superfluæ ejus partes in transitu per glandulæ substantiam secernuntur et per lymphæductus auferuntur; purusque liquor per nervos in eandem disseminatos resumitur in partium nervosarum totius corporis usum. Quod vero hic sit usus hujus glandulæ probabiliter creditur, quia pars hæc dulcior, delicatior, et visceribus aliisq. plurimis glandulis albidior est" . . . "Est autem"—he has the modesty to add—"scruposa hæc sententia, multisq. objectionibus obnoxia"!!

Relation to the lymphatic system: as a diverticulum;

A large majority of the new theories depended, as one might anticipate, on the recent discoveries in the lymphatic system. Bartholin[3] declared that the Thymus must act as a diverticulum for the chyle—"ne copiâ oneretur subclavia vena:" Verheyen[4] and Hoffmann[5] partly admitted the same provision; the former apprehending—"ne nimis affatim admisceatur sanguini;" the latter—"ne cerebrum aggravaret, aut ad minimum corticis exterioris poros et meatus infarciret." Our countryman, Cowper[6], advocated the same theory of its diverticular use.

as a modifying agent;

Others maintained that the chyle passed through it for the purpose of being changed in its physical properties; a notion which Schenck[7] first promulgated, and Gibson[8]

[1] The Anatomy of the Thymus gland, by Sir A. Cooper, Bart., F.R.S. London, 1832.

[2] In op. cit.

[3] Anat. quartum renovata. 1673.

[4] Ph. Verheyen, in anat. 1683; and in Halleri Coll. disput. anat., vol. ii. p. 455,—"est enim sanguinis calor et motus in primâ ætate admodum debilis, adeoque a magnâ chyli copiâ facile suffocabilis."

[5] J. M. Hoffmann, Idea machinæ humanæ. Altdorf, 1703, p. 179.

[6] W. Cowper, Anatomy. 1702, tab. 21, where he likewise states (following Blancard), that the gland particularly corresponds to the upper lymphatics of the body, and "varies its magnitude according to the quantity of the lympha that is necessarily transmitted through it from the superior parts;" becoming smaller with advancing years, as the proportion of the head to the trunk diminishes.

[7] J. T. Schenck, Schola partium hum. corporis. Jenæ, 1664, p. 127,—"emunctorii vicem gerit, ut quasi per spongiam lacteæ depuratiorem chylum cordi inferrent."

[8] Gibson, Anatomy of humane bodies. Lond. 1688, p. 250. He likewise reverted to the old mechanical theories, arguing with Galen that the gland "props and strengthens the divisions of the vessels;" and, further, that it "defends them from compression by the claviculæ in stooping forward."

afterwards adopted. Teichmeyer[1] and Heister[2] admitted the same use in reference to the chyle, but explained their views of the operation without the same straining of anatomical facts. Monro[3] believed that the Thymus and Thyroid "do always supply the place of each other," and ascribed to both the same use, viz. "the separation of a thin lymph for diluting the chyle in the thoracic duct before it be poured into the blood."

as a conglobate gland.

Cowper's opinion, that the Thymus might be merely a lymphatic gland of large size, has been frequently adopted; and those, who take this view of its structure, generally maintain that its uses are only such, as belong to the whole class of conglobate glands. Such was the opinion of the great Haller[4]; it was likewise entertained by Lucæ[5], (to whose monograph I shall presently more particularly refer,) by Martini[6] and others.

Various reasons assigned for its use as a part of the lymphatic system in the fœtus.

But many of those who follow Cowper's theory of its nature, have endeavoured to account for its temporary existence by inventing some new hypothesis. Thus Oken[7] attributes the function of absorbing the liquor amnii to the mammæ of the fœtus, and believes that their lymphatics transmit it to the Thymus, whence, after such elaboration as is necessary, it passes into the thoracic duct.[8] Schreger,[9] who assigns the same nutritive absorption to the lymphatics of the cord, notices as an important fact, that the long axis of the Thymus is in a line from the umbilicus to the root of the neck, and corresponds to the course of these vessels; he accordingly judges that it receives their contents from below, and transmits the same, after due preparation, to the veins above. Wrisberg and Michaelis (as quoted by Haugsted, p. 252) seem to have previously expressed a similar opinion.

Rudbeck's[10] discovery of the course taken by the superior lymphatics of the liver

[1] H. F. Teichmeyer, Elem. Anthropologiæ. Jenæ, 1719.—"Quoniam chyli particulæ cum sanguine materno ad fœtum allatæ minus existunt subactæ et nutritioni adaptatæ, duo Deus ideo in fœtu viscera adornavit, quorum illud lympham, hoc vero chylum filtrando et subtiliorem reddendo, liquida hæc nutrientia faciliori postea sanguificationi ac nutritioni adaptat," p. 160.

[2] L. Heister, Compend. anat. 1717, p. 66,—"forte lympham secernit, eamq. per vasa lymphatica ductui thoracico infundit pro chyli dilutione sicut glandulæ mesentericæ, aut chylo pro diverticulo inservit."

[3] A. Monro *primus*, Essay on comp. anatomy, published by his son, 1744, p. 37.

[4] Halleri Elem. Phys. tom. iii. p. 118,—"eamdem ejus utilitatem esse crediderim quæ aliarum glandularum conglobati generis."

[5] S. C. Lucæ, Anatom. Untersuchung der Thymus. Frankf. 1811.

[6] L. Martini, Lezioni di fisiologia. Torino, 1828, vol. vii. p. 439.

[7] Vid. Osiander's Handb. der Entbindungskunst. Tüb. 1819. 1 Th. s. 510. I am indebted for this reference to Burdach and Haugsted, for I have been unable to find this work of Osiander's in London. Haugsted (op. cit. p. 257) erroneously ascribes this belief to Bohnius, whose belief [see J. D. Bohnius, Circulus anat. physiologicus, Lips. 1710, in progymn. 2. p. 29] was, that the mammæ of the fœtus *secrete* the liquor amnii.

[8] This theory derives additional interest from the circumstance of its having been temporarily adopted by the great German physiologist, Müller, in a juvenile essay on the respiration of the fœtus. (De resp. fœt. commentatio physiologica in acad. borussicâ rhenanâ præmio ornata; Lips. 1823.) The original work appears not to have reached any of our public libraries: my acquaintance with its contents has been made through a very copious digest given in Rust u. Caspers critisches Repertorium, vol. 17. In his recent System of Physiology Müller makes no reference to the earlier production, and has probably long since renounced the views embodied in it.

[9] B. N. G. Schreger, Saugaderlehre. Leip. 1793, p. 10.

[10] Ol. Redbuck, Exercit. anat. exhibens ductus hepaticos aquosos. Arosiæ, 1653.

through the anterior mediastinum, gave origin to the theory of the younger Caldani[1]: viz., that these vessels convey, for assimilation, from the liver to the thymus, those materials of nourishment which have entered the system by the umbilical vein; and that the thymus wastes after birth (si discioglie lentamente in molte minori glandule conglobate) because superseded in its function by the mesenteric glands. Treviranus[2], on the supposition that the nourishment of the fœtus is mainly due to cutaneous imbibition, and that the nutrient lymph is transmitted from all directions to the centre through the cells of areolar tissue, groups together the spleen, thymus, thyroid, and supra-renal capsules as the conglobate glands of this system of absorption, and attributes to the Thymus in particular, the function of assimilating so much of the lymph as is derived from the cells of the upper half of the body.

Theory of its forming nuclei for blood-discs. Hewson.

Among the speculations on the Thymus, which refer it to the lymphatic system, occur the interesting researches of Hewson[3], and his discovery of the peculiar corpuscles which the gland contains. While examining its fluid with a glass of $\frac{1}{23}$ inch focus, he perceived a "great number of small, white, solid particles, exactly resembling in size and shape the central particles in the vesicles of the blood, or such as are found in the fluid of the lymphatic glands." To these last he had previously attributed the destiny of becoming nuclei for the vesicles of the blood; and he now surmised that the Thymus might be considered as an appendage to the conglobate glands, and participate in their function of forming the nuclei. He considered the probability of this to be the greater, "from observing that the Thymus exists during the early period of life only, when these particles seem to be most wanted;" and he "found reason for suspecting, that the lymphatic vessels were possibly the excretory ducts of the Thymus." After a long period of neglect, Hewson's general theory of the relation of the lymph-corpuscles to the coloured particles of the blood, has received extraordinary confirmation, and almost universal acquiescence. That particular portion of it which concerns the Thymus, seems to me, for many reasons, inadmissible; but it has lately obtained partial support from one[4] of the most eminent German physiologists, and I shall hereafter state the considerations which induce me to dissent from it.

Theories of its use in hæmatosis:

Many authors have attributed to the Thymus the function of working particular

[1] Floriano Caldani, Nuovi elementi di anatomia. Napoli, 1825. (Also, Congetture sopra l' uso della glandula timo. Venezia, 1808.) "Io penso che quella glandula serva ad attenuare vieppiù la linfa che col sangue viene al fegato del feto per la vena ombellicale. Nel fegato infatti succede quella separazione, e se non ha esso un numero maggiore di vasellini linfatici che ogni altro viscere, è però vero che dalla sua superficie convessa nel legamento sospensorio passano al diaframma, et tra quelle fibre si fanno strada al mediastino anteriore per recarsi al timo, e da questa glandula al condotto toracico." Vol. ii. p. 424.

[2] G. R. Treviranus, Biologie. Gött. 1814. 4ten. B. s. 531. Blancard (Anatomia reformata. Leidæ, 1687) had previously declared his opinion of its use—"quod vasa lymphatica superiora recipiat, et in ductum thoracicum se exoneret."

[3] Wm. Hewson, Experimental Inquiry. Lond. 1777, part iii, particularly in c. 3 and 5.

[4] Bischoff, Entwickelungs-geschichte der Saügethiere und des Menschen. Leip. 1842, p. 527.

changes in the blood of the fœtus, and especially in those elements of it which are believed to come from the maternal system. Thus Boeckler[1], followed by Rösslein[2], erroneously believing that the maternal blood passes directly into the umbilical vessels, ascribes to the Thymus the power of operating upon it, so as to adapt it to the nutrition of the fœtus.

by acting on the maternal blood;

by assimilating a placental secretion;

In the seventeenth century, the placenta was supposed to secrete for the nourishment of the fœtus a milk-like fluid[3], which, by entering the roots of the umbilical vein, or in some other way, might pass into the general circulation. Some of the earlier examiners of the Thymus thought that in its secretion they could recognize and identify this nutrient juice; and, as they conceived the placental fluid to be analogous in its nature and purpose to the subsequent secretion of the mamma, so they did not hesitate to call the contents of the Thymus by the name of *milk*, and to assign to the gland the function of receiving that fluid, and promoting its conversion into blood. This opinion seems to have been obscurely entertained at an early period of the new researches[4], but I do not find it very distinctly stated before the middle of the eighteenth century, when Morand[5] supported it in an elaborate thesis. He particularly claims for the Thymus the power of sanguificating this uterine product, and compares its action with what he supposes to be the influence of respiration in the hæmatosis of extra-uterine life. Under the same head must be mentioned the quaint conceit of Samuel Collins[6], that "the most noble use of the animal liquor, dropping out of the terminations of the nerves into the substance of the Thymus, is to contribute its mite to the gentle fermentation of the blood;" and the opinion of Vercelloni[7], which is not much more intelligible, "cum in puerulis sanguis naturâ serosus cordis thalamos aptè satis dilatare nequeat ut per successivam constrictionem ad extrema parvarum arteriarum præcipuè bronchialium, quæ minimæ sunt, pertranseat, fit ut Thymus e vicinis carotidibus latè imbibens illius serum, hoc postea per proprios canales lymphaticos eroget in tracheam atque in pulmones."

or otherwise.

Theories referring its use to the respiratory system:

Among the most interesting and plausible hypotheses on our subject, must be accounted those which refer the activity of the Thymus to the quiescence of the lungs,

1 Fr. Reebman præside, P. H. Boeckler de thyroideæ glandulæ, thymi, et glandularum supra-renalium in homine functionibus. Argent. 1753. My knowledge of this thesis is derived from contemporary works, as I have been unable to find the original.

2 A. Rösslein, dissertat. de differentiis inter fœtum et adultum. Argent. 1783, p. 33.

3 *Lac uterinum;* see Bredschneider in Klinkosch. dissert. Prag. vol. i.: also Malpighius in Epist. ad Sponium. Bonon. 1681.—Gul. Harveius, De generat. animalium. Lond. 1651, p. 285.—J. Bartholinus, De lacteis thorac. Lond. 1652, p. 43; and in his Epist. de pulmonibus, sect. 1.—T. Wharton, in lib. cit., p. 253.—Needham, De formato fœtu. Lond. 1667, *passim.*—R. de Graaf, De mul. org., p. 297. Ludg. B. 1672.—Trew, De chylosi fœtûs in utero. in Hall. disput. anat., vol. v. 452.

4 Horstius, Deusingius, Munnicks, loc. cit.; and Bassius, in Observ. anat. chirurg.

5 Sauveur Morand le fils, Hist. de l'Académie des Sciences de Paris, 1759. A similar opinion has recently been defended by J. O. A. de Vest (de respiratione et de glandulæ thyroideæ functione. Vindob. 1831). It is not to be confounded with the much better supported theory which assigns to the Thymus during fœtal life a definite chemical action, equivalent to atmospheric respiration (vide infrà).

6 System of Anatomy, 1685, p. 699.

7 Jac. Vercelloni, in Mangeti Theatr. anatom. Genevæ, 1717, vol. ii. p. 183.

and suppose that, more or less directly, it fulfils in fœtal life the later functions of these organs, either in oxydizing, or in decarbonating the blood. Such notions have obscurely existed for some time: the doubts of Lindanus (as quoted by Bartholin) "an feriante pulmone et antequam obliteretur foramen ovale, huc concedant excrementa cordis fuliginosa," is the earliest hint I have met with. Morgagni[1] alludes to the belief; it formed part of the complicated theory of Puteus (who even proposed to call the Thymus *pulmo succenturiatus*) and Morand nearly approached it. Autenrieth[2] (at the commencement of the present century) seems to have brought it into general notice; Sprengel[3] soon followed him: Meckel's[4] admirable treatise, and Tiedemann's[5] dissection of the marmot, tended in the same direction, and the doctrine has since then been advocated by Lenhossék[6], Burdach[7], and Arnold[8]. Slight differences of opinion prevail among these writers, as to the detail and exact nature of the change suspected. Autenrieth and Sprengel believe that the fœtal blood actually becomes arterial in traversing the tissue of the Thymus; the others maintain a view, first distinctly announced by Tiedemann, that the oxygenization is merely relative, that the change consists in the elimination from the blood of a highly carbonaceous compound[9]. Burdach slightly modifies the theory in applying it only to that portion of the blood which traverses the ductus arteriosus; for he, with most modern embryologists, believing the distinctness of two separate streams of circulation through the fœtal heart, conjectures that the Thymus may decarbonize the stream of the descending cava, just as the placenta has decarbonized that which enters the inferior vein. I shall have occasion hereafter to refer again to these views of the relation of the Thymus to the respiratory organs, and shall now merely observe that the arguments used against them by Becker[10] and Haugsted are quite unanswerable; being founded on the fact that the chief development of the gland is not during the period of uterine life, nor the commencement of its decay simultaneous with birth; its activity, in other words, is *not* greatest during the quiescence of the lungs; although then, according to the opinions quoted, there would be the chief, or only, necessity for its decarbonizing action on the blood.

as an organ of vicarious respiration;

[1] J. B. Morgagni in Epist. xx. 66:—"ex ingeniosissimo dum viveret, ac celeberrimo viro audivi, ut glandulæ suprarenales simul cum thymo respirationis in fœtu defectum compensent; videlicet, succum secernendo subtilissimis ac maxime activis refertum particulis, quales ex aere per respirantium pulmones induci in sanguinem non dubitabat."

[2] J. F. H. Autenrieth, Handbuch der empir. Physiologie. Tübingen, 1801. 1 Bd. s. 332.

[3] K. Sprengel, Institut. physiolog., vol. i. p. 454, and vol. ii. p. 80. Amsterdam, 1809.

[4] F. Meckel, Abhandlungen aus der menschl. und vergleichenden Anatomie, and in Zusätzen zu Cuviers Vorlesungen. 4 Bd. s. 723. Halle, 1806.

[5] F. Tiedemann, in Meckel's Archiven. 1 Bd. 1815. Vide infrà.

[6] M. A. Lenhossék, Institutiones physiologiæ. Viennæ, 1822, vol. i. p. 287.

[7] C. F. Burdach, Die Physiologie als Erfahrungs-wissenschaft. Leipzig, 1837. 2 Bd. s. 752.

[8] F. Arnold, Lehrbuch der Physiologie des Menschen. Zürich, 1837. Theil II. s. 265.

[9] I am uncertain whether I should distinguish from this view that advanced by Mr. Renaud, (Lond. and Edinb. Journal of Medical Science, 1843, p. 181,) "that the function of the Thymus gland is that of affording a non-azotised and carbonaceous fluid, on which the oxygen taken in by the placenta may act and re-act."

[10] F. G. Becker, De glandulis thoracis lymphaticis atq. thymo. Berolini, 1826. Haugsted, op. cit.

as a diverticulum to the pulmonary circulation.

Here, too, may briefly be mentioned (as open to the same objection) the doctrine of Karch[1] and Danz[2], that the use of the Thymus consists in its diverting the current of blood from the fœtal lungs; and the conjecture of Kait, as quoted by Soemmering[3], that it prepares the blood for undergoing, after birth, the process of ordinary respiration.

Use as a receptacle of bony matter.

To the notion just quoted—that the Thymus serves as a diverticulum to the pulmonary circulation during fœtal life—Mr. Tuson[4] adds the original suggestion, that it may be a receptacle for such quantity of osseous matter, as is not required for use in the animal œconomy until after birth.

Use to equalise nourishment for the upper and lower halves of the fœtal body.

Nicolai[5] advanced the strange opinion, that the Thymus is connected with the organs of circulation in the fœtus, for the purpose of equalising the nourishment of its upper and lower parts,—that it withdraws certain vital powers from the more aerated blood which has traversed the foramen ovale, and imparts the same to that other stream, which has passed through the ductus arteriosus to the descending aorta.

Various uses assigned to its secretion.
An excretory duct described.

Short notice will suffice for those theories which endeavour to assign particular local uses for the secretion of the gland. Muralt[6], though he still clung to the Galenic doctrine of its mechanical use (divisiones vasorum sustinere) exerted himself to demonstrate the presence of a duct, "qui in tracheam liquorem suum, vel etiam ad pericardium vicinasq. partes deferat:" and Verheyen[7] also, in addition to supposing the Thymus a diverticulum for chyle, suggested that it might serve to separate the liquor pericardii. Avicenna, a colleague of Muralt's [quoted by him in loc. cit.] believed in the existence of a duct opening upwards into the mouth: this is, according to him, the channel of profuse ptyalism; which, he argues, is very easily produced by the application of mercurial plasters to the neck. Petit[8] describes a secretion intended to moisten the trachea and bronchial tubes—"pour les garantir de la sécheresse que l'air y produirait en passant et repassant par le poumon," and attributes its formation in

[1] J. G. Karch, De usu glandulæ thymi verisimillimo. Jenæ, 1792.

[2] F. G. Danz, Grundriss der Zergliederungskunde des ungeborenen Kindes. Giessen. 1793. Bd. II. s. 61.

[3] In a note to p. 681 of his edition of Haller's Grundriss der Physiologie, re-edited by Meckel, 1788.

[4] John Tuson; Physiological inquiry into the uses of the Thymus gland; in the London Med. Surg. Journal for Jan. 5, 1833.

[5] A. G. Nicolai, über den Nutzen der Thymus; in Rust's Magazin für die gesammte Heilkunde, 1826, p. 327.

[6] J. de Muralto, Exercit. anat. Amstelod. 1688. See also the Ephem. nat. curios. (Norimb. 1687, p. 56), where he describes the "jucundum spectaculum" of ducts passing to the pericardium.

[7] Ph. Verheyen, Corp. human. anat. Lovanii, 1693; and in Haller's Collect. disput. anat., vol. ii. The latter tract formed part of so acrimonious a controversy between Müller and Verheyen, that Haller esteemed it requisite to apologize to the reader of his collection for having inadvertently admitted so warm a disputant. Müller's thesis (which, with one exception, was the earliest monograph on the subject of the Thymus) had attacked the opinions quoted in the text. Verheyen angrily vindicates himself in an answer,—"Quâ retorquentur injuriæ," &c.; and Müller gives a last blow in a work polemically entitled Defensio exercitationis suæ de Thymo; "quâ Ph. Verheyen in literis ruditas, in physicis ignorantia, in anatomicis imperitia demonstrantur." Lug. Bat. 1707.

[8] Petit, Remarques sur un enfant nouveau-né: in Mém. de l'Acad. des Sciences de Paris, 1733. Art. i.

the fœtus to the Thymus gland; Steller[1] also adopts a similar theory. But an adequate answer to all such opinions is contained in the few, but very pertinent words of Bordeu[2] — "un vieillard a besoin d'avoir sa trachée et son œsophage humectés tout comme les jeunes gens;—le liqueur péricardine lui est aussi nécessaire . . . . pourquoi donc en serait-il privé?" Local uses of its secretion.

Lobstein[3] follows a suggestion of Diemerbroeck's[4] that the fluid of the Thymus, by being mixed with the blood, renders this an adequate stimulus to the activity of the heart: a function which might just as well be assigned to any other organ in the animal œconomy. Use to the heart.

This appears the place for mentioning certain views, built on the imagination of an excretory duct supposed to communicate with some part of the alimentary canal. Dr. Bellinger[5] fancied an union of the upper prolongation of the Thymus with the submaxillary gland; and conceiving, with many contemporary anatomists, that the Thymus serves to separate from the blood a peculiar lacteous fluid given to it by the placenta, he announced as a discovery that the fluid, so appropriated from the maternal circulation, must pass from the Thymus into the salivary glands, and be transmitted by their ducts into the mouth and alimentary canal of the embryo, as so much digestible material for its nourishment. Martineau[6] had a similar physiological theory, but believed the communication with the fœtal alimentary apparatus to be by means of certain canals, which he did not pretend to demonstrate, opening into the œsophagus, or the stomach. Use to furnish digestible nutritive material.

The most important recent contributions to the general anatomy of the Thymus are to be traced in the monographs of Meckel, Lucæ, Haugsted, and Cooper.

Meckel's[7] inquiry likewise includes the physiology of the thyroid body and supra-renal capsules, and aims particularly at illustrating the subject by the light of comparative anatomy. He carefully considers the circumstances which determine a greater Meckel.

[1] G. W. Steller, De bestiis marinis: in Nov. Comment. Acad. Petropol., 1751, p. 380,—"conclusi hanc glandulam secernere liquorem pro irrigandâ larynge."

[2] T. Bordeu (par Richerand). Paris, 1818, p. 102. M. Pestre of Montpellier is quoted by Bordeu as having, in 1746, communicated to him the discovery of a duct opening into the trachea.

[3] J. F. Lobstein, Sur la nutrition du fœtus. Strasbourg, 1802, p. 130.

[4] Isb. Diemerbroeck, Anat. corp. human., lib. ii. cap. iv. Ultraj. 1672. Lobstein did not follow Diemerbroeck amid his extraordinary fancies about the fermentation and effervescence of the blood, and the necessity of the thymic fluid to maintain that wholesome state.

[5] F. Bellinger, Tractatus de fœtu nutrito, 8vo., Lond. 1717. His observations were made on the fœtal pig, in which animal the submaxillary gland is so closely applied to the upper enlargement of the Thymus, that the error above-mentioned might easily befall a superficial dissector.

[6] Martineau, mémoire sur les usages du Thymus; in Journ. gén. de Méd. etc. redigé par Sedillot, tom. 17. Some Italian anatomist had described to Boerhaave, before the year 1731, a duct passing from the Thymus to the lower portion of the œsaphagus. (H. Boerhaave, prælect. academicæ, ed. A. von Haller, Gött. 1740; vol. ii. p. 474.)

[7] F. Meckel, Abhandlungen aus der menschlichen und vergleichenden Anatomie und Physiologie. Halle, 1803.

size, or longer persistence, of the Thymus; investigates it especially (p. 200) in rodent and marine mammalia; notices, for the first time, in certain birds (p. 214) an organ which he believes to be analogous to that under consideration, and quotes numerous instances of disease affecting it in the human subject (p. 234). The theoretical conclusions of his work are the following:—I., (p. 261,) that the brain and nerves, liver, spleen, thyroid, thymus, renal capsules, and parts of generation, constitute a system of organs for diminishing the quantity of carbon and hydrogen in the body, and thus indirectly increasing the healthy preponderance of oxygen: II., (p. 262 et seq.,) that their development is in inverse proportion to direct pulmonary respiration: III., (p. 275,) that the renal capsules, in discharging the above function, have especial relations to the activity of the generative organs, and a peculiar sympathy with them; but that the thymus and thyroid body are without any particular connexion of this kind, and are united to their class only in general harmony of use, as a system of parts *inverse and opposite to those of true oxygenization.*

Lucæ.

Lucæ's investigation of the Thymus was anatomical, and chiefly regarded its minute construction[1]. He recognized its cells and their arrangement around the lobular cavity, and distinguished the former as secretory, the latter as receptacular; but he erroneously considered each cell as an acinus containing within itself a plexus of blood vessels. Tiedemann[2] more correctly explains the true relation of these anatomical elements: he describes each lobule as formed of many cells, round which a vascular network is expanded, and the cells as all communicating with the common cavity of the lobule.

Sir A. Cooper.

Sir Astley Cooper's work finally fixed this view of the structure of the gland as completely as could be done without the use of the microscope. By means of very fine and successful injections, he filled the minutest cavities of the organ, and displayed the relations of each to the common cavity of the whole. The following are his anatomical conclusions:

"I. It is composed of a gland on each side, united only by cellular membrane.

"II. It is formed of two ropes which can be with care unravelled, and they are of considerable length.

"III. The ropes are constituted of small and large lobes, which appear as knots upon the rope.

"IV. These are disposed in a spiral or serpentine course, from the upper part of the cervical to the lower extremity of the thoracic portion.

"V. Each portion of the rope is a secretory structure.

"VI. The lobes contain secretory cavities or cells, which may be readily shown by filling the gland with alcohol, air, gelatine, or even wax.

"VII. A pouch of communication exists between the lobes and the reservoir.

[1] S. C. Lucæ, in op. cit.; also Anatomische Bemerkungen über die Diverticula am Darmkanal, und über die Höhlen der Thymus: Nürnberg, 1813.

[2] F. Tiedemann, Bemerkungen über die Thymus drüse des Murmelthiers; in Meckel's Archiven, 1815, vol. i. p. 481.

"VIII. The gland has a central canal or reservoir.

"IX. This cavity is not straight, but spiral or serpentine.

"X. The reservoir is lined by a very vascular mucous membrane.

"XI. The ropes of the gland pass in a spiral or serpentine direction around the mucous membrane which lines and principally forms the reservoir, and these ropes, being united by that membrane to each other, assist in forming the cavity."

In the same year with Sir Astley Cooper's work appeared the far different one of Dr. Haugsted.[1] It is less remarkable for anatomical than for literary research, but in this respect is unrivalled; every author who has written on the subject is made tributary to its pages, and it is scarcely possible to improve on his selection as regards either the number or pertinence of the quotations; his criticism of the various opinions is likewise sound and perspicuous. To our knowledge of the anatomy of the gland he contributed little or nothing; in comparative anatomy he made several examinations, though not always with the happiest results. Perhaps the chief physiological merit in his work, is the prominence he gives to the fact of the increase of the Thymus after birth; for although Verheyen, Palfyn, and others, had cursorily noticed this circumstance, it had not obtained general attention; and men had continued arguing and inventing hypotheses for the Thymus as a fœtal organ, in ignorance of the essential error which must infect every theory so founded. Haugsted established, beyond the possibility of doubt, that the Thymus does not attain its greatest development, either absolute or proportional, until after a considerable interval from birth. Haugsted.

The theory of its use which he founded on this observation is curious[2]: "Organa classi mammalium propria vix alia reperiuntur tam notabilia quam mammæ et thymus; quæ organa, cum simultaneo tempore,—lactationis dico,—illud quidem in matre, hoc vero in infante lactente, vigeant, eidem functioni perficiendæ dicata videri possunt; . . . . et sponte sese offerre videtur opinio, thymum *lactis assimilationi vel animalisationi in infantibus mammalibusque lactentibus quodammodo inservire*." This conjecture depends for its plausibility on the assumption that the Thymus is "organum mammalibus proprium;" and it is at once and totally refuted by a fact, which I shall presently illustrate, that a Thymus exists *beyond the class of Mammalia*, namely, in birds and in reptiles. Haugsted's theory of its use in lactation.

With the two last mentioned writers terminates the literature of our subject so far as concerns that elder school of anatomy, which contented itself with an almost

[1] F. C. Haugsted, Thymi in homine ac per seriem animalium descriptio. Hafniæ, 1832.—Haugsted was probably indebted for references to Becker's learned thesis, (De glandulis thoracis lymphaticis atque thymo, Berolini, 1826,) which is a meritorious compilation, and contains a very copious selection from various authors of instances of disease in the gland.

[2] Bellinger may claim priority in this erroneous opinion; as having argued (vid. supra) that one use of the Thymus is to promote the "more easy digestion and dissolution of the curd of the milk."

exclusive study of relative position and outward form. To that school of descriptive anatomy we owe the greatest obligations. From the time of Galen to our own, it has been intimately connected with the progress and practical perfection of the healing art, and has included all the greatest masters of our profession: it has produced important physiological discoveries, has created our means of distinguishing disease, and laid the foundations of scientific medicine. It may at length be thought to have exhausted its materials, and fulfilled its task.

New School of Histology.

Simultaneously with the completion of its labours, began the development of a new school—that of structural anatomy: it may be called a new school, for from the bright era of Malpighi onwards, the science which he established had encountered almost universal neglect. I doubt whether the history of the natural sciences can furnish an instance of more striking revolution in the bent and character of philosophic research than was effected in the years 1838 and 1839, by the enunciation of Schwann's histogenetical theory.[1] The study of structural anatomy had been considered utterly futile, as alike destitute of practical application, and unmethodised by any common principle which could give it even an abstract and scientific interest. For some time preceding the year signalized as the date of Schwann's memorable work, there was, so to speak, a period of *incubation:* the facts were being collected which he afterwards combined into so masterly a system.

Schwann.

The great extension of knowledge in structural botany by the works of Brown, Mirbel, Meyen, and Schleiden, the discoveries and speculations of Purkinje, Turpin, and Henle, as to the nature and mode of growth of epithelia; the admirable embryological researches of Valentin, and his early notice of the resemblance of various growing animal tissues to the cellular structure of plants,—all these were requisite preliminary steps towards the enunciation of the great general law. *Facts* enough of cell-structure and of cell-growth, were known before the time of Schwann, just as *facts* of gravitation were known before the time of Newton; but in each case it was only the final announcement of a law, comprehending and interpreting these, which gave to them their coherence and scientific value. Of course no great discovery can be viewed isolatedly, or be conceived as independent of those which have preceded it. Schwann could no more have developed his theory apart from the researches of Schleiden and Valentin, than Newton, in the vaster world of physics, could have consummated his great ideas in anticipation of Kepler and Copernicus. But without derogating from the merits of others who have contributed useful details, we may, and in justice must, accord to Schwann, the high merit of having first expressed the various acts of growth in the simplicity of a general law, and of having unfolded amid these complex phænomena the singleness and consistency of scheme, which distinguish the operations of nature.

The enunciation of his views constituted a new æra in physiological research; it taught us not to content ourselves, in the study of structure, with peering through a

[1] Thomas Schwann, Mikroscopische Untersuchungen über die Übereinstimmung in der Struktur u. dem Wachsthum der Thiere u. Pflanzen. Berlin, 1839.

microscope for the square, or the round, or the oblong, but to contemplate physical objects, however minute, only as signs or symbols of the processes effected in them, and ever to aim at interpreting their language; it bade us inquire the meaning and signification of ultimate organic forms and the nature of the molecular operations of life; it founded, in a word, the science of *structural morphology*.

Progress in anatomy of the glandular system.

So immediate was the application of Schwann's grand view of organisation as to convince us, if proof were needed, how immensely the promulgation of any scientific law quickens the cultivation of detail. For (to confine myself to its effects on our present subject) within the few years which have since elapsed, how completely has the structure of glands been examined and explained! Henle[1] (in his General Anatomy) and Valentin[2] (in a masterly series of essays in Wagner's physiological dictionary) have almost exhausted inquiry in the direction suggested by Schwann's discoveries, accomplishing, in the detail of the ultimate anatomy of glands, all that Müller had previously outlined in respect of their general configuration. Bischoff[3], Berres[4], and Krause[5], in Germany, with Mr. Goodsir[6], Mr. Bowman[7], and Dr. Todd[8], in this country, have contributed new facts and arguments to the establishment of the modern doctrines of secretion, or have otherwise enlarged our knowledge of the structure and functions of secreting organs.

Nor must I omit to specify, among the means and moving causes of a better knowledge of physiology in relation to our subject, the eminently practical turn given to Organic Chemistry by Liebig[9], and the careful elaboration of detail by many of his followers[10].

Progress in anatomy of the glands without ducts.

In regard of the glands without ducts, our increase of knowledge has been indirect and fragmentary. Purkinje[11] recalled attention to their peculiar corpuscles, and suggested a probable relation of these to the development of blood and lymph. Henle[12], with

[1] J. Henle, Allgemeine Anatomie. Leipzig, 1841.

[2] R. Wagner's Handwörterbuch der Physiologie. Braunschweig, 1842, art. "Absonderung," "Ernährung," "Gewebe."

[3] Th. L. W. Bischoff, Entwickelungs-geschichte. Leipzig, 1842. There is a recent work on the subject of the glands without ducts, which, in spite of numerous attempts, I have been unable to obtain from Berlin: A. Schwager-Bardeleben, observationes microscopicæ de glandularum ductu excretorio carentium structurâ, deq. earundem functionibus experimenta; Berolini, 8. It is noticed in Valentin's Repertorium for 1842, and is cited by Bischoff, in Entwickelungs-gesch. I the more regret being unable to quote this work directly, as it is understood to have been written under Bischoff's direction and to embody his views; but I believe the references given include all which is most important in the original volume.

[4] J. C. Berres, Anthropotomie. Wien, 1841; and particularly in the Mediz. Jahrbuch des österreichischen Staates, 1840, p. 411.

[5] C. F. Krause, Handbuch der mensch. Anatomie. Hannover, 1842.

[6] J. Goodsir, in the Transact. of the R. Soc. of Edin. vol. xv. p. 2: "on the ultimate secreting structure and on the laws of its function:" a paper of the greatest originality and merit.

[7] W. Bowman, Phil. Trans. 1842; and art. "Mucous Membrane" in Cyclopædia of Anatomy and Physiology.

[8] R. B. Todd, Lectures on the mucous membrane of the stomach and intestinal canal, Med. Gazette, 1839 & 1842.

[9] Just. Liebig, Anim. Chemistry, edited by Dr. Gregory, 1842.

[10] As particularly in J. F. Simon's Handbuch der angewandten medizinischen Chemie. Berlin, 1840.

[11] Im Berichte der Versamml. d. Naturforscher zu Prag, 1837: Okens Isis, 1838, p. 575.

[12] Henle, in Hufelands Journal, Mai, 1838; über Schleim und Eiter-bildung.

many other able anatomists, dazzled for the time by Schwann's luminous morphology, conceived the whole structure of these bodies to consist of nucleated cells: but he retracts this hasty judgment, and gives much sound information on the subject in his invaluable system of General Anatomy. Pappenheim[1] reports his researches into their structure, and describes with questionable accuracy the distribution of nervous fibrils throughout their substance. Berres[2] judiciously includes them in his general classification of the glands, but adds little definite knowledge on the subject of their intimate structure. Mr. Gulliver[3] details the effects produced by various chemical reagents on the corpuscles of the Thymus; argues the identity of these with the globules of the chyle and lymphatic juice; and believes the Thymus to be "an additional gland for the elaboration of nutrient matter specially provided to meet the wants of the economy at the precise time when these wants are most urgent." He includes the corpuscles of the Thymus in his theory of the destination of lymph-globules,—conjecturing that they "will prove to be so many germs for the formation of those cells which the excellent researches of Schwann have shewn to be intimately concerned in the development of the animal tissues generally."

No attempt has hitherto been made, amid the new school of physiology, to expound the structure, or inquire the uses of these organs, in the cautious spirit of philosophical generalisation. Indeed,—though the authors just cited have given numerous isolated remarks, which, so far as they go, are sufficiently accurate,—it cannot but be felt that the glands without ducts have as yet scarcely been received within the pale of modern physiology. There has been no certain knowledge of their structure; nor any such doctrine of their uses, as a scrupulous lecturer might confidently address to his class. It would be impossible to illustrate this fact more completely than by stating, that the very latest essay[4] on the subject of the Thymus gland, reverts to the physiology of two thousand years since, and defends a theory of its use no less mechanical than Galen's.

Yet there do seem to exist in the present day nearly all the elements so long wanted, for resolving the problem which is the subject of the present essay: the means, on the one hand, for correctly interpreting the ultimate anatomy of organs; and on the other for correctly expressing the nature of their functions in the terms of chemical science:—means which I hope I may be able to employ, in some small proportion to their efficiency, in the difficult investigation to which I now advance.

[1] Pappenheim, in Müller's Archiv. 1840, p. 536; and in the Neue Zeitschrift für Geburtshülfe, von Busch, d'Outrepont und Ritgen, 1841, p. 296.

[2] In österreich. Jahrbuch, 1840.

[3] In the Appendix to his translation of Gerber's Anatomy, p. 95 et seq. This *elaboration*, or second digestion, is, according to Mr. Gulliver, such that the nutrient matter may "be modified and prepared to aid in the growth and preservation of the animal; and a leading result of it is, doubtless, the formation of globules, perhaps as an immediate consequence of the increase of fibrine."

[4] Luigi Picci, dell' ufficio del timo; in commentarii dell' Ateneo di Brescia per l'anno accademico 1840, Brescia, 1842: (Annali univ. di Medicina, vol. 107, p. 593:)—è solamente nell' adulto che il torace si modella perfettamente sui polmoni, mentre nella più verde età avea il timo, che in loro vece sul torace si modellava; etc.:—è un organo vicario ai polmoni di ufficio come dire meccanico; etc.

CHAPTER II.

DEVELOPMENT OF THE THYMUS.

Exterior anatomy of the Thymus not now to be discussed.

THE general shape of the Thymus, its relative position, the divisions of its surface, and the ordinary arrangement of its larger vessels, are all so abundantly set forth in various systematic works, and in the treatises of Lucæ, Haugsted, and Cooper, that this branch of the subject may be considered complete.

Slight differences in this rougher anatomy of the gland are frequent and utterly unimportant. The proportionate development of its parts varies remarkably; sometimes the right portion will preponderate, sometimes the left; sometimes a cervical prolongation will reach higher on this side, sometimes on that. The arrangement of lobes and fissures is scarcely found the same in any two consecutive dissections; in one, the gland appears bi-partite and exactly symmetrical,—in another, presents the most irregular intersections of surface, longitudinal, transverse, and oblique,—in a third, displays such faint traces of division, that it might readily be taken for a single azygous organ. The immediate source of its arterial supply is subject to infinite diversity; "mirum sane," says Haugsted,[1] "quantum varietatis ac inconstantiæ in origine arteriarum thymicarum reperiatur." The termination of its veins also varies within smaller limits; and, according to the different descriptions of authors, that of its lymphatics is likewise uncertain.

But what is more common in conglomerate organs than some abnormality of exterior conformation, without any consequent difference in their activity? Witness, for example, the numerous exceptions to any standard description, which are found in the shape and superficial divisions of the liver or kidney! What more frequent than some irregularity in the origin and course of large visceral arteries (those of the brain, the chylo-poietic system, or the kidney) involving no impairment of function in the organ supplied, however delicate in structure, or vital in use? Nature allows great latitude to such individual variations. Indeed, while they do not affect that which is characteristic in form, or essential to function, they cannot be considered of scientific importance; their circumstantial description can conduce neither to physiological knowledge, nor to other practical usefulness, and may justly be accounted among the trivialities of anatomy.

I could add but little to our present abundant information on the details of the superficial anatomy of the gland; and therefore, and as I consider the *functions and*

[1] In lib. cit. p. 67.

intimate structure of the Thymus to be the peculiar subject-matter of the present essay, I shall refrain from dwelling on the former exhausted topics, and shall proceed at once to give the results of my researches in the development, permanent structure, and morphology of the gland.

SECTION I.

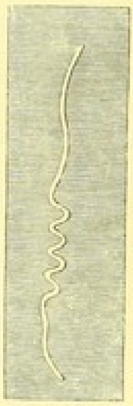
Development of Structure.

THE first appearance and early growth of the Thymus are points of much interest in its history; and I have taken the greater pains to arrive at correct conclusions, as this part of my subject has been hitherto almost untouched. My investigations have been chiefly conducted on the embryos of swine and oxen; but I have never in other animals seen anything, which would induce me to believe that the process is in any respect peculiar to those, from which I more particularly describe it. On the contrary, the most superficial and fragmentary notice of its development in various animals suffices to convince the observer that in it, as in other organs, the type of growth is definite, constant, and universal, — marked by peculiarities, which are essential and characteristic. These peculiarities, such as they are, have a ready explanation in other analogous acts of growth: this particular process, viewed in its most general signification, is but a variety of glandular development; its specific differences, though they give it an individual character, do not detach it from its class, nor hinder its comprehension in the common genesiology of secreting organs.

First appearance.

By the naked eye, or with the assistance of a simple lens, its existence may be distinctly ascertained in fœtuses of about $1\frac{1}{2}$ inch length; and, by careful manipulation, it may be followed under the microscope in its earlier stages, even in embryos little more than half an inch long.

Fig. 1.



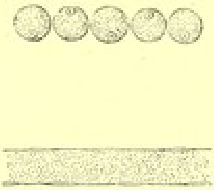
Primary tube.

The earliest form, in which I have discovered it, has been that of a simple tube; (vid. fig. 1;) lying, in the animals I have mentioned, along the carotid vessels, and surrounded by the faint indications of nascent areolar tissue. The contents of the tube are seen (with a magnifying power of 400 diameters) to be granular and dotted, but do not as yet shew distinct corpuscles. Its figure is defined by the abrupt outline of the membrane, which constitutes its wall, — an exquisitely delicate, transparent, homogeneous tunic, presenting at regular intervals slight elongated thickenings of its substance.

Although I have carefully sought for an earlier stage of its development, I have not succeeded in demonstrating this unequivocally; but, for various reasons, I believe that the first rudiments of the gland would be found in a series of primordial cells, arranged in a line along the cervical vessels and pericardium, and coalescing on each side of the neck, to form the tube I have described (vid. fig. 2). This mode of origin would be in strict accordance with analogy, and would explain the peculiar thickenings which are found in the wall of the tube;—for, as these occur at regular intervals, and exactly resemble the early markings of other embryonic tissues, which certainly originate in cells, (*e. g.* those which are found in the sarcolemma of muscle, and in the single tunic of capillary blood vessels,) it would be difficult to assign them any other origin, or to consider them in any other light, than as attenuated nuclei of primordial cells.

Probable origin of the primary tube.

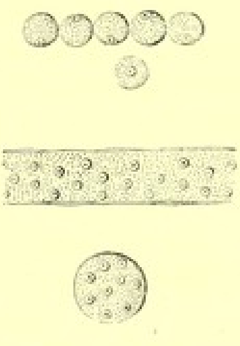
Fig. 2.



In a fœtal pig of $1\frac{1}{3}$ in. length, this primary tube measured nearly $\frac{1}{700}$ in. diameter; and in one of $\frac{3}{4}$ in. length, about $\frac{1}{1150}$ in. I have not seen it of smaller diameter than the last; but the measurement is quite compatible with the theory of its origin, which I have suggested.

Indirectly, too, I have some evidence to the point: for, in one instance, while examining the Thymus of a fœtal pig $2\frac{1}{2}$ inches long, I discovered the following remarkable irregularity; there was among the normal parts of the gland, a single *isolated* vesicle, diam. $\frac{1}{525}$ in., constituted by a distinct membrane, and containing dotted corpuscles (vid. fig. 3). It had in fact every appearance of being a portion of the gland, except the fact of its isolation, and the first supposition might well be, that it had been dissevered by violence from the general mass . . . . but it was quite complete and uninjured in outline, the tube shewed no traces of fracture, nor could I find any source of fallacy. I am unable to account for its existence, except on the hypothesis of a cellular origin for the tube. I should suppose that one of the primordial cells had been in excess, had been dislocated from the line of coalescence, and had undergone a solitary development of size in its original cell-shape.

Fig. 3.



I may take this opportunity of briefly noticing Arnold's opinion, that the Thymus is a development from the respiratory mucous membrane; that it originates from the larynx, and gradually extends downwards.[1] My dissections have never shewn me anything which could give the smallest support to this theory; the connexion, which Arnold conceives, could scarcely be overlooked, if carefully sought for; yet I have never seen any indication of it; the primary tube of the gland has never appeared to have any dependence whatever on the respiratory apparatus, but has been quite distinct from it, and closed in all directions.

Connexion with the larynx?

[1] Fr. Arnold, Lehrbuch der Physiologie, Th. ii. p. 265; and Salzburg. med. chirurg. Zeitung, 1831.

Connexion with the thyroid body?

Neither have I found reason for believing with Bischoff,[1] and some other embryologists, that its origin has any particular relation to that of the thyroid body. Undoubtedly there is a period, when it is impossible to say how much of the unshaped blastema of the neck belongs to one organ, how much to another; but this is at a time antecedent to the real distinguishable existence of either Thymus or Thyroid; for, so soon as the microscope can discover the first traces of their development, it likewise affords unquestionable evidence of their distinctness, and shews each as separate in itself, and as peculiar in structure, as at any later period of growth.

The primordial cells, which I believe to be the earliest elements of the Thymus, probably form a single series for each half of the body, and are arranged in a line which corresponds to the axis of the future gland, and pretty nearly represents its length in proportion to the surrounding parts; for the tube, in the youngest fœtal calves in which I have been able to trace it, has seemed to possess at first its entire proportionate length, reaching from the pericardium, below, to within the angle of the jaw, above.

Bulging of the primary tube to form follicles.

The second stage in the progress of development is in analogy with the mode of growth attributed to true glands: the tube bulges at certain points of its length, on one side or the other, and gives origin to diverticula or follicles, which maintain their connexion with its cavity (vid. fig. 4). These follicles have precisely the same contexture as the parent tube, of which in fact they are mere evolutions; they are bounded by the same delicate tissue as constitutes its wall; they contain, too, the same material, in which may now be seen the peculiar dotted corpuscles hereafter to be described.

Fig. 5.

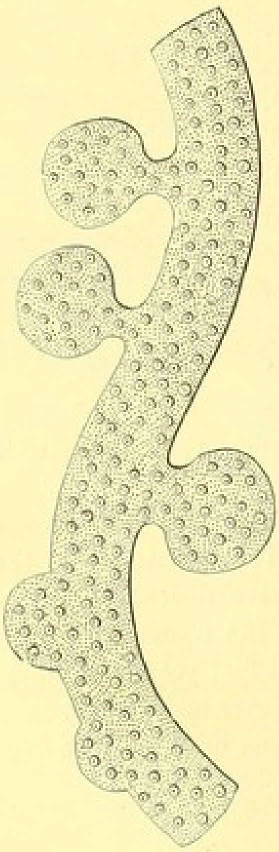
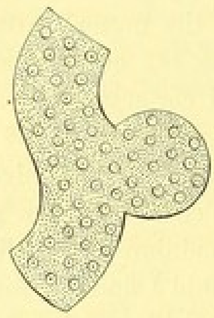


Fig. 4.



These growths from the tube are merely transitional forms, and therefore vary according to the stage of their development; the annexed diagrams are chiefly from the fœtal calf ($2\frac{1}{2}$ — 3 in. long), which affords great facilities for the study.

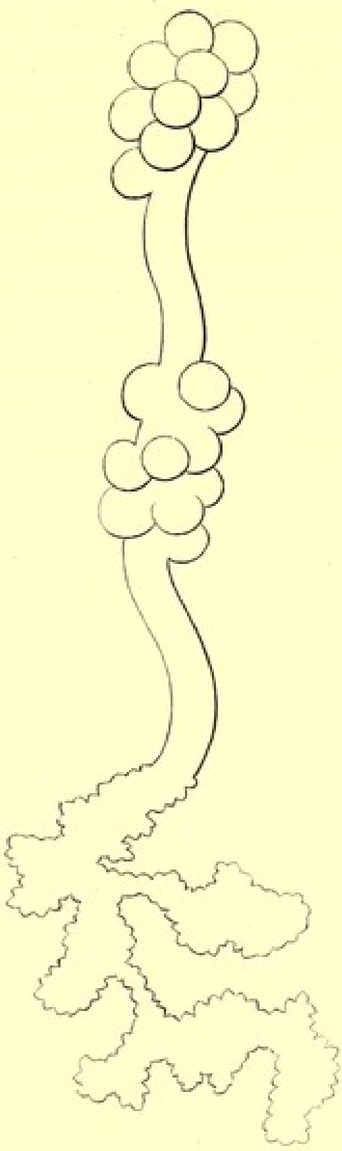
Their form, in the present stage, is that of larger or smaller segments of a circle; sometimes projecting but little beyond the general line of the tube, sometimes exactly hemispherical, but always tending in their growth to become peninsular, and to retain their connexion with the main canal by means of a narrow isthmus of communication (vid. fig. 5). Thus in the portions of the gland, where they are most thronged together, they may be seen in profile forming a series of flask-like appendages to the tube.

[1] Th. L. Bischoff, Entwickelungs-geschichte der Saügethiere u. des Menschen. Leipz. 1842, p. 288.

Extension of this process throughout the gland.

The steps of development are not simultaneous in all parts of the gland; they advance most rapidly at certain particular points; namely, at those which ultimately attain the largest size. For example, in the fœtal calf, there are three centres of early development, occurring in those points of the tube which correspond, respectively, to the pericardium, to the upper part of the trachea, and to the angle of the jaw. At these points we find the above-mentioned bulgings of the tube to have advanced considerably in their progress, at a period when the intermediate portions are simply and uniformly tubular (vid. fig. 6).

Fig. 6.



Partial modifications and varieties.

An interesting modification occurs in the growth of the pericardiac portion. It must be remembered that the cervical part, being situated in loose intermuscular spaces and the like, can grow equally in all directions: the tube can bulge into follicles equally from all points of its axis; its growth assumes a *solid* form. The pericardiac part of the organ, on the other hand, particularly at the beginning of its development, tends rather to *superficial* extension. With little increase of thickness, but in a broader and flattened shape, it creeps over the area of the membrane, which it has to cover, and does not till a much later period affect the rounder forms, presented in the remainder of the gland. This difference may be particularly noticed in the Thymus of the fœtal pig, where the part in question seems quite identified with the pericardium, stretched over its area, and growing with its growth.

There are two varieties I have noticed in this stage, which I here mention, though I do not consider them important, certainly not essential. First, the tube sometimes bulges uniformly in its whole circumference for some extent, forming a very distinct ampulla; and secondly, in parts where there are yet no bulgings, it is sometimes flexuous or even contorted. In the Thymus of mammalia these peculiarities are never more than local, and do not derange the general development of the gland[1].

[1] The former variety appears the usual mode of development in the Thymus of birds and reptiles; and even in the full-grown gland of these animals the ampullary form predominates over the vesicular.

Commencement and progress of ramification in the follicles.

The third distinct step of advancing development is made by the commencement of ramification in the follicles. This process usually begins when the follicle has attained the shape of three-fourths of a sphere, or somewhat later; and occurs without any elongation of the isthmus connecting the follicle with the main canal; so that these secondary and tertiary extensions of the cavity do not possess the tubular structure in so marked a degree, as the axis from which they spring (vid. fig. 7). In some instances I have seen partial exceptions to this mode of growth, as is illustrated in the adjoining diagram (vid. fig. 8), which represents part of the pericardiac portion of the gland in the fœtal lamb. In this particular case the follicles must have formed cæca of considerable length before dividing; but the form is unusual. Almost always the follicle branches without having undergone any previous lengthening, so that the secondary portions of the gland are connected with its primary tube by the shortest possible stem; they are, in fact, sessile. It is not easy, nor perhaps requisite, to fix the exact ratio of frequency in which the varieties of branching occur; the dichotomous and quaternary have presented themselves to me most frequently, and are, I doubt not, the ordinary forms of division. In the former case, two,—in the latter, four new follicles are seen to sprout from the fundus of the old follicle, just as it sprouted from the axis of the tube (vid. fig. 9). By the extension of this process of follicular growth to all portions of the gland successively,—by the repetition on each new crop of follicles of the same acts of development and ramification,—and by the continued molecular increase, which pervades the entire substance uniformly, as the means of interstitial growth, the Thymus attains the bulk and the complexity of structure which distinguish it in the mature fœtus. There is no change whatever in the nature of the phænomena; the later steps are exact iterations of the first: the type of development is established by the earliest bulging of the primary tube—by the first vesicle that buds from its side. That type essentially consists in the *lateral growth of branching diverticula from a central tubular axis.* And as the extremities of these diverticula, like the follicle whence they first sprang, tend always to assume the vesicular shape, and to represent large segments of spheres, the permanent structure of the gland, no less than its mode of development, may be named *tubulo-vesicular.*

Fig. 7.

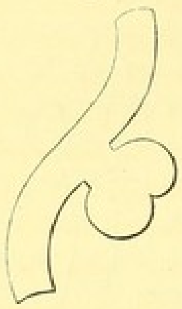


Fig. 8.

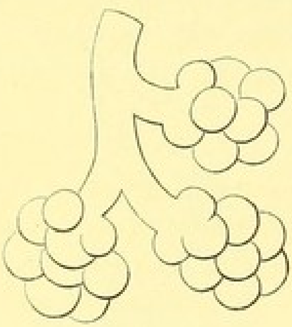
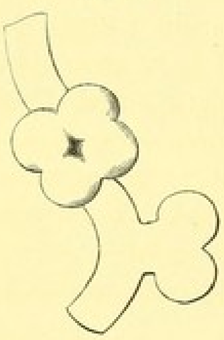


Fig. 9.



In the mature Thymus, the primary tube—although it has increased pari passu with

Comparison with the mature gland.

the growth of the region to which it belongs—is yet so hidden and eclipsed by the disproportionate bulk of its parasitic follicles, that many anatomists have overlooked its existence or real nature. It is true that Haller [1] and Puteus [2], by inflating the gland of each side from an aperture made in its extremity, and Sir Astley Cooper, by his admirable injections, had demonstrated its continuous cavity, with as much completeness as can be attained in these modes of investigation. But to many this evidence appeared inconclusive. The distinctness of the superficial follicles of the gland, and the extreme difficulty of tracing each directly to its stem, had induced various sound anatomists to describe the Thymus as wholly constituted by an aggregation of independent vesicles. This was the opinion of the celebrated Bichat [3]: it has lately been adopted in Germany, and set forth more clearly and more positively than heretofore by Berres [4] and Bischoff [5], who certainly deserve to be accounted among the first of living authorities on such questions: even Henle considers the matter as still undecided and uncertain. I would venture to hope that the foregoing observations may serve, not only to vindicate and confirm, in all important particulars, the justice of the older view, but likewise to explain those peculiar appearances and sources of fallacy, which have led others to adopt a contrary opinion.

Modes of investigating the structure.

It appears to me that there are only two ways by which the true structure of the Thymus can be satisfactorily ascertained; namely, either by the artificial distension of its cavities, or by studying the successive stages of its development in early embryonic life: for the structure is too intricate in the mature gland to be unfolded by mere dissection.

Sir A. Cooper's.

Of the two modes I have mentioned, the first was carried to great perfection by Sir A. Cooper, and formed the foundation of his views. It is recommended by its facility of performance, by its fitness for the purposes of demonstration, and by its great apparent conclusiveness; but it is in reality open to one almost unanswerable practical objection. With the most dexterous and careful management, it is nearly impossible to hit the exact medium between imperfect and excessive injection of so delicate a structure: an error in either way will, of course, disturb the result, and render the preparation deceptive. For even without actually lacerating the walls of the cavities, and extravasating the material used for filling them, there is the constant risk of overdistending

[1] Haller, in Elem. physiolog., vol. viii. p. 364. Compare also A. L. de Hugo in dis. de Glandulis. Goetting. 1746, p. 29. It appears that Haller subsequently changed his opinion, and believed that these inflations had merely distended the interlobular filamentous tissue: for he says in the Auctarium, Fasc. 3. p. 10, "antequam Thymum vulneraveris, nihil vere cavi adest præter intervalla lobulorum; ubi læsisti, aer in cellulosam telam subiens caveam facit, quam natura non præparavit. Quæ vero cavea videtur lobulorum, ea intervallum est."

[2] Puteus in Comment. acad. Bonon. T. ii. p. 148, (1745,) "si per incisuram quam feceris, expresso humore, cannulam immittas atque infles, aer illico ex aliis in alias permeabit vesiculas, et lobulos universos pervadet."

[3] Bichat, in Anat. descriptive, t. v.

[4] Berres, in medizin. Jahrbuch d. oesterreich. Staates, 1840, p. 411.

[5] Th. L. W. Bischoff, in op. cit. pag. 289, where he criticises Sir Astley Cooper's views at some length.

one part at the expense of another. And that this has actually occurred in many of Sir Astley's preparations, as it previously occurred in those of Morand and Duvernoy (vid. supra) can, I think, scarcely be doubted. The cavity, to which he gave the name of *reservoir*, has never presented itself to me in the form exhibited in many of his plates (*e. g.* op. cit. pl. 1. fig. 3; pl. 2. fig. 8; pl. 3. fig. 9. D; pl. 4. figs. 6. 8. 10. 11. 12; pl. 5. figs. 7. 10. 11): and I feel assured, both from those representations and from his original preparations, which I have carefully examined, that the appearance of a large cavity is artificially produced by the means employed for expanding and exhibiting the interior structure of the gland. But, although the exclusive employment of this method induced Sir Astley to over-estimate the proportional size and importance of the "reservoir," as is illustrated in the last figure of his book, the general accuracy of his anatomical conclusions is but slightly affected by this particular exception: and his opinion that *all the parts of each gland depend on a single common cavity* is, beyond doubt, the true description of its anatomy.

Study of early and transitional forms.

The other mode of examination, that, namely, of following under the microscope the gradual development of the gland, presents us with its natural, unprepared, and uninjured form, without any risk of artificial appearances; it has the great advantage of enabling us to begin with a form of extreme simplicity, and thence gradually to trace the successive complication of parts up to the term of maturity. The formation of the simple tube, the growth of follicles from its side, and the subsequent ramification of these, are steps which may be watched with such distinctness, as belongs to our observation of few of the vital processes.

Central cavity?

This mode has, so far as I know, never before been adopted; and hence, probably, has arisen the discrepancy of opinion concerning the interior structure of the Thymus. For while those, who affirmed the existence of a cavity, based their doctrine exclusively on the results of inflation and injection, their opponents were able to refuse confidence to these modes of preparation, as too rough for the purpose, and as actually producing the appearances they professed only to demonstrate.

As is usually the case, the truth lay between the extremes: there certainly is a central cavity; but it is one which bears only a small proportion to the entire mass of glandular structure. It is the above-described primary tube, which, though increased in size, is yet hidden from casual observation by the abundant peripheral off-shoots developed from it; and which, when exhibited by the former modes of preparation, had been seen with a deceptive exaggeration. But not the less there is a common central cavity; and I trust that the preceding observations may suffice, not only to elucidate its origin, nature, and relations, but likewise to explain those peculiarities in the structure of the mature gland, by which the discovery of its cavity is rendered so difficult, that many accomplished anatomists have been induced to discredit its existence.

SECTION II.

Development of Size.

THE interest in the preceding investigation of structural development is almost entirely anatomical; but there is another sense in which the growth of the Thymus may be studied, which is of paramount physiological importance; that, namely, which refers to fixing the epoch of its greatest activity.

That it is essentially an organ of temporary, or occasional activity, is admitted by all, and is indeed unquestionable; but authors are not equally agreed as to the exact time of its usefulness. Early investigations were conducted somewhat superficially in respect of this point: the gland was observed to be always present in the fœtus, and always either absent, or diminutive in the adult; and it was hence argued by an over-hasty induction, that it must have attained its greatest bulk, and have exercised its chief activity during fœtal life—that it must be considered as an embryonic organ, referable, as regards use, to the peculiarities of uterine existence.

Nothing in the history of the Thymus can be esteemed of higher moment, than the verdict to be given on the accuracy of this opinion; for, if it can be shewn that the principal development of the gland is at a period considerably later than birth, it is obvious that we shall no longer have to search, among the peculiarities of fœtal organization and fœtal life, for the conditions of its utility.

Its function must assuredly be most energetic at the time when its size is largest: in it, as in every other organ of the living body, activity of operation and perfection of use must coincide with the maximum development of the operating structure. Is the Thymus largest during embryonic life? Haugsted's careful investigations enable us most positively to reply in the negative to this question. The Thymus can with no more propriety be referred to the needs and uses of fœtal life, than the mammæ of the female can be considered subservient to the period of utero-gestation. Breasts and Thymus—this in the embryo, those in the mother—both alike grow during pregnancy: but in each instance the phenomenon of development is only in anticipation of a later necessity,—only in preparing to discharge a function, which in neither case establishes itself till after birth.

When is the Thymus largest?

It is most fortunate for the physiology of my subject, that this fact admits of being stated as a positive and unquestionable truth; for it at once defines and restricts the scope of the investigation. A glance at the accompanying table will exhibit the secure basis, whereon the conclusion is founded. The facts adduced by Haugsted are abundantly sufficient for the proof; but, in the subjoined analysis, chiefly derived from his work, I have incorporated twenty-four experiments of my own, for the sake of that confirmation, which the concurrent testimony of independent observers gives to a particular result.

Name.	Age.	Total Weight.	Gland.	Name.	Age.	Total Weight.	Gland.
1 *Dog	newly born	3380 gr.	4·75 gr.	33 *Cat	. .	16297 gr.	28·5 gr.
2 „	1½ day	11½ oz.	7 gr.	34 „	4 years	8¼ lbs.	20 gr.
3 „	„	14 oz.	15 gr.	35 „	6 years	6½ lbs.	3 gr.
4 *„	40 hours	3380 gr.	9·75 gr.	36 „	„	6¾ lbs.	2 gr.
5 *„	„	4590 gr.	10 gr.	37 *Rabbit	21 days	2740 gr.	3·5 gr.
6 *„	2½ days	3976 gr.	8·25 gr.	38 *„	37 days	3277 gr.	3·25 gr.
7 „	6 days	1¾ lb.	20 gr.	39 *„	„	3627 gr.	2·4 gr.
8 „	„	2¾ lbs.	30 gr.	40 *Pig	fœtus ⅔	4949 gr.	10 gr.
9 *„	6 days	6812 gr.	12·5 gr.	41 *„	„	4762 gr.	9 gr.
10 *„	8 days	8670 gr.	23·3 gr.	42 *„	„		11·5 gr.
11 „	13 days	2⅛ lbs.	56 gr.	43 *„	1 day	10420 gr.	42 gr.
12 *„	15 days	17830 gr.	71·5 gr.	44 *„	„	9408 gr.	62·3 gr.
13 „	23 days	5 lbs.	130 gr.	45 *„	„	8601 gr.	56·5 gr.
14 *„	39 days	31907 gr.	75·75 gr.	46 Lamb	fœtus	1 oz.	½ gr.
15 „	2 months	6½ lbs.	150 gr.	47 „	„	8 oz.	12 gr.
16 *„				48 „	„	12 oz.	24 gr.
17 „	3½ months	8¾ lbs.	360 gr.	49 Calf	fœtus	1¾ oz.	3 gr.
18 „	5 months	13 lbs.	390 gr.	50 „	„	12 oz.	5 gr.
19 „	6 months	19 lbs.	240 gr.	51 „	„	8¾ lbs.	540 gr.
20 „	1 year	21 lbs.	245 gr.	52 *„	3 days	. .	559 gr.
21 „	1¼ year	36 lbs.	780 gr.	53 „	1 month	. .	2460 gr.
22 „	3 years	37½ lbs.	150 gr.	54 „	2 months	. .	4320 gr.
23 „	4 years	16½ lbs.	46 gr.	55 Human	fœtus 7 months	3⅛ lbs.	33 gr.
24 Cat	fœtus	2 oz.	3 gr.	56 „	fœtus 8 months	2¾ lbs.	40 gr.
25 „	newly born	3½ oz.	6½ gr.	57 „	newly born, large	9 lbs.	240 gr.
26 *„	2 days	1900 gr.	5·3 gr.	58 „	newly born, small and thin	5 lbs.	84 gr.
27 *„	„	„	7·2 gr.	59 „	4 weeks	6 lbs.	120 gr.
28 *„	„	1697 gr.	5·3 gr.	60 „	9 months	11½ lbs.	270 gr.
29 „	4 days	5½ oz.	8 gr.	61 „	10 years, scrofulous	. .	110 gr.
30 *„	18 days	3072 gr.	9·5 gr.	62 „	10 years, scrofulous female	. .	30 gr.
31 „	19 days	13½ oz.	30 gr.	63 „	17 years, male	. .	90 gr.
32 „	37 days	23½ oz.	44 gr.	64 „	21 years, male	. .	40 gr.

Note.—The experiments marked * are the author's; the others are Haugsted's.

The experiments here analysed, were performed on different animals, and under various circumstances; but all, which concern this particular point, strictly agree in their testimony to the increase of the Thymus after birth. Thus, while the weight of a dog's Thymus at birth may range up to *ten* grains, we find it subsequently increasing with such rapid paces, that after five months it weighs nearly *four hundred*. Thus, too, in the cat; at birth, it may weigh some *six or seven* grains; but has increased, within six weeks, to upwards of *forty:* and a similar progression is observed, I believe without exception, in other brutes, and in the human subject.

Circumstances modifying its size.

It is easy to demonstrate the general fact of the increase of the Thymus after birth, but exceedingly difficult to fix *precisely* the period at which it reaches its maximum growth and begins to decline. The nature of the difficulty will be apparent from the following consideration of varieties, which depend on merely individual causes.

First, There is probably a great range of original differences; for example, our table shews us the Thymus of a dog, one year old, weighing 245 grains, while that of another dog, three months older, weighs 780 grains. It would assuredly be a mistake, if we should hence argue that, in the fifth quarter after birth, the Thymus triples its bulk. We must, in such cases, necessarily ascribe the extreme difference to individual peculiarity, or to some other circumstance that escapes numerical registration.

Secondly, For reasons, which will hereafter appear, I think it extremely probable that the Thymus may, within a few days, if not hours, vary remarkably in the same individual, according to the immediate state of the general nutrition. Its size seems to be, cæteris paribus, if I may venture to use the phrase, a barometer of nutrition, and a very delicate one; for, supposing we should state exactly the average weight of *ordinary* bodies at birth, with that of their Thymuses, and fix the proportion between these averages to be, say, twenty-two grains of Thymus to each pound of bodily weight, we should find in all *extraordinary* bodies that the proportion would be destroyed. In the very large bodies, the Thymus would be not only *very* large but *disproportionately* large; bearing a ratio, perhaps, of twenty-seven, or thirty grains (vid. experiment No. 57) to each pound of the entire weight: while similarly, in the very small bodies, the Thymus will be not only *very* small but *disproportionately* small, as in experiment No. 58, where its ratio to the entire weight was only seventeen grains per pound.[1]

Thirdly, Its proportion to the entire mass will decline according to the development and exercise of the muscular system in the individual; in other words, according to the use and waste of the animal tissues, even although that waste be adequately restored by fitting nourishment. For instance, so long ago as the time of Wharton, it had been noticed that, if a young ox were put to the plough, the disappearance of its Thymus was much accelerated; so that, instead of continuing of large size for the first five years of life, it would vanish within the first year.

Fourthly, Besides these variations, which are within the limits of health, there are others apparently associated with particular morbid states, which I shall hereafter notice.

The sources of fallacy enumerated would render it impossible, except by very copious data, to fix precisely the average epoch of its greatest development, even for any single species of the animal kingdom: and it is certain that this time varies exceedingly for different genera, and even species, according to differences in their mode of life.

Cæteris paribus, the gland belongs to the *period of growth;* and particularly to

[1] If I may be allowed to illustrate my meaning by the algebraic symbols, the following formula will exactly express it: let $\frac{b}{t}$ be the ordinary ratio; in cases of extremely bulky infants, this would become $\frac{b}{t} \times \frac{1}{1+v}$; in cases of extremely feeble and small children it would be $\frac{b}{t} \times \frac{1}{1-v}$.

Laws of its duration, growth and wasting.

the commencement of extra-uterine life—to infancy. It is true that these words "infancy"—"period of growth"—have no numerical definiteness; but they are on that account a better physiological standard. The great æras of life cannot be expressed in terms of strict measurement: we cannot, without great inaccuracy, say of infancy, or of childhood, or of puberty, or of manhood, that its duration is of so many years, or months, or weeks. Of any given large number of children born on the same day, how few, after the lapse of fifteen years, would be found in exactly the same state of development! Some, favoured by climate (which is scarcely less potent in maturing the animal, than the vegetable, frame) or by inherited vigor of constitution, or by judicious training, would have reached adult life—would be fathers and mothers: some would have been stunted into deformity, feebleness, and disease, by neglect, inanition, severity of climate, or untimely toil; others would fill the long interval between these extremes of arrested and precocious development, with numberless stages of growth, and numberless degrees of healthfulness—stages and degrees determined, for each individual case, by factors that are known to us in kind, but not measureable in amount,—such as are original power of constitution, climate, atmosphere, physical training, diet, habits, and accidental diseases. These various influences do not admit of being weighed in the balance, nor can the vital maturity which they develope, be measured by the vibrations of the pendulum. And if, in assigning the highest development of the Thymus to the *age of early growth*, I use an expression that is chargeable with some vagueness, I would observe that, on that very account, it is better adapted to our purpose.

Growth notoriously has its origin in disparity between waste and nourishment; more is added to the body than passes from it, and bulk increases. In infancy waste is at its minimum, and growth, in normal nutrition, at its maximum: there is a familiar exaggeration of this fact in a popular saying, that infants "grow visibly." It is to the period marked by this inequality between supply and expenditure (in a word, to the period of growth)—and eminently to those earliest years in which the disproportion is most intense,—that the Thymus gland belongs, as an organ subsidiary to the predominant function of the period.

It is no more possible to fix by a general rule for all individuals the exact duration of its existence, or the date of its chief development, than it is practicable to express in numerical terms the precise extent of that period of growth, to which its usefulness applies. The first months of life are passed in a condition analogous, in many respects, to the annual torpor of partially hybernating animals: sleep occupies the majority of hours; the brief intervals of waking are spent in the consumption of food; muscular activity, with its consequent waste of tissue, is inappreciably small, and the means of preserving an independent temperature are feeble in the extreme. In proportion as the characteristics of infancy are effaced,—in proportion as the hours of sleep become fewer, the intervals of waking longer and more active, the muscular functions more energetic, the waste-materials for respiration more abundant, and the means of maintaining individual warmth therewith

Laws of its duration, growth and wasting.

more secure,—even so, pari passu, the time has elapsed in which the Thymus fulfilled its main service. Not only is this inverse ratio, between its development and the vital motility, to be found in individuals of the same species, but it is yet more distinctly the rule (as observations presently to be specified enable me confidently to affirm) for the animal kingdom, viewed comparatively. For, as the extremes of the scale are marked by reptiles and birds respectively,—the former distinguished by the *lowest*, the latter by the *highest activity* of respiration and muscular movement,—so do we find in the former the longest persistence of the Thymus, in the latter its quickest vanishing. But the changes in the individual life, and no less the grades of functional activity throughout the animal kingdom, are blended into each other by insensible transitions, which cannot be set forth in numerical notation. The correctest expression for the duration of the Thymus is, therefore, in my judgment, *not that which measures it by years, but by the state of contemporary functions, and in terms denoting their excess or deficiency.*

The human Thymus: after birth.

The general and rough results of the examinations of the human subject seem to be the following:

First, During the period next succeeding birth, the activity of the Thymus is remarkable; it increases considerably in size, becomes turgid with secretion, and its specific gravity is lowered by the greater fluidity of its contents. This first growth is far out of ratio to the general increase of the body, but gradually subsides into a stage of less activity, which merely suffices to maintain the proportion so acquired.

Secondly, During several months it continues to increase at a diminished rate, and merely in proportion to the general growth of the body; its further enlargement ceases about two years after birth.

Thirdly, From this time, during a very variable number of years, it remains stationary; and, supposing the individual to be adequately nourished, gradually assumes the structure of fat. This stage, in which the bulk remains unaltered, but the texture changes so curiously, extends perhaps in the largest number of healthy individuals to the 8th, 9th, 10th, 11th or even 12th year of life; but it cannot be restricted even to these loose limits, for some years later the gland will often appear to have undergone no diminution in size. The intimate nature of its interesting structural change will be explained in connexion with the general morphology of the gland.

Fourthly, The duration of its decay, and the epoch of its entire vanishing, are still more uncertain. About puberty it seems, in most cases, to suffer its chief loss of substance, and to be reduced to a vestigiary form; but still for many years its flat and emaciated lobes may often be dissected from the pericardium, and shewn as a connected body. Distinct remnants of the gland may generally be exhibited in subjects of from twenty to twenty-five years of age; but beyond the latter time it is unusual to distinguish any positive traces of its existence amid the areolar tissue of the mediastinum. There are exceptions to this rule. I have sometimes discerned faint remnants of its form in subjects up to thirty years old; and Meckel[1] and Haugsted[2] quote

[1] Meckel's Abhandlungen, p. 234 et seq.

[2] Haugsted, op. cit. p. 188 et seq.

various instances of its alleged persistence to a much later period[1]. In several of these last-mentioned cases the gland was evidently the seat of the disease; and in others its abnormal continuance seemed associated with other morbid affections, chiefly of the respiratory organs; such irregularities need not interfere with our calculation of the usual date of its disappearance.

Before birth.

I conclude the present section with a few observations on the first appearance of the Thymus in the human subject particularly, and on its growth during uterine life.

Embryologists, apparently contented with inspecting the parts by unassisted vision, have fixed its earliest appearance in the ninth or tenth week of pregnancy, when, indeed, it is first very manifest to the naked eye. But its origin must be far anterior to this period, and, I have little doubt, may be referred to the beginning of the second month. During the continuation of this part of my researches I have not been able to obtain, in its fresh condition, a single human abortion younger than two months, and am unwilling to found any positive statement on the inspection of such as have been preserved in alcohol. But the general impression derived from a comparison of these last with the numerous embryos of quadrupeds, which I have dissected in all their stages of growth, leads me to the conviction I have stated; for, assuming a parallel scale of development for the organs of man and other mammalia, the primary tube of the Thymus ought to be found in the human embryo of the fifth week. I believe that I have detected traces of it even within this period; but only in cases where the subject had been so altered by alcohol, that I could not implicitly rely on the observation. I trust to have opportunities hereafter for obtaining additional information on this uncertain point.

At the time when the gland first becomes distinctly visible to the naked eye, in about the ninth week it consists of two minute elongated parallel parts, lying chiefly on the upper part of the pericardium, and presenting, under the microscope, a distinct tubulo-vesicular structure. Its growth from this date forward is not strictly uniform, but becomes accelerated towards the termination of pregnancy, especially in the last month. This later increase of bulk is attended by a reduction of its specific gravity, (vid. Haugsted, in lib. cit. p. 43,) from the greater proportion of fluid contained in its cells; so that, while at seven months it is about 1·1 specific gravity (water being 1·0), at maturity it is found to have fallen to 1·071, and a fortnight after birth to 1·02. In structural development it follows exactly the same steps as I have traced in the embryos of quadrupeds.

[1] Krause (Müller's Archiv. 1837, p. 6) gives the following five instances of high measurement, but without particularizing the circumstances under which they occurred; except in the case of the child who, he states, died suddenly with laryngismus stridulus.

Subject.	Age.	Weight in Grains.	Volume in Cubic Inches.	Specific Gravity.
Male.	25	292·5	0·977	1·0352
Male.	25	380·3	1·156	1·0311
Male.	20	356·5	1·083	1·0309
Female.	28	69·2	0·211	1·0267
Child.	14 weeks.	440·	1·272	1·0591

CHAPTER III.

MATURE STRUCTURE OF THE GLAND AND NATURE OF ITS SECRETION.

The mature structure of the Thymus presents for our consideration the following particulars:—First, The arrangement of its cavity; Secondly, The texture of the walls of that cavity; Thirdly, The nature of its contents; Fourthly, its means of vascular and nervous organization.

The full account, already given, of the development of the Thymus, anticipates the present chapter in much that relates to the first two points mentioned; for the arrangement of the cavity of the gland is but a further complication of the tubulo-vesicular form of its early growth; and the wall of the cavity is but that same homogeneous membrane, which bounded it from the first period of its distinct existence.

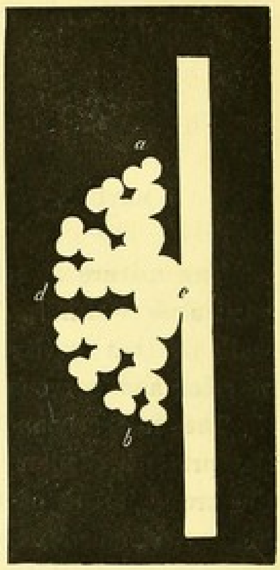
Arrangement of the cavity of the Thymus.

I. In closely examining the surface of the Thymus, after the removal of all vessels and areolar tissue, we observe that it is divided into a vast number of apparently distinct portions, measuring in diameter from half a line to almost two lines. These minute parts are recognised, even by the naked eye, as membranous cavities: at their circumferences, they are somewhat flattened by mutual pressure, so as to present a polygonal outline; their centres project slightly on the general surface of the lobe. On removing a thin slice of the glandular substance, and compressing it between two pieces of glass with great care and delicacy of manipulation, this arrangement may be perfectly seen: the compressed surface will seem to consist of a multitude of polygonal cells of the dimensions above mentioned; and the edge of the preparation will appear festooned by a number of spheroid bulgings, as a profile of the same cellular structure.

These membranous cavities are the terminal vesicles of the gland. Some observers, as I mentioned in the last chapter, have supposed them to be separate closed cells; the inaccuracy of this view has been shewn in the history of the development of the gland, and may now be additionally proved in the mature organ, by the utter impossibility of obtaining a *separate cell with a perfect circular outline.* Any attempt to dissect the vesicles shews them to be free and unconnected only in about three-fourths of their periphery; the remaining part (that which lies deepest) is found to be attached. It is by this portion, that each is grafted on to the general trunk of the glandular substance, and opens into some diverticulum of its common cavity.

On further dissection we find it possible, without disturbing any natural union of parts, to resolve the structure of the gland into masses ranged round an axis. Each mass constitutes a sort of cone of glandular substance;—its apex pointing to the axis, or mesial line, of the gland; its base directed to the surface, where it presents its innumerable vesicles; while its intermediate part contains those successive branchings of the follicle, which terminate superficially in the vesicular form.

Fig. 10.



The very large size of the base (fig. 10, *a* . . *b*) of this glandular cone, in proportion to its length or axis (*c* . . *d*) depends on the fact which I mentioned in describing its development; namely, the peculiar shortness of each primary or secondary follicle at the time of its division. The lateral parts of the gland contain no appreciable tubular structure: and it is this peculiarity which makes it impossible to complete one's knowledge of the construction of the Thymus by the exclusive study of its mature state. For the remaining anatomy of the cavity I must accordingly refer the reader to my previous description of its growth. (Vide chapter II., sect. 1.)

Texture of the walls of the cavity.

Limitary membrane.

II. The texture of the walls of the cavity of the mature Thymus may likewise be inferred from a knowledge of its development. If a minute portion of the gland be prepared in the manner above described, so as to shew the outline of its vesicles, and be examined with a magnifying power of 300—400 diameters, it will be seen that the proper substance of the wall is a material of the most exquisite delicacy. It is indeed recognised rather as a very definite boundary line, than as a membrane admitting of isolation, and is of a tenuity that renders accurate measurement with the micrometer almost impossible. It certainly cannot exceed $\frac{1}{15,000}$ of an inch in diameter, but still is of unquestionable reality as a continuous tissue. It is identical with the membrane, which, in the earliest stage of development, we saw forming the primary tube of the gland, and protruding itself to constitute the first follicles. In the continued progress of growth, it has branched and elongated itself more and more, and may now be traced throughout every portion of the organ, limiting and uniting the various divisions of its substance. It is transparent and quite homogeneous, with the exception of still presenting, here and there, those slight thickenings of its substance, which I have previously mentioned as probable reliques of the cells of its first development. While this delicate tissue forms and limits the cavities of the gland, a close capillary network, furnishing the materials for secretion, lies in intimate contact with its outer surface, and is adapted to its various irregular inflexions.

Areolar tissue.

This exquisitely attenuated, but tough and elastic, membrane is the only proper wall of the glandular cavities. It is strengthened on its exterior surface by an expansion of areolar tissue, which penetrates into every interval, and invests every part of the organ. This is of extreme fineness where it clothes the vesicles, and can only be adequately examined by the aid of the microscope. Intermixed with it may be seen a small proportion of elastic tissue, in the form of very delicate straight fibrillæ crossing the surface of the vesicles in various directions, so as to form a network with wide meshes. It is probably these fibrillæ that Dr. Pappenheim has mistaken for organic nervous fibres.

Elastic tissue.

Contents, or secretion of the Thymus.

III. The contents of the cavities of the Thymus consist of a fluid, in which (as Hewson discovered) an immense multitude of microscopical corpuscles float. Two modes of examination are here necessary,—the microscopical and the chemical.

Dotted corpuscles.

1. Examined with a sufficient magnifying power, (400 — 600 diameters,) the corpuscles of the Thymus are found to be circular discs of nearly the same size as the coloured particles of the blood. The average of several measurements gave me $\frac{1}{3830}$ of an inch for their diameter; but there is considerable variation in different subjects, and in different corpuscles of the same subject; $\frac{1}{2555}$ and $\frac{1}{5750}$ of an inch are the extreme sizes I have measured. The corpuscles are generally flat and circular, but a large number may be found in every examination deviating more or less from the discoid shape, and tending to become globular, or to assume irregular outlines. They have certain characteristic markings of their substance in the form of a variable number of minute dottings. These may present themselves as exceedingly small dark spots, to the number of two, three, four, or even five; or there may be only a single one, which is then found proportionally large, and attracts notice by its high power of refraction. The dottings are supposed to be the minutest molecules of fat in combination with the solid albumen, or fibrin, which constitutes the bulk of the corpuscle; and certainly this composition would account for the effect, which, when aggregated into a single globule or nucleolus, they produce on transmitted light.

Nucleated cells.

In specimens taken from animals past that period of life when the Thymus is most active, I have found cells, in which these dotted corpuscles occupied the relation of nuclei. The cells are at first little larger than the corpuscles themselves, and contain a perfectly pellucid material; but, as they grow, their contents become molecular, and they develop themselves into perfect fat-cells, which lie in the cavities of the gland, and in some instances completely fill them. During the period in which these cells are being developed, the application of acetic acid to the preparation, as it lies under the microscope, shews them to have great affinity to embryonic cells; for the acid dissolves the cell-membrane completely away, and leaves the nucleus of the cell (the dotted corpuscle) unaffected by its action.

To the real nature and signification of this peculiar process of development I shall return, in examining the morphology of the gland.

Chemical analysis.

2. When we consider how intimately the use of the Thymus must depend on the nature of the fluid which fills its cavities, we must allow that no part of the present investigation has more importance than that, which relates to the chemical composition and properties of this material.

I have not sufficient practice in chemical experiments to encounter the great difficulties of organic analysis, and am therefore indebted to others for my data in this respect. I have had various specimens of the gland submitted to chemical examination, for both its ultimate and proximate composition, and subjoin the results of an analysis, which I believe to be accurate and trustworthy; with it I likewise append Sir Astley Cooper's analysis, and Morin's, as furnished by Berzelius. (Thierchemie, p. 393.)

These investigations have been made on portions of the glandular mass, for it is not possible to obtain the secretion of the Thymus quite apart from the secretory structure. In the case of the glands without ducts, this difficulty appears of little consequence; I believe that in carefully analysing their entire substance, we may approximate very closely to the nature of their secretion, as I shall have occasion to shew in a later portion of my essay.

Sir A. Cooper's Analysis.	Morin's Analysis.		Analysis of Thymus of Calf about three Months old.	
100 parts contain 16 of solid matter.	Water	70	Water	77·20
Incipient fibrin.	Fibrin and phosphates	8	Fibrin, gelatinous tissue, and traces of fat	12·72
Albumen.	Albumen	14	A substance between Albumen and Casein	4·13
Mucus and muco-extractive matter.	Gluten	6	Watery extract	3·80
Salts, chiefly muriate and phosphate of Potash and phosphate of Soda.	Animal matter	·3	Salts, principally phosphates of Soda and Lime	2·15
	Extractive matter	1·6		
		100·0		100·00

Inferences from chemical analysis.

The results of these examinations agree with each other, and with those of ultimate analysis in a particular of extreme importance; they conclusively demonstrate, that no theory for the use of the Thymus can be just, which involves the supposition of its secreting and containing highly carbonated matters, through the period of uterine life. Tiedemann, Arnold and other almost equally great authorities have argued, that the activity of the Thymus is in inverse proportion to that of the lung, and that, during the quiescence of this organ, it effects for the embryo a kind of vicarious respiration by separating a carbonaceous product from the blood. Chemical analysis suffices to display the instability of this hypothesis; it shews that the Thymus, in the period of its highest activity, instead of being surcharged with carbon, in reality contains no more of that element, than may be found in blood or muscle.[1]

[1] As may be seen in comparing the subjoined ultimate analyses of the organic portions of blood, muscle, and thymus, viz.—

	Flesh.	Blood.	Thymus.
Carbon	54·12	54·20	54·02
Hydrogen	7·89	7·65	8·12
Nitrogen	15·67	15·73	13·42
Oxygen	22·32	22·12	24·44

At a later period of life—in becoming comparatively idle—and especially in undergoing that remarkable structural change which attends its persistence in hybernating animals,—it is true that the Thymus presents a difference of chemical constitution. As it assumes the structure, so likewise it acquires the elementary composition of fat, and becomes fraught with hydrogen and carbon. But this change in its chemical characters is, for other than chemical reasons, quite incompatible with the theory, to which I have referred; for,—however much, under these new circumstances, its composition might justify the belief in question,—there is the insuperable difficulty of anachronism in the argument: the gland only secretes *exspirabilia* at a time when there can no longer be any possible need for vicarious respiration.

The analyses have a further application, to which I shall hereafter return. The various terms,—"fibrin," "gelatinous tissue," "albumen," "casein," "gluten,"—all admit of being translated out of the technical language of chemistry into a single common expression. All these organic substances admit of reduction to nearly identical ultimate elements, are but slight variations from one common formula, and stand severally in the closest affinity to the universal nutrient material—the liquor sanguinis. The actual and ultimate nature of the secretion of the Thymus is therefore expressed, as nearly as may be, by the formula of Protein; in other words, it is identical with the common material of organic nourishment. And perhaps the greatest positive service, which Chemistry can render to the present investigation, is thus to shew us that we may securely dispense with the special phrases of the laboratory, and may venture, in general physiological language, to describe the *secretion of the Thymus gland in the young animal as* NUTRIENT MATTER.

IV. I have next to examine the means of vascular and nervous organization, presented in the human Thymus.

1. As regards the arteries and veins, their general course is so well known to all practical anatomists, that no circumstantial account of them is necessary. The former come from various sources; most usually from the internal mammary and inferior thyroid,—sometimes from the trunk of the subclavian, or from the vertebral, or carotid artery,—occasionally even from the arch of the aorta. Of the veins, some accompany the arteries, and terminate (according to the uncertain origin of these) in the mammary, or inferior thyroid, or jugular; while others, coursing in the median line, discharge their blood into the left brachio-cephalic vein, as it crosses the trachea. That which is really important in the vascular anatomy of the gland, is not the course of these larger and most irregular vessels, but the nature of their capillary terminations. These I have frequently injected; and so abundant is their distribution, that in case of successful injection, the whole organ is deeply coloured with the material employed. A specimen of this kind, examined under the microscope, shews the injected capillary network to be of the completest description. It is so arranged as to include each individual vesicle

Thymic arteries and veins.

Capillaries.

within a vascular capsule: the capillaries are closely applied upon the transparent texture (*limitary membrane*), which bounds the cavities, and so exceedingly dense is their network, that the meshes are of even less diameter than the vessels themselves. Every portion of the glandular substance is thus exposed in the completest manner, and at every point of its surface, to the penetration of the fluid ingredients of the blood.

Lymphatics.

2. Of the real arrangement of the lymphatics I am unable at present to offer any satisfactory account. Authors describe an absorbent trunk which terminates in the upper part of the thoracic duct, after traversing some of the absorbent glands of the mediastinum, and (according to Mascagni)[1], communicating with the pulmonary and internal mammary absorbents. I believe I have sometimes seen a small branch on the right side passing to join the lymphatic trunk of that side of the neck just before its termination in the subclavian vein.

In one instance I have seen a capillary lymphatic, reduced to a single tunic, amid the vesicles of the Thymus; but I was unable to trace it to its termination.

I think, from the result of my researches in the limitary membrane of the Thymus, and from the evidence therein afforded of the perfect closure of its cavities, I may be warranted in arguing, that the lymphatics do not fulfil the office of carrying off the secretion in the manner of excretory ducts; that here, as elsewhere, they serve only to appropriate and convey, in their own mysterious manner, certain interstitial superfluities of the nutritive process. It is a physical impossibility, that the corpuscles of the Thymus could, as Hewson suspected, enter the lymphatics in their solid form; this could not be effected otherwise than by a dissolution of the limitary membrane of the gland.

Nerves.

3. The nervous supply of the gland is mainly derived from the plexus, which surrounds the first part of the subclavian artery, and which has its chief origin from the *inferior and middle cervical ganglia*. A small twig detaches itself from this sympathetic plexus just opposite the origin of the internal mammary artery, accompanies that vessel in its course, and, on arriving at the point where the thymic branch arises, sends filaments along it into the substance of the gland.

A second source of supply is the cardiac branch of the *pneumogastric*, which gives, on each side, a minute filament to the superior part of the gland. I have seen the appearance of a large branch taking this course on the right side, but found, on careful examination, that it merely passed through the upper portion of the Thymus to the cardiac plexus, giving off the usual small filament in its course.

In one instance, I have seen a very minute fibril of the *descendens noni* emerge from the substance of the sterno-thyroid muscle, and reach the cellular investment of the

[1] Thymica ex Thymo procedunt, ac diversis truncis in glandulas se immittunt, in quibus partim cum mammariis communicant, partim cum iis qui ex pulmone proveniunt consociantur.—Mascagni vas. lymph. historia, p. 56.

Thymus; and I have sometimes seen delicate twigs of the *phrenic* also detached towards the gland; but in each case the nerve has appeared to restrict its distribution to the surface and coverings of the organ, and has not accompanied any of its vessels.

Pappenheim[1] has investigated the distribution of nerves in the interior of the Thymus, and professes to have distinguished there both sympathetic and cerebro-spinal fibrils. The latter he describes as particularly following the distribution of the arteries,—the former as presenting very fine ramifications and plexuses amid the glandular substance. All that I have been able to see of this arrangement is the distribution of filaments along the arteries; I have found one or two ultimate tubules of nerve running, as Pappenheim mentions, along small arterial branches, and apparently becoming lost in their coats. The distribution of the sympathetic fibrils in "very fine ramifications and plexuses" has never presented itself to me; I cannot but suspect that Dr. Pappenheim must have been misled by the fibres of elastic tissue which I have described as crossing the surface of the vesicles, and that he must have taken them for fibrils of the sympathetic.

[1] Neue Zeitschrift für Geburtshülfe von Busch, d'Outrepont u. Ritgen; in loc. cit.

CHAPTER IV.

COMPARATIVE ANATOMY OF THE THYMUS.

I HAVE devoted great labour to the following important section of my subject; and having been so fortunate as to obtain the means of dissecting many rare animals, I am able to state some particulars, which I trust may prove an interesting addition to the records of earlier observation.

The general result of my dissections may be stated as the discovery, that *the Thymus gland belongs, without exception, to all animals breathing by lungs, and to no others;* a proposition which it is my object in the ensuing pages to illustrate in detail.

MAMMALIA.

MAMMALIA.

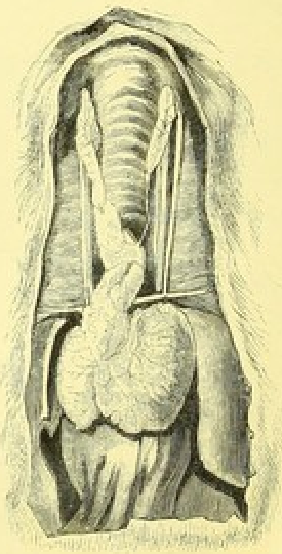
1. *Quadrumana.*

In the more anthropoid Apes, the Thymus has nearly the same general shape and relations as in the human subject. Tyson[1] described

Simia Satyrus.

it in the *simia satyrus* as "about an inch long and placed as 'tis in man; downwards 'twas divided, but upwards 'twas joyned together:" Vicq d'Azyr[2] also mentions it in his description of the anatomy of this animal. I have noticed in examining a young individual of this species, that the cervical prolongations are scarcely more developed than in the human gland; and have likewise been able to satisfy myself by the dissection of a full-grown oran-otan, that it has no peculiar persistence beyond the usual period.

Fig. 11.



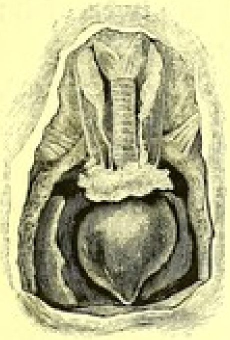
Macacus.

In the fœtal *macacus* (see fig. 11), I found a very different arrangement; the Thymus was sufficiently large, in its pericardiac portion, to cover the upper half of the heart; it extended upwards, without dividing, to about the middle of the trachea, and then branched into lateral continuations, which expanded at the side of the larynx.

[1] Tyson, Anatomy of a Pigmy, 1751, page 47.

[2] Encyclop. Méthodique; Anat. des Animaux; art. "Pithecus."

Fig. 12.



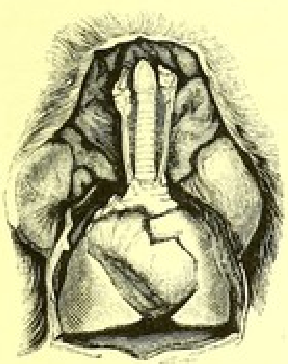
In a young *lemur*, (see fig. 12,) I found the thoracic part of the gland less developed, and covering only the base of the heart; a slender prolongation reached upwards on each side of the trachea, and expanded in the vicinity of the larynx. Kuhl[1] described it in the *galago* without mentioning its extension into the neck.

MAMMALIA. Lemur.

Galago.

2. *Cheiroptera.*

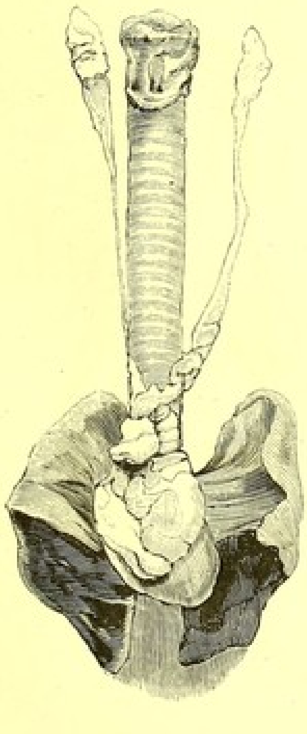
Fig. 13.



Meckel[2] expresses a belief that the Thymus is persistent through life in the genus *Vespertilio;* and my dissections certainly tend to confirm his view. I have dissected the adult animal in several species, including three or four specimens of the large *pteropus edulis*, and rarely have failed to find the gland of considerable size. The representation I have given, is from the adult of a small species; (fig. 13;) it shews the arrangement to be similar to that described in the lemur; the thoracic portion embracing the base of the heart, and the cornua ascending, parallel to each other, on either side of the windpipe.[3]

Vespertilio.

Fig. 14.



The Thymus of the *galeopithecus* I do not find previously described: I have dissected it in four specimens; namely, in two adults, in a young individual, and in a fœtus. I found it larger in the young one than in the fœtus, and very much developed in the adults, so as quite to maintain its earlier proportion to the bulk of the animal. In the annexed representation of an adult specimen, (fig. 14,) it will be seen that the thoracic part has a greater proportional development than in the vespertilionidæ; that it covers the upper half, or two thirds of the pericardium, and extends some distance along the trachea before dividing.

Galeopithecus.

3. *Insectivora.*

In this family I have not observed the great development of the Thymus, which some authors describe, nor have I

[1] Kuhl, Beiträge zur Zoologie und vergl. Anat. Frank. 1820, p. 35.

[2] Abhandlungen, p. 198.

[3] It will be seen that the cornua are very slender at their commencement, and, as in most instances, expand beside the larynx. I think it probable that Haugsted, in his dissection of the *vespertilio auritus*, lost the line of union, as he appears (see his fifteenth figure) to have overlooked the cervical part of the gland.

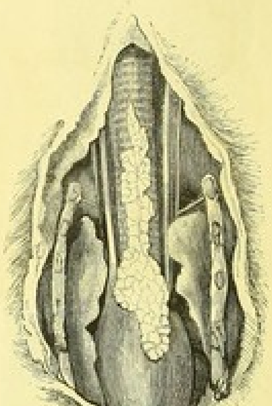
MAMMALIA. Erinaceus. Talpa. Tupaia. Sorex.

found reason for believing its continuance through life, as stated by Meckel. In the adult hedgehog (*erinaceus europæus*), I have frequently failed to find any trace of it; as also in the full-grown mole (*talpa europæa*), and in the *tupaia javanica*.

I have certainly seen it in full-grown specimens of the common shrew (*sorex araneus*), and may here mention, that these animals also possess in some degree the accumulation of axillary fat observed in hybernating rodentia; but, in the tropical species (*sorex myosurus*), I have found no signs of the gland being persistent.

S. Myosurus.

Fig. 15.



The form of Thymus common to this family is that of two nearly equal lobes lying on the base of the heart, and origin of the large vessels, with greater vertical than transverse dimensions.

4. *Carnivora.*

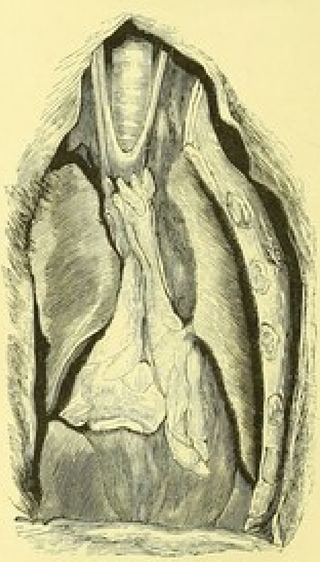
Nasua. Ursus Meles.

Among the *Plantigrada;* I have dissected it in the coati (*viverra nasua*, fig. 15,) and in the badger (*ursus meles*), and find its arrangement to be such as I shall presently describe.

Mustela Putorius. M. Erminea. M. Lutra. Canis Familiaris.

Among the *Digitigrada;* I have examined it in the polecat (*mustela putorius*), and have found it to be deficient in an adult specimen of the ermine (*mustela erminea*); I have not found it to present in the otter (*mustela lutra*, fig. 16) that high development which, according to Tiedemann's theory, it should possess in all animals of aquatic life;[1] I have frequently dissected it, and have traced all the stages of its growth and decline in the common dog (*canis familiaris*).

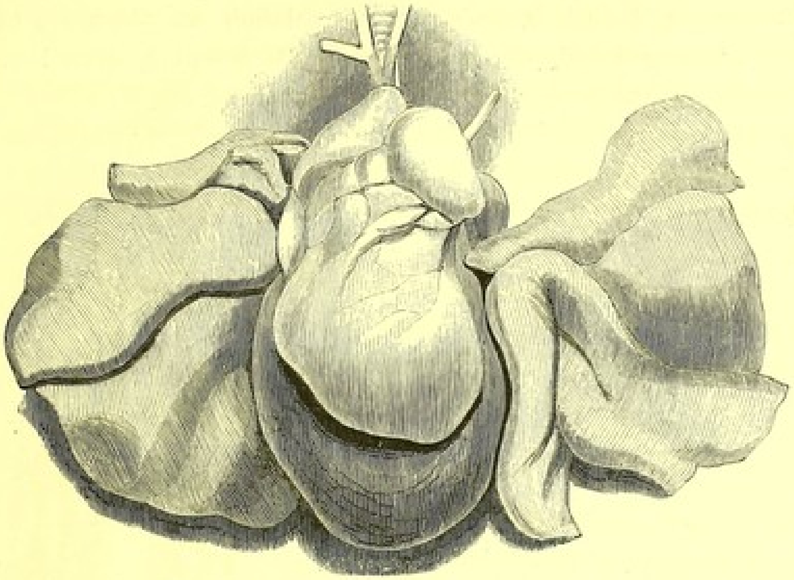
Fig. 16.



The following description will apply equally to all these animals; the gland is entirely thoracic, not extending to the neck, but corresponding to the upper part of the pericardium, and to the origin of the vessels; when mature, it has considerable thickness and substance from before backwards, and its right and left lobes irregularly overlap each other, so as to render the separation between them indistinct (fig. 17). It will be remembered that in all the animals of this family, the thorax is very deep and the mediastinum proportionally long; as the Thymus remains stationary, or diminishes in size during the period that

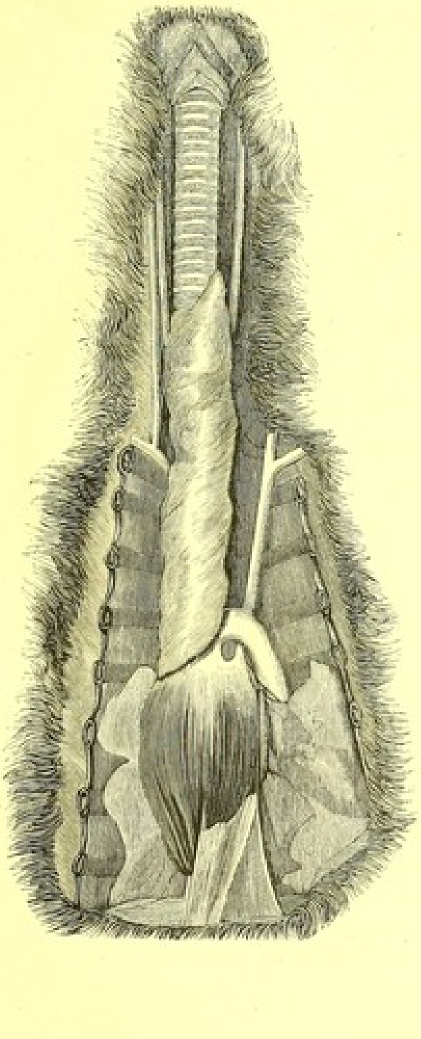
[1] See Tiedemann's paper on the dissection of a marmot in Meckel's Archiven, Bd. i. pag. 490. The gland is mentioned by Sir E. Home (in his "description of the anatomy of the sea-otter," in Phil. Trans. 1796, p. 385) as occurring in the fœtus of the *lutra marina*, but not in the adult animal. Other authors have likewise failed to find it in the adult; and I should think it probable that Tiedemann's specimen, which weighed seven pounds, was a young though full-grown animal. The gland was well described in the same species by Steller in Nov. comment. acad. Petropolitanæ, 1751, p. 380); he found it (though diminished in size) in full-

Fig. 17.



this peculiar character of the chest is becoming developed with the age of the animal, it may be anticipated that its own shape will undergo some alteration. And such is found to be the case: the gland, as it declines in actual bulk, becomes considerably elongated with the growth of the parts to which it adheres, and assumes the form of a triangle with its apex much prolonged upwards; in the same process of attenuation, the division between its lobes becomes perfectly manifest. MAMMALIA.

Fig. 18.



In the genus *Felis*, which may be considered the type of the carnivorous family, the Thymus appears to vanish at a very early period. In two young lions (*felis leo*) 8½ and 9 months old, Meckel failed to discover any remnant of it; in a leopard (*felis leopardus*) 10½ inches long, I have also been unable to convince myself of its existence;[1] but Wolfstrigel, who, like Meckel, failed to observe it in the lion, describes it in a young tiger, as reaching to the pericardium.[2] In the domesticated specimens of the common species (*felis catus*, fig. 18), this very early disappearance of the gland is not noticed; but it must be remembered that their artificial mode of life is in total opposition to the peculiar activity of their genus. The form assumed by the gland is that of two narrow, elongated parallel lobes, reaching from the upper third of the pericardium to within the root of the neck; so that its length is often four or five times in excess of its other dimensions.

Felis Leo. F. Leopardus. F. Tigris. F. Catus.

grown animals, and in one instance saw it in a pregnant female "in quendam saccum immutatum."

[1] My specimen was exceedingly meager and emaciated.

[2] Misc. Acad. nat. curios. Dec. 1. Ann. 2. p. 25. Compare Blasius, lib. cit. p. 125; and for its mention in the lion, p. 85.

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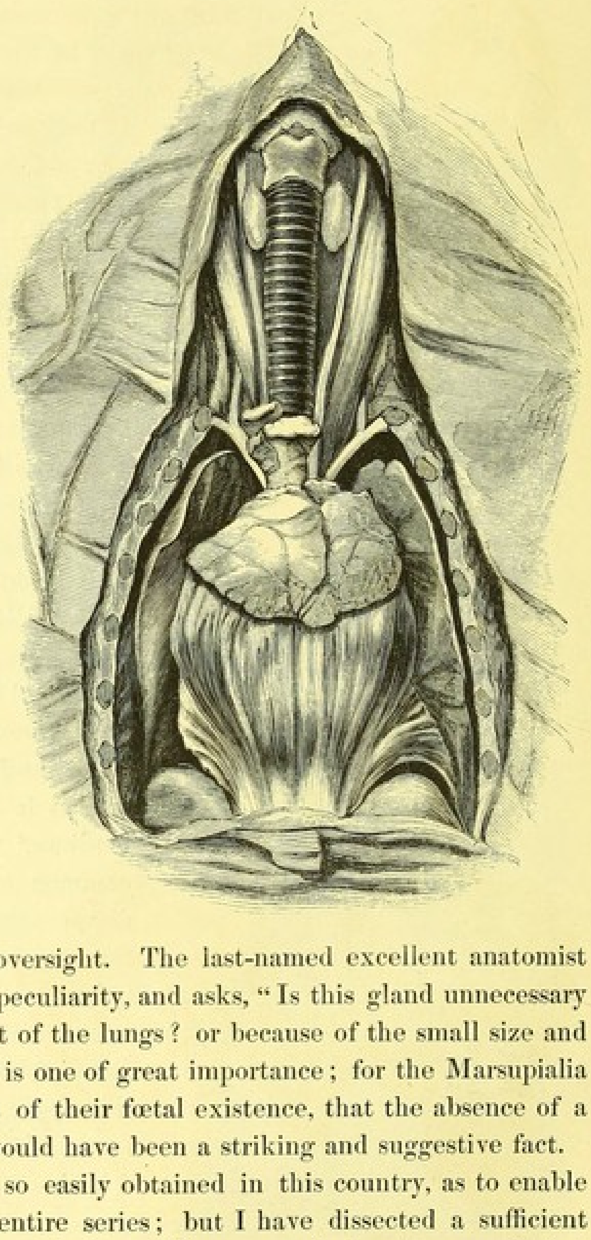
5. *Amphibia.*

Phoca Ursina.

Steller mentions the Thymus in the *phoca ursina* as being larger at two years of age than at birth; but Meckel, who was little likely to overlook its presence, states that in a common seal, three feet long, he was unable to detect any trace of it whatever. Other anatomists, quoted by him, have also dissected young seals without noticing the existence of the gland, and Kuhl[1] states that he found it of small size in a seal under full growth. Probably, therefore, it follows the same general laws of development and decline in this family as in most other mammalia.

Fig. 19.



P. Vitulina.

I have dissected it in two specimens of the common seal (*phoca vitulina*), and find the following to be its arrangement. In form, (fig. 19,) the gland is nearly symmetrical; it consists of two broad, thickish, pericardiac lobes, which prolong themselves upwards to the root of the neck, and abruptly terminate by clubbed extremities: the anterior surface of these prolongations is deeply grooved by the left vena innominata.

6. *Marsupialia.*

In this interesting family, the existence of a Thymus has been entirely unrecognised. Vicq d'Azyr[2], M. de Blainville[3], and Professor Owen[4], have successively encouraged this unaccountable oversight. The last-named excellent anatomist even endeavours to explain the supposed peculiarity, and asks, "Is this gland unnecessary on account of the precocious development of the lungs? or because of the small size and gradual growth of the brain?" The point is one of great importance; for the Marsupialia are so peculiarly characterised in respect of their fœtal existence, that the absence of a Thymus throughout their single family would have been a striking and suggestive fact.

Fœtal or young Marsupialia are not so easily obtained in this country, as to enable one in a limited time to examine the entire series; but I have dissected a sufficient number of them, with the constant result of finding a Thymus, to feel quite assured that

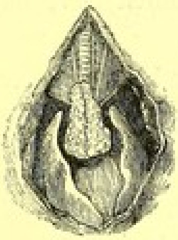
[1] Op. cit. p. 43. [2] Vicq d'Azyr, in Encyclop. méthod., Anat. des Anim., art. "Didelphis."

[3] Bulletin des Sciences par la Soc. Philomath. 1818, p. 27.

[4] R. Owen in Cyclopedia of Anatomy and Physiology, vol. iii. art. Marsupialia, p. 326.

there is no difference, as regards this organ, between the present and any other family of mammiferous animals. My dissections have been as follows:— MAMMALIA.

Fig. 20.



In the opossum (*didelphis opossum*), the Thymus may be found (fig. 20.) to consist of two symmetrical lobes, broader below than above, and having their chief diameter in the vertical direction; they cover the upper third of the pericardium, and reach to the level of the upper edge of the sternum. In the *perameles obesus*, the gland is somewhat thinner than in the opossum: but it is more expanded below, where it covers the upper half of the pericardium, and more prolonged above, where it clears the strait of the thorax. Didelphis Opossum. Perameles.

In a full-grown specimen of *phalangista cavifrons*, I found evident traces of it remaining in the mediastinum: in a nearly full-grown *phalangista vulpina*, (fig. 21,) I discovered a distinct rounded remnant, situated on the vessels a little above the heart: and I likewise observed traces of the gland in an adult specimen of the *didelphis pigmæa*. Phalangista Cavifrons. P. Vulpina. D. Pigmæa.

Fig. 21.

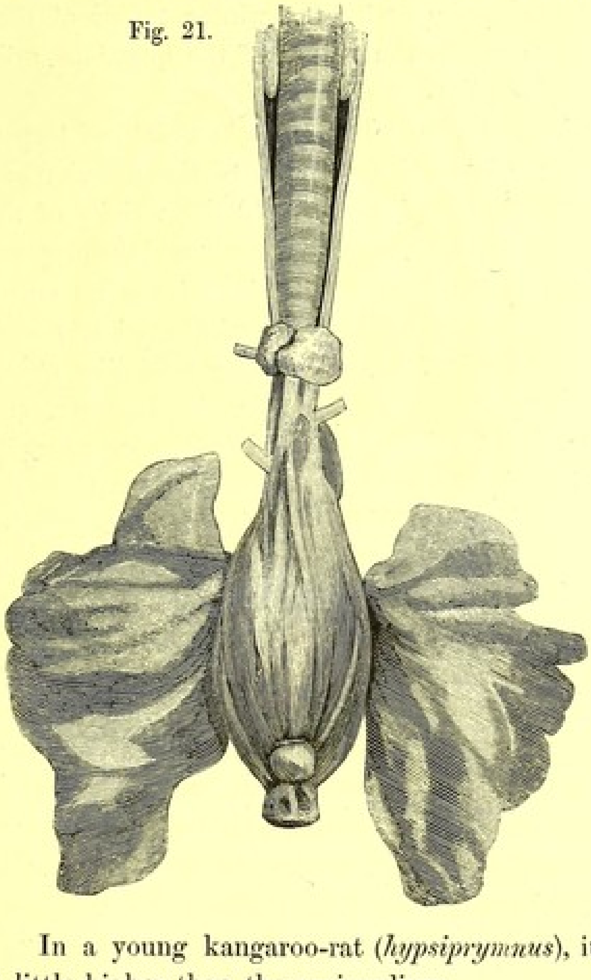
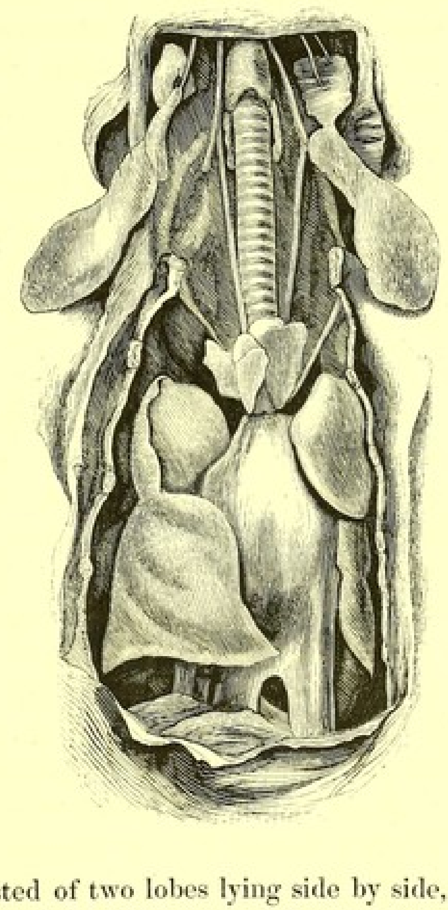


Fig. 22.



In a young kangaroo-rat (*hypsiprymnus*), it consisted of two lobes lying side by side, a little higher than the pericardium. Hypsiprymnus.

In a mammary fœtus of the kangaroo (*macropus major*), I found the gland occupying a position somewhat above the heart, and having a remarkable trifoliate division (fig. 22); Macropus.

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one lobe was on each side with its surface adapted to the pleura, while the third stood prominently forward between the laminæ of the mediastinum; it was certainly small in proportion to the size of the animal. I suspect from the unfavourable specimen of phalangista vulpina in which I have dissected it, that in that animal it must have had a similar unusual shape.

In the koala (*phascolarctos*) and wombat (*phascolomys*) I have yet had no opportunity of making the examination.

7. *Rodentia.*

The accurate study of this family is of vast importance to the physiology of the Thymus; for here, among the hybernating species, occurs a great exception to the general law of its development, in the fact of its becoming a persistent organ.

Hybernating animals.

Scheuchzer, Harder, Velsch, and Pallas, had directed notice to some of the peculiarities of the hybernating rodentia; Meckel had particularly dwelt on those which I am about to describe; and Tiedemann's essay on the anatomy of the marmot contains an elaborate inquiry as to the connexion of the Thymus with the winter torpor of that animal.[1] Perhaps I shall be best enabled to expose the nature of the questions, arising in the subject, by examining the views of the last-named physiologist.

Tiedemann's dissections and theory.

In dissecting a marmot, killed in the month of November, while in a state of torpor, he found the Thymus in the following state: "It filled the whole of the anterior and posterior mediastina, extended along the great vessels of the neck to the vicinity of the lower jaw, spread itself out above the clavicles on each side of the neck, and even passed behind the clavicles and pectoral muscles into the axillary spaces; it weighed an ounce and ten grains, or about the twenty-fourth part of the total weight of the animal; each lobe was composed of many roundish vesicles, filled with a dull white fluid like chyle, and surrounded by a vascular network; the vesicles were $\frac{1}{2}$—1 line in diameter, and communicated with each other." In a second dissection, performed in the summer, he found the gland "collapsed and dry; it contained no fluid, nor could its cavities be recognised; its bloodvessels were in small number; its weight was only ten scruples, or 160th part of the entire weight of the animal." From these observations he goes on to contend "that the Thymus becomes considerably enlarged during hybernation (?), partly from the afflux of blood, partly from the secretion of a chylous fluid into its cells and vesicles; that it declines after the period of hybernation (?) from being less vascular and containing less fluid; that it belongs to a period (?) characterised by extraordinary quiescence of the respiratory functions, and serves by its secretion to compensate for this inactivity; for as the secretion is chylous, and consequently but little oxygenated, its elimination from the blood must tend to *increase the relative oxygenisation* of that fluid; that the condition of the fœtus, in respect of respiration, is analogous to that of hybernating animals, and that the Thymus in both is highly developed."

I have ventured to place a sign of interrogation against those parts of this ingenious

[1] Scheuchzer in Phil. Trans. vol. xxxiv. p. 237; Harder, Eph. nat. cur. Dec. 2. Ann. 4. p. 237; Velsch, Act. nat. cur. Dec. 1. Ann. 1. p. 298; Pallas, Novæ species quadrupedum ex glirium ordine, passim; Meckel, Abhandlungen, passim; Tiedemann, in Meckel's Archiven, vol. i.

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argument, which seem to me particularly objectionable; but, before endeavouring to refute them, I will state the result of my own dissections.

Mus alpinus.

In the marmot (*mus alpinus*, figs. 23 and 24), I have found in four instances the following structure, which nearly coincides with that described by Tiedemann: A large solid Thymus surrounds the base of the heart and about half the length of this organ, and prolongs itself by direct continuity (passing along the concavity of the subclavian artery to the upper part of the posterior mediastinum) into a material of the same appearance as itself, which lies along the vertebral column on each side of the aorta. It is impossible to say where one begins and the other terminates; the Thymus appears to reach into and along the posterior mediastinum. Masses of nearly the same appearance filled the axillæ, and extended a little distance into the posterior regions of the neck. I have not noticed any such cervical prolongations from the thoracic part of the gland as Tiedemann describes.

Fig. 23.[1]

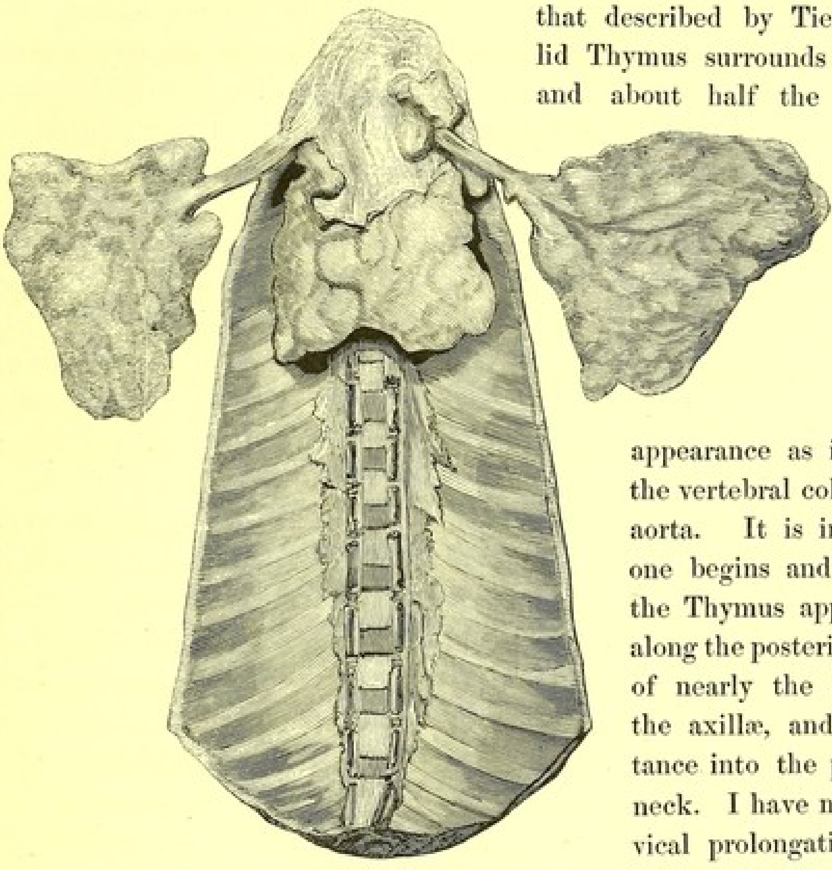


Fig. 24.[2]

Of my four specimens, two (a fœtus and an adult) were preserved in spirit, and were therefore not sufficient for satisfying all the doubts which occurred to my mind in regard of this remarkable apparatus.

The other two were recent specimens, adults; and I hastened to apply the only conclusive test of structure with which I am acquainted, viz., the microscope. The question which most pressed for solution was, *whether the entire mass was Thymus:* that the part lying on the pericardium was so, could hardly be doubted; its

[1] Fig. 23 shews part of the trunk of an adult marmot: in the median line, the heart has been removed from under the Thymus, which is left *in situ;* the mediastinal continuations are likewise seen on each side of the bodies of the vertebræ: laterally the axillary fat-masses are left attached, but are somewhat raised from their natural position.

[2] Fig. 24 shews a dissection of the thorax and root of the neck in a fœtal marmot: the Thymus is seen on the upper part of the pericardium: on each side (exterior to the cut extremities of the ribs) are displayed the lateral fat-masses reaching from the axilla into the root of the neck.

form, position and general appearance seemed to put it beyond suspicion; but the axillary masses, and the mediastinal extension of the same substance,—what were they? the naked eye could detect no difference between them and the material covering the pericardium.

I first examined the mediastinal and axillary portions with the microscope, and readily satisfied myself that they were fat only. But on proceeding (as has always been my habit in these investigations) to contrast the true with the imitative structure,—on submitting a piece of the pericardiac mass to the same test, what was my surprise to find, that it likewise presented through its entire substance the unequivocal characters of the same material!—*it too was fat.*

Fortunately, it was just at this time that I was engaged in investigating the Thymus of reptiles; and I had accordingly not to wait long for an explanation of the unexpected phenomenon.

I believe I may venture to state as a certainty, that in all cases where the Thymus becomes a permanent organ, it does so under an altered character; namely, by a singular and striking transformation of its ultimate elements,—by *developing its natural cytoblasts and fluid contents into a system of nucleated fat-cells, held within a limitary membrane.*

The whole mass then, pericardiac, axillary, and mediastinal, is but an accumulation of nourishment in the form of fat; and the distinctive peculiarity of the first is, that it developes itself out of the elements of the temporary Thymus, and converts the secreting apparatus of that organ to a permanent use in the economy. I have endeavoured in another part of this essay to explain the morphology of this change, and the exact and beautiful manner in which it harmonises with the ordinary function of the Thymus in young animals.

I presume that the subject of Tiedemann's description, in which he found fluid secretion within the gland, must have been a young specimen, wherein the organ had not yet acquired its permanent characters.

Tiedemann's theory of its efficiency as an indirect oxygenator of the blood, and his belief that in hybernating animals, as in the fœtus, it compensates for the inactivity of the lung by discharging the office of that organ in a vicarious manner, are as untenable for the hybernating animal as for the fœtus. They are untenable in the latter case, for reasons warranted by numerous and exact admeasurements; viz., that the Thymus does not attain its chief bulk during fœtal life; that, instead of diminishing after birth, it then grows most rapidly and fulfils its chief function. And on similar grounds, according to Tiedemann's own data, his theory cannot be received for the use of the Thymus in these hybernating rodentia: for, instead of having its chief size at the commencement of hybernation (November, vid. supra), it should, on his shewing, possess its chief development (from the continued accumulation of the secreted product) at the end of that term: it should grow day by day during the whole period of torpor, be smallest at its beginning and largest at its close:—but the contrary is the fact.

Moreover, there is, in the animal economy, one instance of an organ fulfilling a function somewhat analogous to that ascribed by Tiedemann to the Thymus; the function, namely, of separating from the blood during a certain time *an ingredient unfavorable to life.* The case is that of the Wolffian bodies, which, during a very early period of embryonic life, act as temporary kidneys, and secrete urea from the blood; thus serving to maintain the healthful conditions of this fluid, just as, according to Tiedemann, the separation of carbon in the Thymus should serve. But how different the principle of construction in these two organs! that which has to separate a noxious ingredient from the blood is furnished with the means of eliminating it; having attracted to itself materials hostile to the vital uses of the blood, it retains them not within closed cells and reservoirs, as if for future consumption, or as if afterwards to return into the circulation which their presence would contaminate; it has a complete excretory apparatus and an exterior outlet. The Thymus, on the other hand, has none such: it secretes into shut chambers. Can Nature have organised these receptacles for the enclosure and accumulation of effete, or poisonous material? MAMMALIA. Mus Alpinus.

I have entered at some length into the discussion of Tiedemann's views, from a consideration of the weight which must belong to any opinion supported by his great authority. The different notion which I entertain, of the function of the Thymus in hybernating animals, may better be stated hereafter: and for the present I will return to anatomical details.

All those rodent animals which pass the winter in a torpid condition, present, with more or less completeness, an apparatus analogous to that which I have described in the marmot.

Tiedemann[1] describes the gland in the beaver (*castor fiber*) as of very large size, weighing two ounces and five drachms, in an individual of thirty pounds' total weight. Castor Fiber. I have dissected it in an adult specimen of the allied genus *couia*, and found its development no Couia. less remarkable than in the marmot: it presented the same shape, and there were the same axillary and mediastinal masses of fat.

In the animals which hybernate less completely, these voluminous organs are not so fully developed; in those which pass the winter in a state of activity, they are absent, and the Thymus, as in other mammalia, is a merely temporary organ.

Fig. 25.

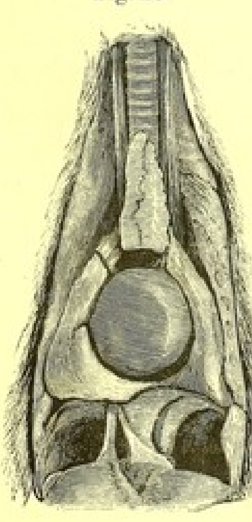
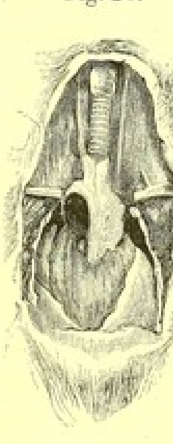


Fig. 26.



The Thymus differs in shape among the various genera; in the rat (*mus rattus*, fig. Mus Rattus. 25), it consists of two elongated parallel lobes, reaching from the base of the heart to the root of the neck; in the hare (*lepus* Lepus timidus. *timidus*, fig. 26), it presents anteriorly a narrow elongated surface extending from the pericardium to the root of the neck, and corresponds on each side to the apex of the lung, which is received into a depression of its deep lateral surface; its chief dimension is antero-posterior. In the jerboa (*mus sa-* M. Sagitta. *gitta*) the conformation of the gland is exactly similar to that observed in the hare.

[1] In loc. cit. p. 490.

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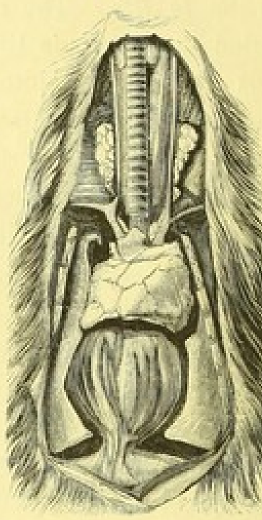
8. *Edentata.*

Fig. 27.

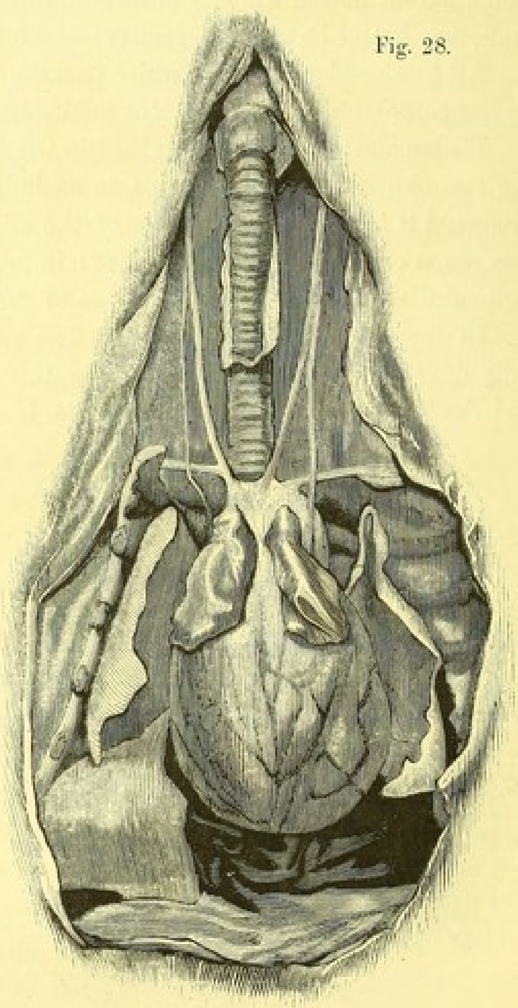


The Thymus has scarcely been mentioned by authors in their description of this family. I have dissected it in all the genera, and find it to vary as follows.

Bradypus. In the sloth (*bradypus tridactylus*, fig. 27), there is a large thoracic portion, situated just above the base of the heart; it extends backwards on each side, so as to surround the large arteries, and adapts itself to the arch of the aorta, which it follows as far as the spine: there are likewise cervical prolongations, ascending half the length of the trachea, and connected with the thoracic part of the gland by so slender a line of union, that they might easily be overlooked.

Dasypus. In an armadillo (*dasypus sexcinctus*), I found the cervical prolongations very small; otherwise the form of the gland was much as in the last.

Fig. 28.

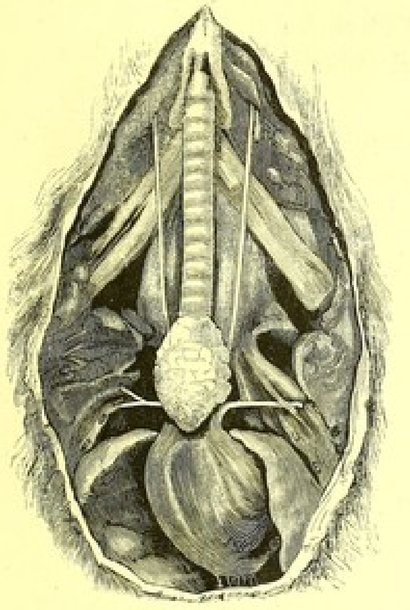


Orycteropus. In a fœtus of the Cape anteater (*orycteropus*, fig. 28), the Thymus consisted of two symmetrical, triangular, somewhat separated lobes; it corresponded to about the upper half of the pericardium, and seemed small in proportion to the size of the animal.

Myrmecophaga. In a *myrmecophaga didactyla*, of four inches in length, the gland presented a singular form: it was triangular, with the base uppermost toward the root of the neck, and the apex just reaching the pericardium: it consisted of disgregated pieces, not arranged symmetrically, but held together by cellular membrane to form the outline I have described.

Manis. In the pangolin (*manis*), I found the general shape of the gland to be the same as in the sloth; the pericardiac portion was smaller, but extended backwards beneath the arch of the subclavian artery on each side, as in that animal. In both genera, the pericardiac part of the gland is curiously compressed between the mediastinal layers of the pleura, so as to be narrowed anteriorly in the form of a wedge.

Fig. 29.



9. *Monotremata.*

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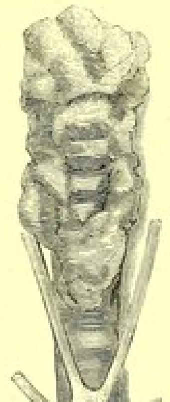
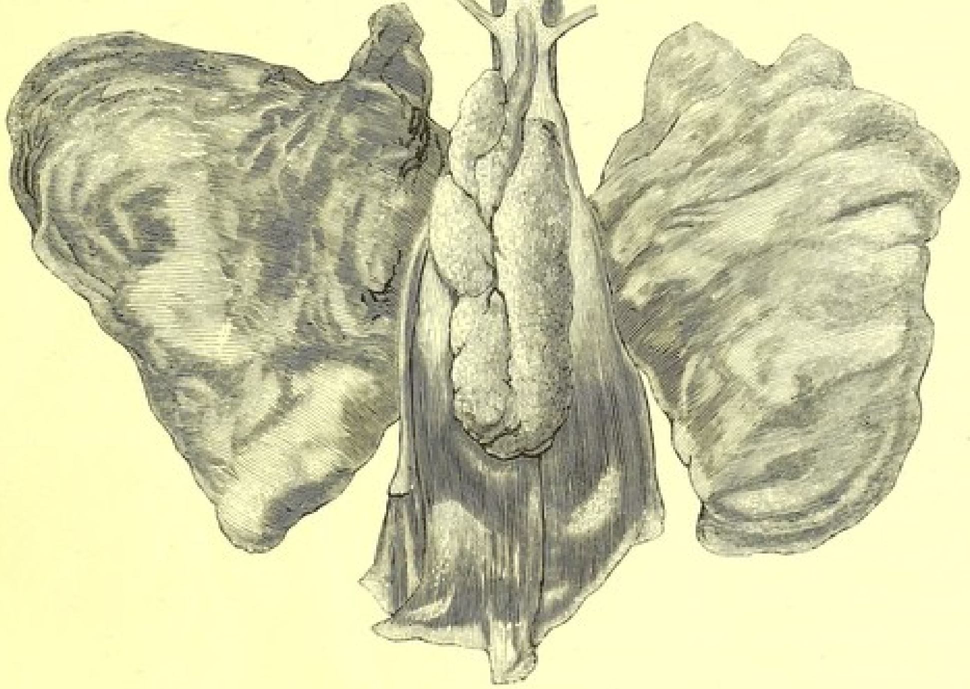
Meckel, in his monograph on the ornithorhynchus,[1] first described the Thymus of that animal. I have dissected it in individuals of both genera, *Ornithorhynchus* and *Echidna*, young and adult: the following description applies equally to both. In the period of its full development it is a flattened body of oval outline, corresponding to the arch of the aorta with the origin of the carotids, and presenting little or no trace of vertical division (fig. 29). As it declines, the separation between its lobes becomes more manifest; and it seems to consist of two distinct symmetrical parts.

Ornithorhynchus.

Echidna.

Fig. 30.

10. *Pachydermata.*

The differences in the development and form of the Thymus through this family are very great; in some the gland closely resembles that of the ruminating animals; in others it is entirely pericardiac; in others almost mediastinal.

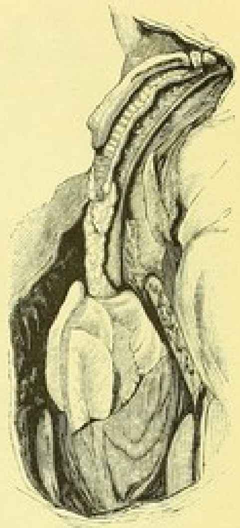
In a fœtal elephant (*elephas indicus*, fig. 30), I found the gland to be flat, and

Elephas indicus.

[1] Ornithorhynchi paradox. descriptio anatomica, 1826.

MAMMALIA. elongated vertically; it presented a distinct median fissure, and sent a short prolongation upwards from its right lobe. The entire gland, with the exception of this process, lay on the pericardium, of which it covered the upper two-thirds.

Fig. 31.



Sus Scrofa. In the common pig (*sus scrofa*), the gland is as completely developed in all its parts as in the ruminantia: the cervical portion is symmetrical; it consists of two cornua which lie in contact with each other over the trachea below, but diverge above, to expand into the masses of glandular substance placed within the angle of the jaw; the thoracic portion is not symmetrical, but inclines somewhat to the left side, and expands over the surface of the pericardium. Dicotyles. In a peccary (*dicotyles*, fig. 31) I have observed the arrangement of the gland to be almost exactly the same; but the cervical cornu on each side seemed of redundant length, and was folded down again beside the trachea after having attained its utmost height.

Hyrax. In the *hyrax* (fig. 32), I found the Thymus entirely thoracic; it was thin, with an oval outline; it covered the upper half of the pericardium and the cervical vessels, as high as the root of the neck.

Fig. 32.

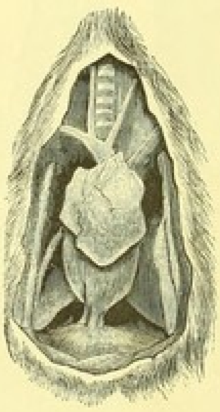
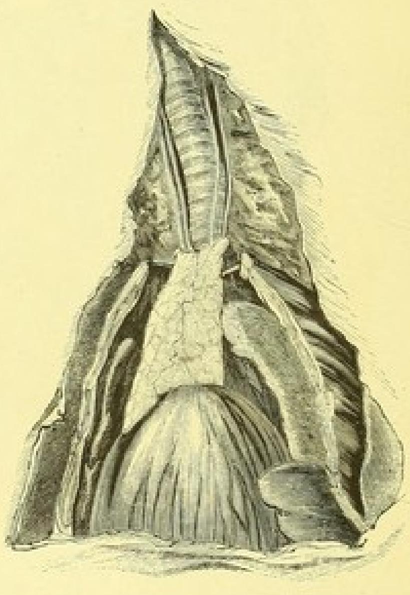


Fig. 33.



Among the *Solipeda*, the gland is either entirely thoracic, or reaches but little into the neck; Equus Caballus. in the horse (*equus caballus*, fig. 33), it is placed between the two pleuræ, and compressed from side to side, so that it presents a thin edge to the sternum, becoming broader behind; it seems to hang loosely, as though it flapped to and fro between the two cavities of the chest.

11. *Ruminantia.*

There appears a pretty constant type for the anatomy of the Thymus in this family, Bos Taurus. which may be illustrated from the calf (*bos taurus*, fig. 34), and is not far different from the form already described in the pig. The gland presents cervical portions, which are highly developed, reach within the angle of the jaw on each side, and form large, complicated masses up to the very base of the cranium; below, these prolongations are narrowed, and united in close juxta-position, to form an isthmus which passes behind the first bone of the sternum, inclines to the left side, and expands into another considerable mass of glandular substance, situated on the upper part of the pericardium, and covered by the left pleura. MAMMALIA.

Fig 34.

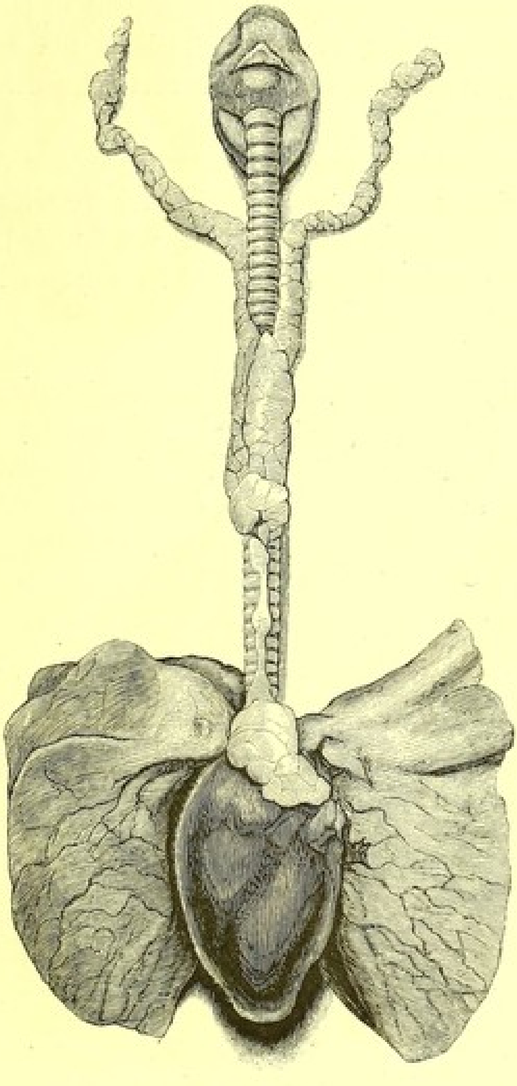
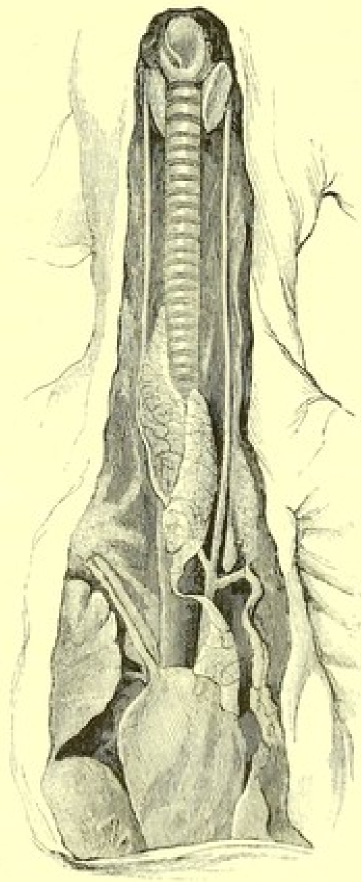


Fig. 35.



In the genera *Camelus*, *Moschus*, and *Camelopardus*, I have had no opportunity of dissecting young specimens, and am unable to find anything bearing on our present subject in the works of previous writers.

In the genus *Cervus*, the above-mentioned type is nearly adhered to; in the reindeer (*c. tarandus*, fig. 35), I found that the cervical portions were highly developed and thick over the lower half of the trachea, and then terminated in conical extre- Cervus Tarandus.

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mities (of which the right was the longer) without attaining so high a level in the neck as they reach in some other species; the submaxillary enlargements, in short, were absent, and the tracheal portions had a compensative size. In the fallow deer (*c. dama*), on the contrary, the cervical portions have their full development up to the base of the cranium; but their lower extremities fall short of the pericardium, terminating just within the first bone of the sternum, and in front of the trachea.

C. Dama.

Antilope. Ovis.

In the genus *Antilope*, I have dissected one fœtus, and find the arrangement in it, as also in the genus *Ovis*, to be exactly that which I have described in the calf. There is, in both alike, an equal development of the thoracic and cervical portions of the gland.

In the calf, we have good opportunities for studying the circumstances which regulate the decrease of the Thymus; the remark of Wharton, which I have already noticed, as to the effect of labor in producing its rapid disappearance, was founded on the observation of oxen, early put to the plough. The anatomy of its Thymus has already been described, as typal for the family.

12. *Cetacea.*

Manatus.

Among the *Herbivora;* in the manatee (*trichechus manatus*), I have had no opportunity of examining the Thymus; and Steller makes no mention of it in his description of this animal. Meckel notices its appearance in an early fœtus of the American manatee, (*op. cit. p.* 196,) in the form of two small bodies in front of the base of the heart. In dissecting a young specimen of the dugong (*halicore dugong*), I found it presenting the same general shape and arrangement of parts, as I shall directly describe and figure in the mysticete whale.

Halicore.

Delphinus Delphis.

Among the *Spouters;* I found its form in the fœtal dolphin (*delphinus delphis*, fig. 36) to be rather peculiar. In the median line within the thorax was a small and symmetrical pericardiac portion of the gland, from the upper angles of which two thick cornua passed backwards to the spine, one on each side, so as to enclose the trachea and œsophagus in the angle of their divergence: each cornu then ascended, in close contiguity to the vertebræ, to the level of the upper part of the trachea, and there again bent inwards in front of that tube, so as to rejoin its fellow in the median line. Thus at first sight the gland appeared (from the great depth of the ascending processes) to consist of two separate lobes, both situate in the median line, one on the pericardium, the other on the upper part of the trachea; but in reality it formed a sort of bent ring (thick and superficial where it corresponded to the median line,—thinner and deep in its lateral portions) through which the trachea was seen and the cervical vessels emerged.

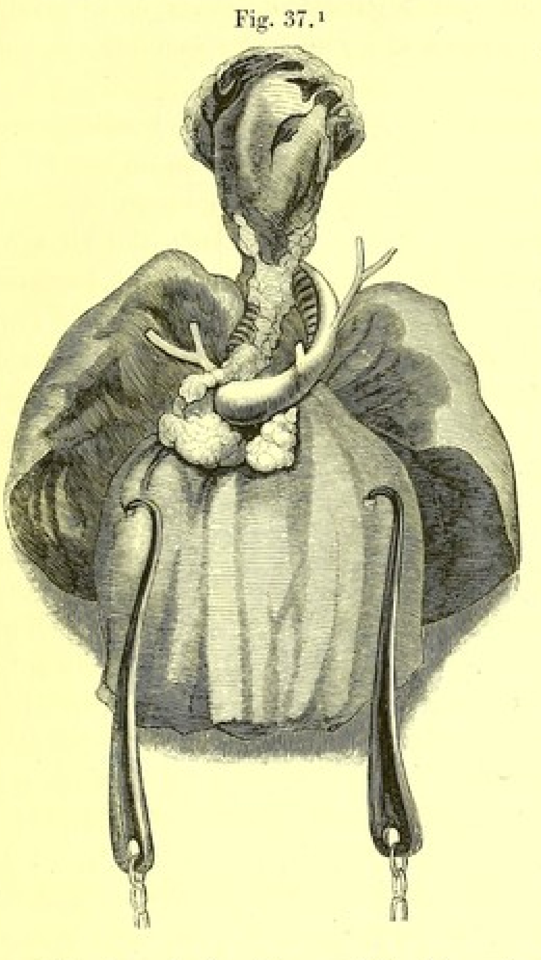
Fig. 36.

In the *balæna mysticetus* (fig. 37), there were two pericardiac lobes, of which the right was the larger; they occupied quite the upper part of the pericardium, and formed together a curve, corresponding to the base of the heart; the right lobe gave origin to a prolongation which extended almost directly backwards across the arch of the aorta, between the innominata and left carotid, till it reached the trachea, and ascended a small distance in front of that tube to terminate in two little cornua. The main bulk of the gland was thus constituted by the right lobe and its continuation; the left appearing to be merely a small accessory portion. In the young dugong above mentioned, the same relative development of parts was observed.

MAMMALIA.

Balæna Mysticetus.

Fig. 37.[1]



AVES.

AVES.

Meckel[2], in the admirable treatise to which I have so often referred, first mooted the question of the existence of a Thymus gland in birds.

He described with considerable minuteness the shape and relative position of a certain organ, which he stated to be constant in diving birds, and, in his belief, peculiar to them; this organ he supposed to be the Thymus. He details the dissection of it in *mergus serratus, colymbus cristatus, colymbus immer, alca lomvia, alca torda*, and *pelecanus bassanus;* and seems to have found sufficient variety in the conformation of the part he describes, to have justified some misgiving as to its nature. Sometimes it appeared behind, sometimes before the trachea, and even presented wide differences of arrangement in male and female individuals.

Meckel's dissection of diving birds.

Not only in the species mentioned, but in some others also,—and in other families of palmipedes, and in other orders of birds, I have found and examined the organ in question. Its usual form is that of a yellowish mass situate on the trachea, just above the inlet of the thorax. Even to the naked eye, it scarcely seems to present that

Author's dissections.

[1] Fig. 37 represents the thoracic organs of the *balæna mysticetus;* the heart is drawn down considerably from its proper level, in order to display more clearly the backward prolongation of the Thymus.

[2] Abhandlungen, p. 215.

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structural similitude to the Thymus of mammalia, which Meckel imputed to it; and all doubt is removed by the employment of the microscope, which conclusively demonstrates that this problematical organ, even in the youngest specimens, is but ordinary fat.

True Thymus found in birds.

However, having detected this fallacy, I had the good fortune to find satisfactory evidence, that a *real Thymus does actually exist in birds*, and that they form no exception to the law, that this organ is universally present in animals breathing by lungs.

Analogies of its form and position.

In following the order of zoological systems, and proceeding from the class of mammalia to that of birds, nothing is easier than to overlook the existence of a Thymus. We have been accustomed, in the former class, to find it almost always a thoracic organ, and to search for it in connection with the central organs of circulation. But I would beg to remind the reader of the anatomy of the ruminantia: the type for the shape of the Thymus in that family was one of great completeness; the gland in the calf was seen to extend from the base of the skull to the middle of the pericardium; it was seen to present three chief centres for the accumulative growth of glandular material, opposite respectively to the heart, the trachea, and the angle of the jaw. And let the reader remember the exact nature of the deviations from this type, presented oppositely in the reindeer and in the fallow-deer. In the former there was an absence of just so much of the gland as should have been formed round the upper centre of development; the sub-cranial part of the gland was deficient. In the latter, on the contrary, the suppression of development was at the thoracic extremity of the Thymus; there was no pericardiac portion,—the gland was exclusively cervical and sub-cranial. Now, when we were led to this instance by easy transitions of form, we found no difficulty in understanding the nature of the glandular masses in question; it was perfectly obvious that they represented, so to speak, the Thymus of a calf (or the typal form for the family), with the omission of a part. But, if we were abruptly to sever this particular instance from those nearest akin to it, and with too much confidence in the anatomy of mere position were to compare it with the form and local relations of the human Thymus, we might almost deny its claim to be considered the corresponding organ,—so anomalous would its position in the neck, and in the neck alone, appear to us. Yet I need scarcely add that there can be no doubt as to the real nature of the organ in question.

Similarly again, in the Sauroid reptiles, we are able to notice the power which this suppression of a part in the development of the gland may have in modifying form. In the crocodile (as in the calf) the Thymus extends from the pericardium to the base of the cranium; and it is impossible to fail finding it in a dissection made for the purpose. But in most families of the true Sauria we find the pericardiac part absent; the entire Thymus being represented by a very narrow slip of glandular substance, which reaches on each side of the neck from the base of the cranium to about the inlet of the thorax, and preserves a nearly uniform diameter in its whole extent. The form and position of the Thymus gland of birds, as represented in the accompanying figure, only admits of being explained or understood by a comparison with the varieties I have mentioned.

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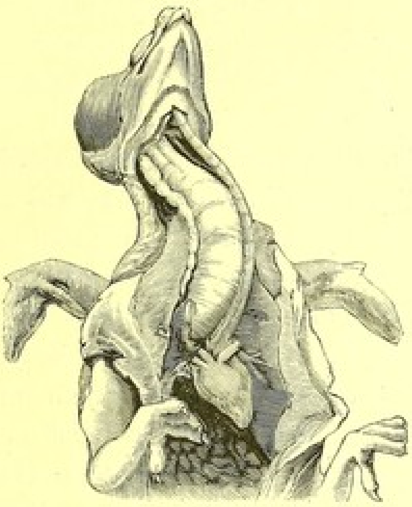
My first notice of the gland was in a young pigeon (*Columba livia*), from which the annexed figure (fig. 38) was copied. I have since been able to ascertain its universality among birds, by dissecting specimens from all the orders, and in most instances from several genera of each. Its arrangement has been found, in all these dissections, to be substantially the same; and the ensuing description, though written from the pigeon, may be understood as applying equally to all the specimens I have examined.

Fig. 38.



Same arrangement of Thymus in all the orders.

In dissecting the neck of a very young bird, after removing the common integuments, the Thymus will be recognised on each side as a semi-transparent ampullated tube, which is distinctly seen, even by the naked eye, to be completely closed in both directions.[1] It follows the line of the superficial cervical vessels, lying along their outer side, extends from within a line or two of the base of the cranium to just above the inlet of the thorax, and is rather broader in the former than in the latter situation. Its lower extremity is in contact with the thyroid body. On removing it from its situation, and placing it in the field of the microscope, its nature is established beyond any possibility of doubt. It forms, from one end to the other, a simple continuous cavity without any diverticula; but presents constricted portions, formed doubtlessly by the less developed parts of the primary tube. The limitary tissue and the contained dotted corpuscles may be seen as satisfactorily as in the corresponding organ of mammalia.

Early disappearance.

The most remarkable law of its development, with which I am as yet clearly acquainted, is, that it ceases to discharge its function at a very early epoch,—much sooner than in mammalia.[2] To this circumstance, and to that of its occupying a position where anatomists have hardly thought of looking for it, I attribute the fact that its existence has so long remained utterly unsuspected.

REPTILIA.

REPTILIA.

Previous dissections.

Nowhere, in the animal kingdom, may the physiology of the Thymus be better illustrated than in this class:—yet, strange to say, it has been universally neglected or mistaken. The literature of this section of my subject requires some notice.

[1] The gland has been overlooked, I suspect, not so much from its inconsiderable size, as from its pellucidness of structure. Previous immersion in alcohol anticipates this difficulty, by rendering the tube opaque and coagulating its contents.

[2] Among Birds, as among Mammalia, the vanishing time of the Thymus varies according to the motility of the animal: in those of active habits and long, swift flight, the gland disappears earliest; in the *Accipitres* (just as in the Carnivorous mammalia) singularly soon.

REPTILIA. Chelonia.

Bojanus, in his elaborate and excellent monograph[1], first drew attention to a peculiar body connected with the vessels at the base of the heart in *chelonian* reptiles, and represented it with such fidelity in two of his plates, as to prevent the possibility of misapprehension. But he was clearly mistaken as to its nature in calling it Thymus;—it is as well-marked a Thyroid as can be found in any vertebrate animal; and the real Thymus is, as I shall presently shew, quite distinct from it, and a double organ. Carus[2] adopts his description, with its error.

Emydosauria.

The only suggestion as to the possible existence of a Thymus among the *Sauroid* reptiles, is a hasty allusion by Carus to certain bodies in the neck of the crocodile, which he thinks may fulfil the joint offices of Thyroid and Thymus. The bodies in question constitute a true Thymus; and the Thyroid (as in every other instance a perfectly distinct organ) is situated in the median line, just above the base of the heart.

Ophidia.

As regards the *Ophidia*, so long ago as the 17th century Blasius[3] described a body, " vasis circa collum situatis accumbens firmæ admodum conditionis, hordei magnitudinem vix excedens," and supposed it to be a Thymus. Charas[4] mentions and figures the same organ under a like impression of its nature; and Carus, in alluding to it, says of it (as of the bodies in the neck of the crocodile) that it may be considered to represent for this family both the Thyroid and Thymus of mammalia. Cuvier[5] describes this body with his wonted accuracy, and states his impression that it is "analogous to the thyroid gland." Such, in fact, is the case: the Thymus is quite distinct from it, and (as well as the remarkable appendage of a fat-body, which occurs in most genera) seems to have escaped the notice of most anatomists. Rathke[6], however, amid his careful observations of the development of serpents, has noticed the Thymus, but has confounded the Thyroid with it, so as to give some error to his description. He saw "about the time of the obliteration of the left carotid artery . . . three small bodies, arranged in a row in front of the vessels springing from the heart . . . which must be thought to represent the Thymus: . . . the middle one is between the carotids, the others on either side of it; . . . the former remains single, the latter in their growth divide transversely . . . the three together form a single, lobulated, moderately large body." It would, I doubt not, be obvious to Dr. Rathke, on re-examination, that the middle of these three bodies is the thyroid gland, and quite distinct in structure from the other two.

Batrachia.

Among *Batrachia*; Treviranus ascribes the double function of Thymus and Thyroid to a mass of fat situate above the heart in the common frog; and Carus (while, without entirely condemning the opinion, he inclines rather to consider this mass as analogous to the accumulation of fat in hybernating animals) seems also to include with it, in the joint exercise of the double function, certain bodies which he found on either side of the hyoid bone in the same animal.

[1] L. H. Bojanus, Anatome testudinis europææ; Vilnæ, 1819 (fig. 66, 156, 173).

[2] Carus; Lehrbuch der Zoologie, 1834, § 740.

[3] In lib. cit. p. 332.

[4] Perrault, Charas und Dodart, Abhandl. zur Naturgesch. der Thiere und Pflanzen, vol. iii. p. 34, and plate 92.

[5] Leçons d'Anatomie comparée, 1805, vol. iv. p. 534.

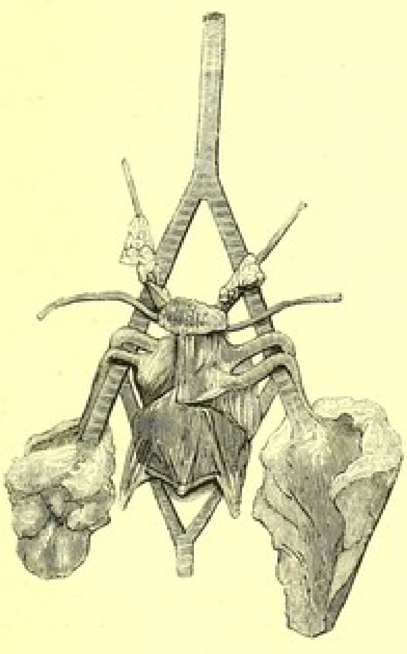
[6] Geschichte des Embryo der Natter von H. Rathke, in the last edition of Burdach's Physiologie (1837), vol. ii. p. 316.

The erroneous or vague descriptions embodied in these few notices, have attracted little attention; Becker[1] and Haugsted[2], who profess to have thoroughly examined the parts referred to, agree in positively denying the existence in reptiles of any organ analogous to the Thymus of mammalia. Meckel quite overlooked the true facts of the case, and Sir Astley Cooper probably did not direct his attention to the point. General assent has naturally followed this array of great authorities; and it has been the common doctrine of the lecture-room and text-book in physiology, that the Thymus is an organ strictly limited to the class of mammalia, and peculiarly adapted to their organisation and mode of life. REPTILIA. Conflicting statements.

I was so prepared to acquiesce in the correctness of these views, from habitual deference to the great anatomists maintaining them, that my first observations, contravening their truth, were admitted only after frequent and scrupulous verification. But I may be allowed to observe, that the careful employment of the microscope, in practised hands, for investigations of this nature, precludes the possibility of error. The Thymus and Thyroid can no more be confounded with each other, or with fat, than the liver and kidney can be mistaken for each other, or for muscle. The tubulo-vesicular structure of the Thymus, the vesicles of the Thyroid, the distinct limitary membrane and peculiar contained corpuscles of each, will serve to identify and distinguish these organs with *absolute certainty:* and I beg to premise, as a warrant for the accuracy of the ensuing descriptions, that they are all based upon, or corrected by, this conclusive criterion. Microscope the only conclusive test of structure.

1. *Chelonia.*

Fig. 39.



The organ represented by Bojanus in the *testudo europæa* is situated in the median line, between the carotids, soon after their origin. It is oval, well defined, firm, and highly vascular; presenting to the naked eye all the appearance of a thyroid gland. Microscopical observation confirms this impression, demonstrating that the organ is a true Thyroid, and not, as Bojanus assumed, a Thymus. Testudo Europæa.

But extending upwards on each side of this body along the carotid, or between it and the subclavian, will be found in all young tortoises an elongated white or yellowish mass, which is the true Thymus gland (fig. 39).

I have dissected it in the *testudo europæa*, the *t. græca*, and the *t. mydas*, and find it in all to offer the same features for observation. I have occasionally seen it disguised, particularly in old individuals of the last-named species, by a copious development of pigment- T. Græca. T. Mydas.

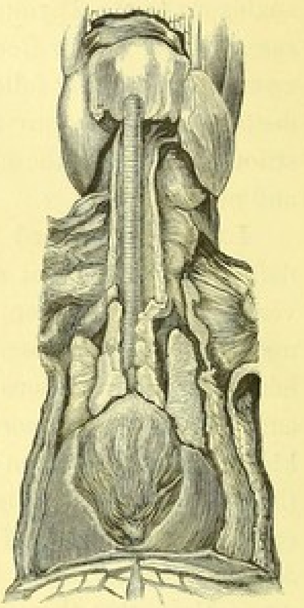
[1] Becker, p. 36.

[2] Haugsted, p. 515.

REPTILIA.

cells in the areolar tissue investing it. This deposit is found in immediate contact with the limitary membrane of the follicles, follows their outline, and, when complete, blackens the whole surface of the gland.

Fig. 40.



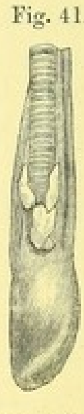
2. *Emydosauria.*

Crocodilus. Alligator.

I have dissected several young specimens of the genera *Crocodilus* and *Alligator*, and have constantly found the arrangement of the Thymus as it is represented in the annexed figure (fig. 40). Its thoracic portions are large, and of prismatic shape: they meet on the base of the heart, so as to hide the Thyroid, which is situated behind and between them. The cervical prolongations contract in the first portion of their ascent, but then continue of uniform diameter: they extend along the carotid vessels (first on their outer side, afterwards behind them) to the base of the skull, where they terminate—just behind the attachment of the pharynx—without undergoing any enlargement.

3. *Amphisbænia.*

Fig. 41.



Amphisbæna.

In the genus *Amphisbæna* (fig. 41), the Thymus appears disposed partly, as in the true serpents (*vid. infra*), along the carotid arteries,—partly, as in the frog, in the median line just above the base of the heart. Of these portions (which are joined together in the form of the letter Y) the former seem of secondary importance, and are often very imperfectly developed: sometimes one of the upper slips will be deficient, and thus render the gland quite unsymmetrical. The Thymus of the *amphisbæna*, like that of the frog, undergoes an early and complete metamorphosis into fat.

4. *Sauria.*

Lacertidæ. Geckotidæ. Chamæleonidæ.

In the *Lacertidæ*, the *Geckos*, and the *Chamæleons*, the arrangement has appeared similar to that just described in the crocodile, with the exception that in all of these the pericardiac part of the Thymus has been absent. The gland has presented itself in the form of elongated slips, reaching, one on each side, along the cervical vessels from the base of the cranium to near the inlet of the thorax.

Iguana Tuberculata.

Although in the *iguana tuberculata* the gland is arranged precisely as in the families last mentioned, the same disposition does not prevail in others of the *Iguanidæ*. In the *istiurus* and *stellio spinipes* I have in vain sought for any trace of Thymus along the cervical vessels. But in several adult specimens of these, as likewise in the *Scincidæ*, I have noticed just above the base of the heart that same accumulation of fat, which I shall

Istiurus. Stellio spinipes. Scincidæ.

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presently describe in certain of the batrachia. I am disposed to believe that this mass is engendered here, as in the common frog, by a transformation of the normal elements of the Thymus, and that, if examined in young specimens, it would be found to present all the more characteristic structure of the gland.

5. *Ophidia.*

Fig. 45.[1]

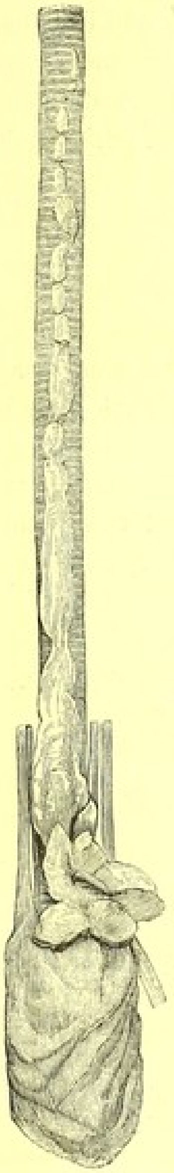


Fig. 43.[1]

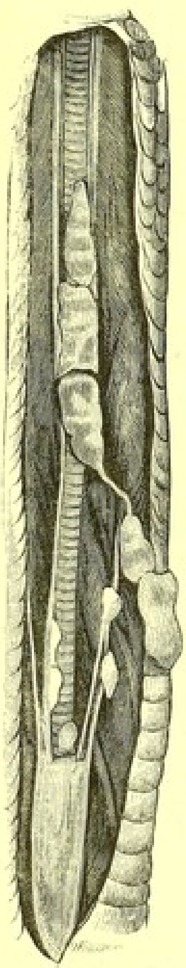


Fig. 42.[1]

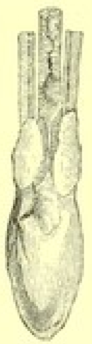


Fig. 44.[1]

Ordinary characters.

In all true serpents the Thymus follows one undeviating type, which consists, as is represented in the annexed figures, of an arrangement essentially similar to that seen in the tortoises. The gland lies—half on each side—along the carotids, immediately above the heart: often it is not strictly symmetrical, but larger on the right side than on the left: its lobes are elongated, and sometimes appear (fig. 43) to be broken into two or more pieces. I have never dissected any of the true serpents without finding traces of its existence, and suppose it to be persistent in them;—a view which is confirmed by the fact of its undergoing the transformation into fat, which I shall hereafter more particularly notice.

Fat-body.

A most remarkable feature in the history of the present order is the large accessory organ, or fat-body, which is developed in close connexion with the Thymus. In many serpents it acquires an immense growth; as, for instance, in the colubers, and particularly in the *python* (fig. 45), where it reaches from the base of the heart to within a short space of the jaw. It consists altogether of fat cells, very closely compacted into a distinctly circumscribed mass. At first sight, it might be readily mistaken for a very large

[1] The above figures represent dissections of the *boa*, *coluber natrix*, *hydrus*, and *python* respectively. In fig. 45 is displayed the fat-body of an enormous *python;* it is reduced to one-half of the natural size. In fig. 43 (*coluber*) the fat-body is drawn aside, so as to shew the thyroid gland in the median line just above the heart, and the Thymus on each side along the carotid artery. In fig. 44 (*hydrus*) the same organs are left apparent by the natural absence of the fat-body. In fig. 42 (*boa*) there is a constriction in the form of the fat-body, so that the Thymus is seen on each side of it, while the Thyroid is hidden behind its lower expansion.

REPTILIA.

Thymus; but the distinction of the two organs is facilitated by the circumstance that, where the fat-body exists, the Thymus is almost sure to be a persistent organ, and therefore to be present likewise.[1] This circumstance establishes a close affinity with the anatomy of hybernating mammalia; one, too, which is much corroborated by the fact of the transformation which the Thymus itself undergoes. The *naia*, the *python*, the *boa*, and the *viper*, all possess the fat-body, with more or less development; and they, I believe, all pass a considerable portion of the year in a torpid condition. The *hydrus*, on the contrary, leading an aquatic life in a medium less liable than our atmosphere to extreme variations of temperature, probably does not hybernate; and it alone, of all the serpents, has never, amid several specimens I have examined, presented any trace of the organ in question.[2] The shape of the fat-body varies a little in different genera: in some, as in the naia and python, it extends very high in the neck; in others, as the boa, a much smaller proportional distance.

Naia. Python. Boa. Vipera.

Hydrus. Crotalus.[2]

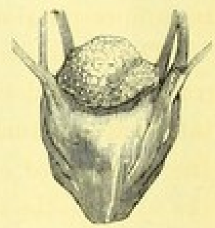
6. *Batrachia.*

With this order concludes the long series of animals in which the Thymus gland may be traced. Though the last link in the chain, it is by no means the least valuable; for it contains in itself the means of testing some of the most important conclusions which may be derived from Comparative Anatomy.

Rana esculenta.

In the common frog (*rana esculenta*) I have ascertained the presence of the gland, and carefully watched its growth. In the adult animal a mass of fat is found lying within the chest, just above the base of the heart (fig. 46): it cannot be distinguished from any other mass of the same composition. In younger animals (those even that are not full grown) the mass is still mere fat, but shews a more definite and vesiculated form; it is also found, on examination with the microscope, to present the clear outline of a limitary membrane. On pursuing the inquiry to a somewhat earlier period (to the very *infancy* of the frog, if I may use the phrase), the true structure of a Thymus will be discovered as the

Fig. 46.



[1] The Thymus is in these instances usually overlapped and hidden by the fat-body. In the accompanying figure of the python (fig. 45) the Thymus has been omitted, in order to give greater clearness to the remainder.

[2] Since writing the above paragraph, I have had the opportunity of dissecting two rattle-snakes. In both I found the Thymus distinct, though apparently dwindled; but neither of my specimens presented any trace of the fat-body. I could learn nothing of their history, but presume they must have come from within the torrid latitudes of the New World. Hybernation cannot belong generically to the rattle-snake: the animal is diffused throughout all parts of America, and no doubt variously adapts itself to the various climates in which its genus exists. The winter sleep of Labrador and Newfoundland could scarcely be needed in Guatemala or Peru. My specimens were probably from the tropical countries; and I have little doubt that specimens obtained from the temperate latitudes, where hybernation prevails, would be found to present the usual apparatus of hybernating animals; viz., a persistent Thymus, and a distinct fat-body.

basis for the future fat-body. Mixed with the dotted corpuscles of the gland will be found many nucleated cells; which, it cannot be doubted, have been developed from the natural cytoblasts of the organ, and are in course of becoming the ordinary fat-cells, which subsequently distend the vesicles of the limitary tissue. The transformation into fat occurs at a very early period in the life of the animal. REPTILIA.

In the toad (*rana bufo*), and apparently in the *Salamandridæ*, the structure of the organ is similar to that noticed in the frog. R. Bufo. Salamandridæ.

If I may so far anticipate (vide note, p. 64), as to state that no Thymus gland is found in fishes, it will be obvious that great interest attaches to the dissection of gill-breathing reptiles.

First,—with respect to the higher batrachia already referred to, in which the branchial respiration is temporary,—it seems necessary to compare the anatomy of the fish-like tadpole with that of the metamorphosed and perfect animal. As the young of the common frog are too small for the purpose, I made my dissections on the gigantic larvæ of the Pseudis (*rana paradoxa*). With repeated and careful examination of these, I was unable to detect any trace whatsoever of Thymus, or of any structure resembling it. On the other hand, in the youngest specimens, in which the pulmonic respiration was established, I constantly found the commencement of the organ in its usual position, as above described. The essential step in reptile metamorphosis is *a higher development of the respiratory system:* as a part of this process we here find occurring the superaddition of a Thymus gland,—its first appearance in the ascending scale of organisation. Larvæ of R. paradoxa.

Next, it was requisite to examine, link by link, that remarkable connectent series of animals—the lower batrachia, in which the apparatus of aerial respiration undergoes a gradual suppression, and gives place to a more or less perfect development of organs for aquatic respiration similar to that of fishes. Ichthyoid reptiles.

The *menopoma* and *amphiuma* commence this transitional series: their lungs, it is true, are well developed; their gills have wasted, and their respiration is aerial: but their incipient degradation of type is shewn by the persistence of a branchial cavity, and by the free channel of exterior communication thus maintained with the pharynx. Next comes the *axolotl*—the most anomalous of the group; which—whatever may be the importance, and whatever the meaning of its apparently persistent branchial tufts, unquestionably follows the genera last mentioned in its capacity for pulmonic respiration. Then, in succession there follow, the *menobranchus*, the *siren*, and the *proteus;* animals in which the means for aerial breathing have remarkably diminished, and in which the organs of the inferior type—those for aquatic respiration—are correspondingly evolved.

Amid this interesting series of transitional animals we find the Thymus vanishing. In the first four genera I have demonstrated the gland: in the rest I have failed to discover it. Its position, in those where I have found it, is cervical; it lies, on each side, along the lateral aspect of the spine, just behind that prolongation of mucous membrane which unites the branchial cavity to the pharynx. Accordingly, it is best exposed from behind. When the posterior integuments of the neck are removed, there come into view a pair of triangular muscles extending, one on each side, from a broad origin in the median line to a narrow insertion at the posterior margin of the branchial aperture. On dividing this muscle about its middle, on either side of the body, the gland is distinctly seen; its upper extremity, which is somewhat enlarged, lies at the level of a line passing to the angle of the jaw from the first arterial arch. It is of course the presence of the branchial cavity, that thrusts the gland backwards into this unusual position.

In the *menopoma*, *amphiuma*, and *axolotl*, I found the gland with perfect facility, as soon as it occurred to me to search in the right place: in these animals, the ends of the gland reach, in both directions, beyond the borders of the muscle covering its middle. In the *menobranchus* it is much smaller in proportion to the size of the animal; but still distinct. In several specimens of *proteus*, and in a single *siren lacertina*, I have made very careful dissections without detecting anything in correspondence with the microscopical characters of the Thymus.[1]

The chief results of the preceding comparative investigation may briefly be stated, as follows:—1. The *presence of the gland* is co-extensive with pulmonary respiration. 2. Its *shape and position* are variable and unimportant. 3. Its *size and duration* are, generally speaking, in proportion to the habitual or periodical inactivity of the animal. 4. Where it remains as a persistent organ, it is usually but one of several means for the accumulation of nutritive material: its continuance, under such circumstances, is generally accompanied—though, in some instances, superseded—by a peculiar accessory contrivance, the *fat-body*.

[1] I am uncertain what value to attach to this apparent absence of the gland in the lower perenni-branchiata. It certainly corresponds with singular accuracy to the general history of the gland, that, as it is absent in fishes and in the gill-breathing larvæ of reptiles, so it should gradually lose itself in the present transitional series of animals. So far as the difference of respiration is abruptly marked, so far we may positively say, that the Thymus belongs *entirely and exclusively* to animals of pulmonary respiration. But, unfortunately, the separation of the two types of construction is incomplete; and among the intermediate forms there are not sufficient grounds for determining the precise relative proportions of the branchial and pulmonary respiration. We are in the vague regions of "more or less;" and can not apply other analogies to an *a priori* judgment of where the gland should cease. Nor do I consider the point, in reference to these anomalous reptiles, to be of much importance. The lower ones, the Siren and Proteus, are so like fishes in respect of their breathing, that I am not surprised at their apparent want of a Thymus; yet, as they are still somewhat above the level of mere gill-breathing, I should not consider it as exceptional or contradictory, if there should be found in them some small trace of the gland, just proportionate to what rudimental pulmonary respiration they may possess. The real *instantia ultimitatis* is afforded in the transformation of the batrachian larvæ. The same animal which, as a gill-breather, was without a Thymus, had become possessed of one, in commencing aerial respiration. Indicat hujusmodi instantia non obscure veras sectiones naturæ, et mensuras rerum, et illud QUOUSQUE natura quid faciat. (Nov. Org. ii. 34.)

PISCES. In fishes, after repeated and careful search in above twenty genera, I have been unable to discover any signs of a Thymus. Carus suggests a doubt whether the peculiar substance which surrounds the heart of the sturgeon, should not be considered a Thymus gland. I have carefully examined some recent specimens without finding any reason for modifying the opinion stated in the text. The substance in question presents no structural similitude to the Thymus of other animals, and differs from it remakably in position, being situated *within* the pericardium, so as to surround the bulbus arteriosus, and descend on the surfaces of the heart.

I have likewise thought it requisite to examine the peculiar apparatus of clustered follicles surrounding, within the pericardium, the large systemic veins of certain Cephalopodous Mollusca. Here, as with the sturgeon, the structure displayed by the microscope has not been such as to warrant any exception to the law above stated. Without hazarding any positive opinion on the structures referred to, I will merely express my decided conviction, that they are not in any manner analogous or comparable to the Thymus.

CHAPTER V.

MORPHOLOGY OF THE THYMUS.

THE preceding chapters have been purely descriptive; they have recorded the results of dissection, microscopical observations, and chemical analysis; they contain the materials for hypothesis.

But, in order to interpret the facts thus furnished,—in order to assign them their legitimate value, and to deduce from them sound physiological conclusions, it now becomes necessary to contemplate a larger sphere than that occupied by the mere single organ in question. Neither the structure of the Thymus, nor its actions, nor its uses, can with advantage be made the object of isolated study. Its physiological history belongs to a system, and cannot be contemplated irrespectively of this. Many comparisons are needed, and many contrasts. There must be directed to the subject all such collateral light, as considerations of analogy can supply: the organ must be compared in all its parts and relations—tissue for tissue, element for element, directly and indirectly, with such as are nearest akin to it, and are better comprehended by us: "harum enim (fœderis instantiarum) optimi sunt usus ad elevandum et evehendum intellectum a differentiis ad genera, et ad tollendum larvas et simulacra rerum, prout occurrunt et prodeunt personatæ in substantiis concretis."[1]

With what organs may the Thymus be compared?

The Thymus Gland has long been associated in anatomical teaching with certain other bodies of equally obscure function; namely, with the spleen, the supra-renal capsules, and the thyroid body. We may naturally inquire, whether this classification has been made in the light of ostensible affinities; whether the several members of the order so constituted are actually bound together by physiological relationship, or merely dwell side by side as joint tenants of a common obscurity. Henle, whose knowledge and judgment are of the highest worth, adopts the latter belief: "These organs are connected with each other," he says, "chiefly by the fact that, in regard of their intimate structure and physiological meaning, they are all equally and utterly unknown to us."[2]

Conscious of the importance of the question, I have extended my researches to the physiology of this entire class of organs, and have carefully investigated the minute structure and functions of each. The results of this inquiry enable me to affirm with confidence, that they do constitute a strictly natural family; that, in all the elements of their composition, they admit of detailed comparison with the so-called *true glands* of the body, forming a series parallel with theirs; and that the title of *glands*

[1] Bacon, Nov. Org. ii. 35.
[2] Von den Blutgefässdrüsen; Allgemeine Anatomie, p. 996.

without ducts, for a long while vaguely applied to them, rightly expresses these homological relations.

It seems to me so indispensable for the full exposition of my subject that these facts should be clearly developed, that I must beg permission to dwell on them at some length. Accordingly in the next ensuing pages, before advancing to the consideration of what is peculiar in the Thymus, I shall demonstrate the characteristics of the class to which it belongs; and, while justifying the constitution of this class, shall endeavour to illustrate the points of similarity and of difference, by which the organs included in it are related to the true glands; the points, in short, by virtue of which the function of these bodies may be considered as forming part of the general problem of secretion.

Section I.

Morphology of the True Glands.

The first and indispensable preliminary is, definitely to fix the standard of comparison. What constitutes a true gland?

The admirable researches of Müller have shewn us, that a gland is but some mechanical modification of the general mucous surface, some development or involution thereof (more or less as a branching follicle, more or less as a tortuous tube) in order to economise space, by conveniently packing in small compass the largest area of secreting membrane.

Yet this general elucidation of the subject only postpones our query, or alters its form: we have still to learn the essential anatomy of the surface, thus folded into the compactness of a gland; we have still to ask what are the organic means for secretion.

Seven years ago, scarcely a step had been made towards removing the difficulties of this inquiry. Purkinje, Valentin, Henle, and Schwann, have since then accomplished what Müller commenced; and the leading facts, which we owe to their industry, are now recorded among the tritest topics of physiological science. It is impossible to approach any question of structure, on which the labours of these great physiologists have not cast light; and difficult to advance any opinion—almost to state any fact—worthy of notice, without trenching more or less on the peculiar original views of some one of them. However, in the next following paragraphs, I shall refrain from quoting them otherwise than by occasional allusions: not only because in matters of detail they sometimes differ so much, that quotation would involve criticism and thus interrupt the argument; but, more especially, because (with all the obligation to their discoveries and to the spirit of their works, which I am proud to acknowledge) I have in no case taken their statements for granted, but have written in every particular from my own observations of structure.

The organic means for secretion, as illustrated in the anatomical structure of true glands, may be stated to consist in an arrangement for the growth of deciduous cells, in close relation with blood-vessels on the one hand, and with an evacuant channel on the other. Essential anatomy of secreting organs.

All the chief acts of the vital economy are carried on by the medium and instrumentality of cells: in evidence of which fact it will be sufficient to cite the process of growth in its various modifications,—whether as seen in the development of the embryo, or in the repairing of injured textures, or in the organization of morbid products. Further, by the proportion in which these microscopical elements (or their rudiments, or their reliques) are present, we are enabled to measure the functional activity of any particular organ; their plenteousness and constancy are direct indications of abundant organic change—of life active in the part: witness comparisons of gray with white nervous matter, of mucous with serous surfaces, of ossifying with permanent cartilage, of muscular fibre (whether voluntary or visceral) with tendon and areolar tissue. Cells.

Now, in examining under the microscope a thin section of any one of the true glands, we find its bulk mainly consisting of cells, or their rudiments, in the closest possible aggregation; nowhere in the adult body do we find greater evidence of nutritive activity than in such a specimen; it is as obviously a growing structure as if it had formed part of an embryo. And when, after contemplating the important functions discharged by cells in other organs of the body, we turn to consider the use and object of their extreme preponderance in glandular structure, we are impelled to believe their essential connexion with the processes here effected. Every analogy leads us to anticipate that, here as elsewhere, they should be the media of organic change,—that their growth should inseparably identify itself with the manifestation of whatsoever specific materials it may be the function of their particular gland to eliminate from the system. But this theory does not rest on conjecture; it is amply supported by the results of observation. Almost every gland in the body contributes its share of evidence and suggestion; however, lest I should occupy too much space with these indirect elucidations of my subject, I shall restrict myself to a few unquestionable examples. Their functions in glands:

In the liver, it is quite certain that the bile is for a period contained within the cavity of the cells. Henle[1], in confirmation of Hallmann's observation[2], states that he has seen these corpuscles of a yellowish tint, and ascribes that hue to the colouring matter of their secretion. But the natural appearance of the liver-cell is liable to certain exaggerations, which, though they originate in disease, are yet serviceable additions to the knowledge derived from healthy structure. For instance: the frequency of enlargement of the liver in cases of pulmonary disease, and its disposition to compensate for defective function at the lung by increased activity of its own secretion, had long been known; Louis had directed attention to the remarkable number of instances in which its fatty degeneration is found coincident with phthisis; and it was a natural illustrated by liver-cells; in health; in fatty degeneration;

[1] Allgem. Anat. p. 904. [2] Hallmann de cirrhosi hepatis, 1839.

step in pathological reasoning to suppose,—as the two organs have a certain analogy of chemical action,—that this morbid development of fat in the liver might have reference to the superabundance of carbon in the system, which the diseased lung could no longer eliminate,—that it might be a sort of vicarious action. It is now known that the actual seat of this fatty deposit is within the cells of the gland, that there is in each cell a morbid increase of the oily matter, which it should naturally contain; and it is argued, with great probability, that these minute elements, so surcharged with their compound of carbon, are but the ordinary channels of health, and that the fat is but an exaggerated secretion of the gland, here surprised in its very transit from the system.[1]

and in cirrhosis. Still more conclusive is the evidence furnished by the following fact, as it relates to changes which have a merely mechanical origin. In cirrhosis, the essential primary disease is an inflammatory action, under the influence of which a quantity of coagulable lymph is poured into the interstices of the vessels and ducts; and, as this product of inflammation becomes organised, it contracts very closely, and surrounds with a dense capsule various isolated portions of the hepatic substance, or forms tough septa and constrictions within the liver and on its surface. By the condensation of this adventitious material, and by its pressure on the normal elements of the gland, there are produced various secondary results, which depend on mechanical obstruction; for example, partial atrophy of some spots with apparent hypertrophy of others; or again jaundice, or ascites. Under these circumstances (probably where the strangulation has especially told on some small duct, and has obstructed or obliterated it) we find certain circumscribed masses of the gland coloured with the deepest yellow, from intense biliary congestion. These parts will invariably present the microscopic appearance to which I wish to refer; namely, the ultimate cells are identified as the seat of this deep ochrous colouring,—they are gorged with bile. And, as this phenomenon cannot be ascribed to the physical cause of imbibition, (for it always prevails first and chiefly in the interior of the cell, and about its nucleus,) there appears no other possible explanation of its occurrence, than the theory here defended,—that the secretions of glands first manifest themselves in connexion with cells, or with their germs,—that the secretory process in glands is one with the cell-growth of their parenchyma.[2]

Crystals in gland-cells. In certain other glands I have likewise discovered a circumstance, which appears even more conclusive than that last mentioned, as to the point in question; viz., the

[1] W. Bowman, on the minute anatomy of fatty liver; Lancet, Jan. 1842.

[2] This deep colouring of the liver-cells (which I have found a pretty constant part of the morbid anatomy of cirrhosis) is by no means unusual, as a healthy phenomenon, in the Invertebrata. Mr. Goodsir drew attention to its occurrence in Mollusca, in his able paper on the physiology of secretion (Transact. of R. S. Ed. vol. 15) and employed it with other facts of the same kind, in his endeavour "to connect secretion with growth as phenomena regulated by the same laws." Mr. G's. opinion (as here expressed) has my entire concurrence; but I cannot so readily participate his belief "that the cell-wall itself is the structure, by the organic action of which each cell becomes distended with its peculiar secretion at the expense of the ordinary nutritive material which surrounds it:" . . . . or, "that it is endowed with a peculiar organic agency according to the secretion it is destined to produce:" the nature and grounds of my dissent from this doctrine will appear in the course of the ensuing pages.

occurrence within a nucleated cell-membrane of solid saline materials, corresponding to those of the secretion. In the urine of fishes, for example, and in the thyroid secretion of many animals, microscopical crystals frequently occur in considerable quantities; and, even where the crystalline form is incomplete, the same peculiar product may be recognised by its dioptric qualities, as its minute masses float in the fluid. In several instances, while examining the kidneys or thyroid gland with the microscope, I have noticed that certain of the cells (unquestionable cells, with complete membranes and distinct dotted nuclei) have been distinguished from those in their vicinity, by the fact of their contents possessing the same refractive properties as the floating particles of the secretion: often too, I have succeeded in distinctly recognising a crystalline arrangement in these inorganic contents of a cell.[1]

Generation of spermatozoa.

Another well-known instance of the generation of eliminable products within the limits of a cell-membrane is furnished in the secretion of the testis. We there witness the development of the spermatozoa, occurring step by step within the cell; and I have frequently seen bundles of them—like tufts of grass—still adherent by their one extremity to the relique of a cell (probably its nucleus), while, in the opposite direction, their free ends have maintained lashing movements, scarcely to be distinguished from the ciliary.[2]

Cytoblast probably the essential part of the cell.

There are many reasons for believing that the so-called nucleus, or *cytoblast*, of a cell is its essential part, and capable by itself of fulfilling the entire functions which have been generally ascribed to the wall of the complete cell; and it is highly important for the physiological understanding of the glands without ducts, that the grounds of this belief should be examined.

It appears that in the development of secretory cells, there are the following steps: First, the formation of the nuclei; Secondly, the deposition of material around them; which step seems the first evidence of their peculiar function; Thirdly, the isolation of this material by the growth of a membrane about it,—in other words, the completion of a cell, which has now all its elements—nucleus, membrane, and contents; Fourthly, a stage of apparent quiescence, during which the specific contents of the cell are probably either increased in quantity, or brought to greater concentration; a stage, in one word, of ripening: Fifthly, the falling of the cell with its contained material, in the form of excretion.[3]

[1] Every practical microscopist will remember various optical illusions, which may give to minute floating crystals, when examined with high magnifying powers, a false appearance of being enclosed in delicate cell-membranes: but careful examination, with the assistance of chemical reagents employed under the microscope, will, I am persuaded, confirm the accuracy of the above-cited observations.

[2] It is surprising that any doubt can continue on the nature of these curious fibrils: that they are, so to speak, floating cilia—cilia, losing earlier than wont their primary connexion with a cell, and assuming freedom of motion for the sake of a special use—seems clearly established by the history of their development, and by the observation of a period in their existence, when they have all the characters of ordinary cilia.

[3] There is room for some little doubt in respect of this final stage in the secretory process, as to whether the cells (where completed) are in all cases deciduous, and discharge their contents only by their own dissolu-

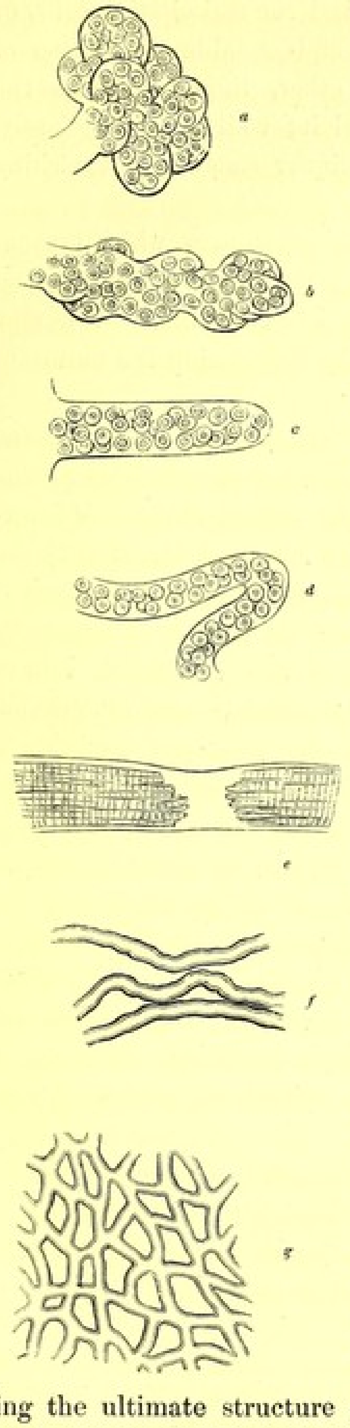
Now, in certain cases (and these bring us very near to the habitual state of the glands without ducts) it seems that the third stage of this process is absent, that no cell-membrane is formed, that the nucleus, with the material developed round it, constitutes the sole physical evidence of activity in the part. Indeed, in all glands this stage appears far less complete than in other organs of the body; in most it seems an exception, rather than the rule, to find the cell-membrane perfectly and definitely formed; the liver is the chief—if not the only—instance to the contrary. Moreover, where we are able to trace the products of secretion actually within a cell (as in the above-quoted instance of cirrhosis of the liver) we find them either exclusively, or at least with a very marked predominance, accumulated in that portion which corresponds to the nucleus; as though this corpuscle were the true centre of attraction, and the cell-membrane only the boundary, or passive recipient, of the matter to be excreted.

Cell-membrane. These considerations and—still more forcibly—various illustrations which may be gathered from the history of the suppurative process and from other pathological phenomena, lead us to the following conclusions: viz., (1) that the cell-membrane—whether perhaps it exert any specific vital influence on the matter with which it has contact, or merely serve for the mechanical isolation of its contents—must be viewed, at least in the secretory process, as a secondary and inessential formation: (2) that its existence, in nutrition generally, bears relation to the rate and perfectness of the cell-growth, and to the permanence of the organic combination effected in that process; that it will not occur where the particular nutritive act is ill-supported by the economy, where it is either absolutely or proportionally accelerated, or where (as in instances presently to be specified) the peculiar functions which have their centre in the nucleus, are exerted for a short time only, and for temporary purposes; (3) that (in respect of secreting organs particularly) the nucleus—from its constancy, from the priority of its formation, and from the peculiar arrangement which the secreted matters assume in reference to it—must be considered as the characteristic and essential part of the apparatus, not requiring the completion of a cell in order to the performance of its functions; and (4), that the act of secretion, though essentially homologous with ordinary molecular nutrition, is peculiarly prone, in various cases and for various reasons, to exhibit its process of cell-growth in a low, and as it were, aborted form.

When I state that this lower condition of cell-development is the one usually manifested in the structure of the glands without ducts, and especially in the Thymus, it will not, I trust, be thought that I have wandered from the proper limits of my subject in the foregoing argument; the application of which will follow presently.

tion; or are, on the other hand, more permanent than this theory would suppose, extending their function over a longer period, yielding their contents by mere transudation, and thus transmitting a large quantity of secretion in successive instalments. The larger array of argument is on the side of the former opinion, as stated in the text: indeed, the single instance of the sebaceous secretion would be conclusive on the subject, if we were warranted in assuming an absolute uniformity for this particular stage in all secreting organs.

Fig. 47.



LIMITARY MEMBRANE IN GLANDS.

Having examined, as far as my space will permit, the physiology of the cells and cytoblasts in true glands, I have next to trace the presence and arrangement of another, nearly universal tissue.

If we examine, with a magnifying power of 300-400 diameters, the structure of a true gland, e. g., of the pancreas or kidney, we find that its assimilating cells are included within a simple continuous tunic; and, as we extend our inquiry, we learn that varieties in the arrangement of this membrane determine the several shapes affected in the ultimate structure of glands. Thus, whether we examine the botryoid vesicles of the salivary glands (fig. 47, *a*), the bulging tubules of the stomach (fig. 47, *b*), the simple follicles of the intestine (fig. 47, *c*), or the long windings and uniform calibre of the urinary and spermatic canals (fig. 47, *d*), we observe the outline of each various form to be marked and limited by the homogeneous membrane referred to.

It is not peculiar to the true glands, but belongs equally to those without ducts; although it has been almost overlooked in their structure, and never correctly described. Nor is it even distinctive of the generic anatomy of glands; for a tissue identical with it is seen bounding the fasciculi of voluntary muscle (fig. 47, *e*), and the tubules of the nervous substance (fig. 47, *f*), as likewise occurring in various other situations. In the mucous and vascular systems it has been named *tunica propria*, or *basement tissue;* in the structure of muscle, *sarcolemma;* in that of nerves, *tubular membrane* or *neurilemma:* but, in each case, its anatomical relations are the same; it is, in each, the *barrier between nutrient vessels and the products of nutrition*,—a barrier that serves to support and to circumscribe the latter, but yet affords ready transit to the materials of constant renovation supplied by the former. Its functions and hysical characters are strictly identical in all its various positions, whether it be seen as the single tunic of a capillary blood-vessel (fig. 47, *g*), or as bounding the ultimate structure of muscle, nerve, or gland; I have therefore ventured to apply to it a name which suits it equally in all these relations, and have, throughout this essay, spoken of it as the LIMITARY MEMBRANE.

It extends, with more or less development, into every organ with deciduous cells, and

Its relation to their other elements.

constitutes in all (with certain rare but striking exceptions) a definite, but permeable, wall between the capillary blood-vessels on the one hand, and the assimilative cells, or cytoblasts, on the other. On its one surface, is the slow and equable circulation of blood through the finest network of capillaries; on its other, there advances the constant function of cell-growth, as I have above described it; while, intermediately, its own delicate tissue imbibes and is traversed by the liquor sanguinis, furnishing materials for the secretory process.

Its absence in certain cases.

It is absent from its ordinary relations in three remarkable instances, which present themselves respectively in the liver and kidney, amongst the class of true glands, and in the spleen, amongst the corresponding group of glands without ducts. We may perhaps be aided in an appreciation of the use of the tissue, by considering the nature of these exceptions to its existence.

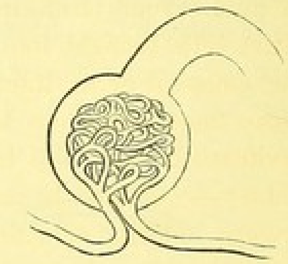
Liver.

1. In the liver of vertebrate animals the limitary membrane belongs only to the excretory tubes, and does not extend into those remoter portions of the gland, where the act of secretion is performed. There, the assimilative cells lie naked, filling the interstices of the capillary network, and in direct contact with its minute vessels: they are exposed without hindrance, or intermedium, to the agency of the liquor sanguinis, as it sweats through the porous tunic of its own canals.

Kidney.

2. In the kidney (according to Mr. Bowman's important observation, which I have repeatedly verified), the secreting tubes have at their distal ends a very remarkable arrangement. The limitary membrane of each tube terminates by admitting within its cylinder (here dilated for the purpose) a cluster of capillary blood-vessels; it fixes itself around the root, or stem, of this vascular glomerulus (the Malpighian body), so that the capillary loops in question are left free and bare within the ampullated extremity of each secreting canal (fig. 48). The result of this arrangement is here, as in the former case, to afford to the assimilative cells the utmost possible freedom of communication with the plastic material of the blood.[1]

Fig. 48.



[1] On the structure and use of the Malpighian bodies of the kidney by Will. Bowman, F.R.S. My friend and colleague, in his excellent paper on this peculiar arrangement, maintains an opinion respecting its object, which seems to me scarcely compatible with known physical laws. He supposes that the Malpighian capillaries give passage to the watery parts of the urine alone, and that the tubular plexuses secrete its salts and peculiar principles. Surely this is a physical impossibility: a transudable organic membrane, such as is the delicate wall of capillary blood-vessels, cannot give passage to "watery parts" of a fluid, without likewise admitting whatsoever is held in solution by them. If the salts were merely *suspended* in the fluid (as the blood discs are) the filtration would be complete; the water would pass, and the *corpuscular contents* would remain. But in regard of *solutions* (and the liquor sanguinis is a perfect one) the rule is totally different; whithersoever the menstruum passes, thither of necessity it conveys its *dissolved contents*. This physical distinction appears to have been overlooked in the theory referred to. (Vid. Phil. Transact. 1842, p. 73, et seq.)

In further reference to Mr. Bowman's interesting discovery, I may take the present opportunity of recording that I have often verified his observation of ciliary motion at the origin of each uriniferous tubule in the frog; and not only here, but I have likewise seen it in the kidneys of various other reptiles, and also, with perfect distinctness, in the skate. Among the higher vertebrata I have found no trace of it.

3. The analogous arrangement in the spleen, with its peculiarities and objects, may more fitly be detailed hereafter; I will now only cursorily mention, that it has many features in common with the instance last described, and tends to corroborate the opinions which I shall deduce from the anatomy of the true glands. Spleen.

In each instance cited, the absence of a limitary tissue appears to depend on some peculiar necessity in the organ, requiring that the access of liquor sanguinis to the glandular cells should be facilitated in the extremest degree. In each case, the supposed end is attained by a similar modification of structure—namely, by the removal of the limitary membrane; as though this tissue were (which in my belief it is) a merely mechanical element in the constitution of the gland. That it does fulfil mechanical uses, in supporting the minuter elements of structure, in binding them into continuity, and in furnishing a membranous plane for the expansion of the capillary network, is certain; that its uses are merely mechanical, I infer from its absence in the cases quoted, where the modification, needed and afforded, is likewise merely mechanical. For it can scarcely be doubted, why the liver and the kidney should be thus privileged in their means of acting on the blood. In the former there are mechanical disadvantages that require to be counterbalanced; the portal circulation is almost destitute of the impetus which favours the function of other glands; it has traversed the minute canals, and overcome the friction of one system of capillaries, at the expense of its first momentum; its tardy and feeble flow through the liver would scarcely suffice to maintain an equal distribution of fluid beyond the nearest vicinity of its capillaries, and we accordingly find the assimilative cells brought into closer connexion than usual with these sources of growth, by the omission of an intermediate tissue. And while the object here is to afford to the organ those conditions for *ordinary* and *average* rapidity of secretion, which its vascular peculiarities must else have compromised, the aim in the other instance—that of the kidney—seems to be an endowment of the organ with *extraordinary*—with *more than average*, velocity of action, in order to qualify it in the best manner for the office of regulating the volume of circulating blood by the constant and unretarded elimination of its fluid excess. But for this peculiarity in the organization of the kidney, and its consequent facilities for rapid function, a summer draught of water would be the occasion of dangerous plethora. Uses of limitary tissue probably mechanical.

Comparative anatomy strongly confirms the opinion here advanced respecting the function of the limitary membrane in glands. On the supposition that its uses are merely mechanical, I have endeavoured to explain its omission in the liver, as the natural compensation in that viscus for a prior peculiarity of structure, and its partial absence in the kidney as the natural provision for an ulterior speciality of function. I have argued that there must be a certain proportion in glandular organs between the *impulse* of circulating blood on the one hand, and on the other the *resistance*, or thickness of texture to be percolated with liquor sanguinis; that a change in one side of this balance either involves a corresponding re-adjustment of the opposite scale, or manifests itself by Illustration from comparative anatomy of liver.

a peculiarity in the secreted product; that the former of these alternatives is illustrated in the liver, where the weakness of the portal current finds its compensation in an unusual proximity of the gland-cells to the capillaries which nourish them; that the latter is witnessed in the kidney, where ordinary momentum with diminished resistance has for its result—as one would anticipate—unexampled rapidity of function. There is a ready test for the validity of this argument in the comparative anatomy of the liver. The weakness of circulation through it (necessitating, as I argue, the omission of a limitary membrane) is not universal; a portal vein belongs only to the vertebrata: in the other great division of the animal kingdom, the liver, where it exists, is nourished by arterial blood. It is on a par with other organs of the body, in respect of the force of its circulation; in acquiring this parity of nourishment, it has no further need for the structural privilege that previously marked it. Nor is it any longer thus distinguished: in the livers of all such invertebrate animals as I have examined, (and the number includes several, both molluscous and articulate,) I have always obtained without difficulty the clearest evidence of a limitary tissue, in the form of more or less elongated follicles.

BLOOD-VESSELS OF GLANDS.[1]

The remaining matter for remark in the structure of the true glands is in regard of their vascular organisation. The larger arteries and veins follow no common law; in some glands (as the liver, testis, and kidney) they are single; in others (as the salivary glands) they are numerous; but in all they are subject to such frequent irregularities, as prove this portion of their anatomy to be of small consequence. That which is essential to function seems rather to be contingent on the nature of their ultimate, capillary distribution. In examining this, we invariably find it to be such as may most effectively and uniformly diffuse the materials of nutrition amid the characteristic structures of the organ: it is a network of the extremest delicacy and closest woof, cast round about the ultimate tissues of the gland, and divided by the limitary membrane alone from the cells, or cytoblasts, which it serves to nourish. In the kidney, besides the plexus which encloses the convolutions of each tube, there is the remarkable cluster of bare arterial capillaries within the dilated commencement of each; and in the liver, likewise, the general description requires to be somewhat modified: but, with these exceptions, the arrangement of capillaries may be described as that of a retiform plexus, with exceedingly minute meshes, spread over the surface of the limitary membrane and accurately following its distribution, whether in lacuna, tube, or vesicle. Since these capillary blood-vessels are composed but of the thinnest homogeneous tissue, it is clear that their walls must be saturated, and freely and perpetually permeated by the fluid

[1] It will no doubt strike the reader that, in the present argument, I have not alluded either to the distribution of nerves in glands, or to the influence they may be supposed to exert over the act of secretion. The omission has not been one of forgetfulness: on the contrary, I have given much study to the subject, and had designed entering on it here at some length. But I have found it impossible to complete this part of my researches in the physiology of nutrition, sufficiently soon for incorporation with the present essay. I hope for some future opportunity of maturing and publishing my views on the subject; meanwhile I had better leave it untouched, than hazard the statement of imperfect experiments and speculations.

parts of the circulating blood: and, since the same physical property of imbibition is possessed likewise by the limitary membrane, which divides the vascular network in question from the peculiar cells of the glandular parenchyma, we may justly consider that these last lie in an atmosphere of liquor sanguinis, and are developed in it, as their blastema.

The organic means for secretion, in their simplest essential form, may accordingly be expressed as a more or less complete growth of cells, in free communication with the blood circulating through capillary vessels; and the steps of the secretory process appear to be the following, viz.: First, the complete *imbibition* of the ultimate tissues of the gland with liquor sanguinis; Secondly, the exertion of a *catalytical force*, under the influence of which certain elements of that fluid withdraw themselves from it, and pass into the structure of cells, or into some other organic combination, with cytoblasts meanwhile arising; Thirdly, the *return* into the circulation of the residual matter. PROCESS OF SECRETION.

An inquiry into the detail of these molecular changes, and into the vital and physical laws which govern them, comes strictly within the scope of the present essay; for these topics are equally included in the physiology of every organ of secretion, and their elucidation would of course involve a better knowledge of our more especial subject. But our positive information respecting the ultimate nature of the processes referred to, is yet insufficient to establish any coherent theory of secretion; and I shall accordingly dismiss the subject with few additional remarks.

The first and third stages, which I have enumerated in the act of secretion, are necessary results of the physical constitution of the parts: for How far to be explained on known physical laws.

1. By force of the mere property of imbibition, which is common to all organic substances, (and which in the present instance is no doubt materially assisted by the continued impetus of arterial circulation, maintaining an uniform distension of the minute blood-vessels,) the liquor sanguinis must transude the walls of the capillaries which convey it, in such quantity as to saturate the secretory apparatus of the gland.

2. That the residue of this exuding fluid (that which remains after the abstraction of matters to be eliminated, and which, in reference to the total composition of the liquor sanguinis, may be considered complementary to the particular secretion) must return to the circulation—admits of explanation and proof on the well-known physical laws of endosmosis.

3. The intermediate stage is that which includes the whole mystery of secretion,—a process which Physics and Chemistry, even in their present development, are utterly incompetent to explain. Certain molecular changes ensue in the eddies of exuded fluid: partial solidification occurs, and partial decomposition. By the former of these steps there are presented a vast number of cytoblasts, or nuclei; around which—as so many quiescent centres—the ulterior catalytical changes of the fluid take place. The development of cytoblasts is nowise peculiar to glands; it is a general phenomenon in the œconomy, scarcely separable from the various organic applications of the blood; the

process seems almost mechanical—almost akin to subsidence or crystallization. But simultaneously with the evolution of these corpuscles—a *generic* manifestation in the several nutritive processes—occur other changes which are eminently *special:* certain chemical elements (specific for each particular gland) are aggregated round the nuclei as they rise; each cytoblast becomes a determinate centre, round which the atoms of the nascent secretion may range themselves. Some physiologists have spoken of these nuclei, or cytoblasts, as though they were independent organs, with various inherent chemical properties,—as though they effected the catalysis of the effused liquor sanguinis, just as acids or alkalies effect the decomposition of particular salts,—as though they exerted specific elective affinities, varying in the several glands, but in all of a purely chemical nature. This view seems to me scarcely less erroneous, than if one should suppose the poles of the voltaic battery to be—in themselves—the agents of electrical decomposition. The cytoblasts are a common product of all glands, and in all have the same chemical characters: whether from the testis, or kidney, or pancreas, or liver, we are unable to discover in them any distinctive sign of their origin—any differential chemical character; in these various organs they have identical properties, and are probably always of the same ultimate composition as the plastic fluid in which they are developed. I would accordingly consider them in their various places, only as so many passive centres, round which severally the materials of secretion collect themselves; I would consider them not as, themselves, the agents of change, but as mere foci of action, and as representing aggregatively in each organ a pole of manifestation for particular chemical products.

In arriving at this point—the specific nutrition of gland-cells—we are as far as mere Anatomy, or *Statical Physiology*, can conduct us; yet how distant still from understanding the actual nature, the actual mystery, of the process! Doubtlessly it is a great generalisation—one that fills the mind of the physiologist with a sense of beautiful harmony—to find, as has been found, that the nutritive and secretory processes are essentially one; their organic instruments alike; their traceable steps parallel. But let not this brilliant discovery be misunderstood, or misapplied; the law developed in it is morphetical, and this merely. Whether we are occupied with the large, or with the little; whether we collect the flowing secretions from divided ureters and gall-ducts, or —armed with all optical resources, and standing on the very confines of the visible world—view the first molecules of bile and of the lithates, as they gather in their respective cells; equally in either case the pursuit is mere anatomy; equally in either case we are in the domain of form and phenomenon, not in that of power and law. With respect to secretion, the microscope has only shewn us in ultimate detail what for ages had been known in its broader features; it has but revealed of the molecules that which was known of the masses. Physiological difficulties are not contingent on size: "Why does the liver-cell contain oil-globules and yellow matter, rather than urea and the lithates?" is a riddle involving the same speculations and requiring the same answer, as that plainer question of our forefathers, "Why does the liver secrete bile rather than urine?" For the solution of these doubts, it is in vain that we scrutinise the lifeless molecules and mechanism of the dissected body. The glands are too essentially alike for us to venture on ascribing to their fancied diversities of affinity and filtration the manifoldness of their several products.

This problem — fundamental in the philosophy of secretion—essentially belongs to *Dynamical Physiology.* Its solution cannot be conceived otherwise than in close dependence on some more developed system of Animal Physics than we yet possess, and on some more comprehensive science of Organic Chemistry. For the kindling of these lights, Physiology must wait anxiously; yet not idly. Premature, imperfect, and unphilosophical as any actual theory on the subject—with our present scanty data—would of necessity be, we yet cannot but entertain some vague presentiment of the nature of the future discovery. For, as we observe the blood, amid all its course and various functions, maintaining an uniform constitution; as we see it evolving in various directions elements of the utmost diversity,—but these, however different, always related to each other by such laws of reciprocal correspondence, that any one secretion may (in respect of the mother-fluid as a whole) be considered complementary to the others; as we mark, too, the essential similarity of all organs by which these various products are evolved,—we are involuntarily reminded of the play of polar forces. We find it just as difficult to separate the function of one gland from that of another, or from the total phenomena of life, as it would be to sunder the two electrodes of a battery, or to conceive their correlative manifestations as independent and isolated forces. The respective secretory actions of the several glands, merging their individual characters in a common dependence, appear but plural functions of a single power; as though the entire blood—submitted to some mysterious electrolysis—presented at different poles the various elements of its decomposition.

Section II.

Morphology of the Glands without Ducts.

Having endeavoured in the preceding Section clearly to set forth the essential anatomy of true glands, and the nature of the processes occurring in them, I now, in pursuance of my scheme, proceed to apply the standard of comparison so obtained to the interpretation of the structure and functions of the Thymus.

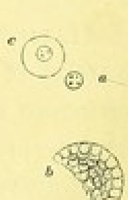
However, as I previously stated, in order to give complete clearness and effect to this morphological comparison, the Thymus must be viewed conjointly with other organs of kindred nature. Some of its elements do not admit of being directly compared with those of true glands, but require to be collated first with other transitional forms. Our means of making these intermediate comparisons lie entirely in the class of glands without ducts; and it will be found that an analysis of their anatomy, in relation to that of the true glands, affords the completest elucidation of all that would else be obscure in the elementary structure of the Thymus.

The special distinction of the *glands without ducts*, is found (as their name implies) in the circumstance of their lacking an apparatus of excretion; while their generic affinity to the true glands consists in their possession of all the organic means for secreting—though only into their own closed cavities. I shall now analyse these means for secretion, in the same order as was adopted in describing the true glands.

CELLS. 1. It is in the phenomena of CELL-DEVELOPMENT that the glands without ducts require the closest observation and study. Their universal possession of dotted corpuscles, such as Hewson discovered in the Thymus, has within the last few years been matter of notoriety and interest; and among the many hasty generalisations that followed Schwann's discovery, was an endeavour to include these corpuscles in the new theory, with the signification of *nucleated cells*:—wrongly, however; for it is not to the complete cells of the true glands, but to their cytoblasts, that these corpuscles exactly correspond; and their peculiarity is the comparative rareness, or imperfection, of any ulterior development in their structure. They are discoid, and of about the size of blood-corpuscles (in the spleen and supra-renal capsules somewhat larger, in the thyroid and Thymus rather smaller), but possessing less thickness. They have the general appearance and physical properties of those dotted discs which we encounter, as the nuclei of cells, in true glands and other structures of the body; and they are, as I shall shew beyond doubt, identical with them in function. Some little space must be given to an account of their differential characters in each of the four bodies under consideration.

In the thyroid gland. *α*. In the *thyroid body*, the habitual stage of cell-development is that of the dotted corpuscles just mentioned, which are seen floating in the pellucid fluid that fills the natural cavities of the gland (fig. 49 *a*, and 52 *a*). In the fœtus and young subject, they lie in close apposition upon the inner surface of the limitary membrane presently to be described; they form a single layer, and are connected with each other by some finely granular material occupying their interstices; they thus compose perfect closed cavities, which seem hardly to require a limitary tissue for their completion; and fragments of these hollow spheres may be seen lying in the field of the microscope, like portions of a minute vaulted brickwork (fig. 49 *b*). In the progress of growth, these corpuscles detach themselves from the walls of the cavity, and are found floating in its pellucid contents: sometimes they nearly vanish in particular parts of the gland, and have at all times (owing to the greater abundance of fluid in which they float) the appearance of being much scarcer than in the fœtus.

Fig. 49.

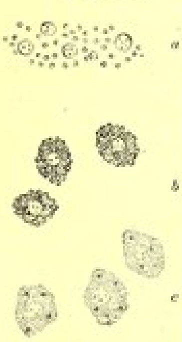


Although their arrangement, appearance, and chemical characters, might naturally induce the observer to compare them with the cytoblasts of true glands, still the evidence is yet hardly complete. But the deficiency is supplied in the fullest manner by the occasional development around them of a complete cell, to which they bear the undoubted relation of nuclei (fig. 49 *c*. and 52 *b*). The first occasion on which I discovered this interesting fact, was in examining a somewhat enlarged thyroid body from the person of a lunatic just dead Scarcely a dotted corpuscle could be seen in it, otherwise than as the nucleus of a cell; the cells, like the vesicles which they lined, were globular and turgid with fluid; they varied considerably in diameter ($\frac{1}{1000}$ — $\frac{1}{2700}$ in.), the greatest number being about $\frac{1}{1200}$ in.; their nuclei were the natural dotted corpuscles of the organ (which I may now securely name cytoblasts), presenting an exaggeration of their natural marking in the form of solitary refractive nucleoli. Since then I have repeatedly made similar observations, and have not only often detected the same appearance in the human subject, but have likewise occasionally noticed it in the lower animals; perhaps more frequently in the cartilaginous fishes than in any. The appearances have commonly been somewhat less marked than in the first case in which I observed them; the cells have seldom exceeded $\frac{1}{1500}$ in. diameter, and have been rather flattened from the globular form; their nuclei have not usually varied from the dotted appearance common to them, nor have they often presented such distinct nucleoli as occurred in the case just mentioned.

Thus, while the completion of cells within the cavities of the thyroid gland is assuredly a departure from the habitual state of that organ, and probably the evidence of protracted activity therein; it is yet just such a deviation as may serve, even better than uniformity, to illustrate the meaning of the structures which present it; for it shews beyond dispute that the dotted corpuscles are in reality homologous with the cytoblasts of true glands.

β. In the *supra-renal glands*, there is likewise a considerable range for differences of structural development. In many cases we find the dotted corpuscles immersed, without any definite arrangement, in an abundance of molecules (fig. 50, *a*; fig. 53, *a*), which have the appearance of some very finely divided oleaginous material: in other instances (which chiefly occur in adults) the discs are seen, each surrounded with granular matter, so as to constitute small separate masses, which have distinct outlines, but are not yet included within a definite cell-membrane (fig. 50, *b*): finally, in many cases the cell-growth will be found to have completed itself by the addition of the last-named structure; the cytoblast, the membrane, the contained material, will be seen—each distinctly; and the nucleated cell, with oily molecules amid its granular contents, has an appearance not unlike that of the secretory cells of the liver (fig. 50, *c*; fig. 53, *b*). There may accordingly be traced in these bodies all the steps of cell-growth;—first, the free cytoblast; next, the definite arrangement of molecules round it, as their centre; lastly, the inclusion of all within a membrane, which completes the cell. In the supra-renal glands.

Fig. 50.



γ. In the *spleen*, cells never occur with any approach to perfectness: the well known Malpighian vesicles consist entirely of mere dotted corpuscles lying bare within a capsule of arterial capillaries. I shall again revert briefly to the condition of this peculiarity, and shall, I hope, shew sufficient reason for interpreting the conformation of the Malpighian vesicles on the analogy of glandular apparatus, and for retaining these obscure bodies in the list of organs now under consideration. In the spleen.

δ. In the *Thymus*, one would at first believe a similar low stage of cell-development In the Thymus.

to be universal; for, in examining the contents of the gland in early life, one finds no trace whatever of complete cells. The dotted corpuscles are undoubtedly quite similar to those which we have recognised as becoming the nuclei of cells in the thyroid body, and in other organs: there is abundant room for conjecturing them to be of a correspondent function—to be, in fact, true cytoblasts: but the arguments for this point cannot be considered quite conclusive without some additional evidence. The desideratum has been, to display the dotted corpuscles of the Thymus actually occurring as nuclei of cells; and this demonstration has not been made by previous observers. Sometimes, as I have mentioned, with a total misapprehension of their homologies, these corpuscles have been, themselves, erroneously considered actual assimilative cells; but this opinion of their nature must have arisen in faulty observation, or in some premature generalisation independently of facts; for neither in size, shape, structure, nor chemical composition, do they at all resemble the cells in question Preceding pages of this essay record observations that are conclusive on the subject; (vid. p. 35, p. 48, p. 62;) they shew that under certain circumstances the ultimate structure of the gland undergoes a change, in the course of which its dotted corpuscles evince their true nature in the clearest manner, by entering, as genuine cytoblasts, into the structure of nucleated cells (fig. 51). In the next chapter I shall have occasion to confirm the view here taken of the nature of the dotted corpuscles of the Thymus, by explaining those peculiarities of function which here (as, in like circumstances, elsewhere) determine the long predominance of a low stage of cell-growth.

Fig. 51.

LIMITARY MEMBRANE.

2. The LIMITARY MEMBRANE admits of demonstration in the glands without ducts, co-extensively with its existence in the true glands:

In the thyroid gland.

α. In the *thyroid body*, where it is particularly strong and distinct, it assumes the arrangement of closed vesicles. These vary in growth according to the age of the subject, and other circumstances, from $\frac{1}{850}$ in. diameter to a size which renders them fully visible to the naked eye. Their primary form is spherical, but in the course of development they assume various irregular shapes, from reciprocal pressure.

The membrane possesses exactly the same physical characters as when presenting itself in true glands (fig. 52): it has about the thickness of the analogous tissue in the tubes of the testis, is transparent and strictly homogeneous. The vesicles formed by it, correspond by their exterior surface to a capillary network, which encloses them and by their interior to the cytoblasts or cells, which, with a pellucid fluid, occupy their cavity. In many of the lower animals, the gland contains far less areolar tissue than in the human subject; it therefore breaks more easily into its elements, and is better suited for microscopical examination. I have never seen the structure of the gland more perfectly displayed than in reptiles.

Fig. 52.

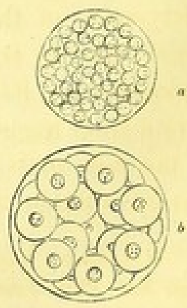
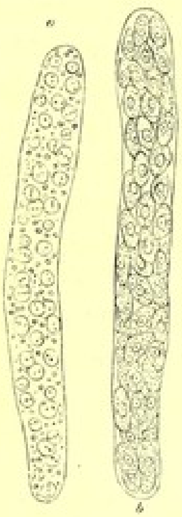


Fig. 53.



β. In the *supra-renal glands,* the limitary membrane has an inferior, though often distinct, development. It occurs in a very rudimentary form in young subjects, and may therefore be studied most satisfactorily in the adult. Its arrangement differs from that observed in the thyroid body, in being tubular (fig. 53); but in other more essential respects is analogous to it. Each tube corresponds outwardly to the capillary plexus, which supplies the materials of secretion; and inwardly to the molecular matter, cytoblasts, or cells. The cortical part of the capsule is entirely composed of these tubules; they run in lines perpendicular to the surface, and occasion that appearance of striation, which is visible to the naked eye. The texture of their limitary tissue is so delicate in proportion to their bulk, that it very readily gives way under examination; especially with that amount of compression, which the extreme opacity of the structure renders indispensable. These circumstances make it impossible to isolate any great length of tube; and it is therefore, of course, difficult to speak quite positively, as to whether the tubes ever communicate with each other. I have never seen anything which would lead me to believe that they do so; on the contrary, both toward the surface and in the depth of the organ, I invariably find such an abundance of blind extremities, as induces me to believe that the tubes are quite independent of each other, that they reach in a straight course from the surface to the interior of the capsule, and are closed in both directions. This is the most delicate form of limitary tissue, that I know of; but with ordinary care its existence and general distribution may be fully ascertained: and as easily in the human subject, as in any with which I am acquainted. The diameter of the tubes ranges from $\frac{1}{1000}$ to even $\frac{1}{350}$ of an inch; the majority are $\frac{1}{700}$–$\frac{1}{800}$ in.; their blind extremities have not appeared to me to exceed the capacity of the remaining portions. In the supra-renal capsules.

γ. In the *Malpighian bodies of the spleen* the limitary membrane is absent: why?

It would be foreign to my purpose to enter at any great length into the anatomy or physiology of the spleen, and I shall dwell merely on such results of my inquiries respecting it, as pertain intimately to the present subject. In the spleen.

The peculiarities in the structure of the spleen are two-fold: first, there is its highly developed and dilatable venous system, by means of which it is enabled to act as the safety-valve of the general circulation, and to palliate the ill-effects of various hyperæmial states by an almost indefinite turgescence. Thus, as Mr. Dobson[1] had the merit of demonstrating, its bulk alters according to the repletion of the system, sensibly increasing after a fresh ingestion of food, and gradually returning to its previous size, in proportion as the new mass of blood is appropriated by the several organs of the body, and the average volume of the circulation restored. The only respect in which this venous

[1] W. Dobson; Experimental Inquiry into the Structure and Function of the Spleen; Lond, 1830: also in Lond. Med. Phys. Journal, Oct. 1830.

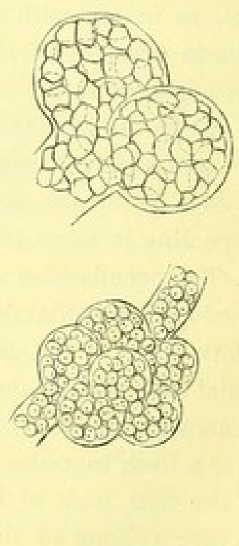
system of the spleen concerns our present argument, is in regard of the fact, that its mechanical functions are called into exercise frequently, suddenly, and transiently.

The other peculiarity in the organ is the presence of the so-called Malpighian vesicles. For each vesicle there is a separate twig of the splenic artery, which suddenly breaks into a capillary plexus, arranged in the form of a hollow sphere, and containing the dotted corpuscles within its cavity. As the corpuscles lie within this minute vascular network, they are not divided from it (so far as I can discover) by any intermediate limitary tissue.

The Malpighian vesicles, then, contemplated as a secretory apparatus, seem—both in their want of limitary tissue, and in the low stage of cell-growth which their elements present—accurately to correspond with those conditions of vital affinity, which Mr. Dobson's researches would lead us to anticipate in the spleen. They present the means of assimilation in the barest and most essential form, just such as might suffice for transient and occasional activity: their minute structure (as interpreted by analogous arrangements elsewhere[1]) quite agrees with what we know of the use and construction of the entire organ. Accordingly I would consider them as a system of minute and rudimentary glandular organs (of the order of glands without ducts); and, ascribing their peculiarities of structure to corresponding peculiarities of function, I would interpret them as the appropriate means for such acts of secretion, as are liable to be suddenly called for, are effected at frequent intervals, and extend over short periods of time.

It will be obvious to the reader, that I do not now attempt to explain the use of the spleen any more than I have sought to decide the uses of the capsules and thyroid gland;—I have merely endeavoured to shew, in each of these bodies, a structure in essential harmony with that of the Thymus, with a view to demonstrate that, in possessing analogous conformation, they constitute with it a natural order of organs, and exert their various functions on a common principle of homology with the true glands.

Fig. 54.



In the Thymus.

δ. In approaching the limitary tissue of the *Thymus* (fig. 54) the reader will anticipate my statement, that this it is which we have already noticed on several occasions. He will identify it with that simple diaphanous membrane, which, in early embryonic life, formed the primary tube of the nascent gland; he will remember how, by bulging and branching, it formed a ramified follicular system; and how it has been seen to constitute in the mature organ the exact boundary of the parenchyma. For these and other points of its anatomy, I will beg to refer back to my previous descriptions.

[1] For on the one hand, in the instance of the kidney, we have found in the partial absence of limitary membrane, a morphological indication that capacity for sudden action is a requisite of the part, and characterises its function: on the other hand, there are reasons for believing that the continued low development of

3. The ULTIMATE VASCULAR ORGANISATION of the glands without ducts is the same as that of the true glands; it consists in the distribution of a perfect capillary network around the assimilative elements. Thus, in the vesicular structures of the *thyroid body* and *spleen*, it assumes a spherical arrangement, and differs for the two only according to the differences of their general construction: so that in the spleen—where the Malpighian vesicles are scattered in the intervals of a predominating venous system—each vesicle has for itself a separate twig from the splenic artery, or from one of its main divisions; while in the thyroid—where the vesicles constitute the entire organ, and are closely compacted together—the vascular system appears common to the entire gland, by the free communications which exist between the capillary circles of contiguous vesicles. In the *supra-renal glands* (where the small arteries and venous radicles have been well described by Müller,[1] as running in straight lines to and from the surface of the cortical substance) the intermediate capillaries form a network arranged round the length of the tubules. In the *Thymus*, as I have elsewhere stated, the distribution of the plexus around the terminal vesicles is such, that it could hardly be distinguished from the secretory network of the pancreas. BLOOD-VESSELS.

SECTION III.

Recapitulation.

IF the two preceding sections have fulfilled their object, I may subjoin the following propositions as general results of the argument:

1. The *phenomenon of secretion* essentially consists in the manifestation of particular products around organic centres, or nuclei, which develop themselves in the effused plasma of the blood, and which, from their actual or potential relation to cells, are called cytoblasts. Act of Secretion.

2. The *cytoblasts* bear no varying relation to the nature of the particular secretion, but are in all instances of substantially the same composition as the liquor sanguinis from which they are engendered, and of which they may be considered a mere solidification. Cytoblasts.

3. The *materials of secretion*, if solid, arrange themselves in almost impalpable molecules around the several cytoblasts; if fluid, they constitute a common medium, in which the cytoblasts float. Secreted matters.

cell-growth is an evidence of instability, or hurriedness, in the organic combinations, which cells represent: and we may infer, that persistent cytoblasts, in actual contact with capillaries, constitute a form of structure well adapted for such manifestations of molecular affinity, as are required most suddenly and for the shortest periods.

[1] Müller, Physiology by Baly, p. 621; and Archiv., 1836, p. 306.

Cell-membrane. 4. The *completion of a cell*, for the isolation of so much of the secreted product as is collected round each cytoblast, is a very frequent secondary process. In the true glands it is very frequent; in those without ducts, exceptional. The steps of its development, and the circumstances regulating its existence, may be illustrated seriatim: viz.—

α. In the Malpighian glandules of the spleen,—where the secretion is fluid and can but rarely be detected by the microscope in a molecular form, where the nutrition fluctuates from hour to hour, and where the assimilative affinities are therefore exerted with equal intensity only for the shortest periods,—a cell rarely, if ever, exists.

β. In the Thymus,—where also during infancy, the secretion is fluid, and where (as I shall presently further illustrate) the assimilative acts probably vary in intensity over short and frequent periods, the persistence of cytoblasts without cells seems at first sight equally regular. And such is actually the case during the time of the gland's most active function; but when it becomes comparatively quiescent, or when (as in many reptiles and some mammalia) it assumes the characters of a permanent organ, it will be found that its cytoblasts have undergone their complete development, and become nuclei of the fat-cells which are formed within the limitary membrane.

γ. In the tubes of the supra-renal glands, where the product is solid, there is constant opportunity of observing that transitional stage, in which the secreted matters are closely aggregated in a molecular form around the several cytoblasts; here, too, the completion of a cell is frequent.

δ. In the vesicles of the thyroid gland, owing to the fluidity of the secretion, no intermediate stage of cell-growth can be seen; but cells, taking the characteristic cytoblasts of the organ for their nuclei, are often developed, and may be seen to contain a fluid of the same nature as that wherein they float.

ε. Where the secretion of mucous surfaces is hurried by irritation, the bulk of it is found to consist of floating cytoblasts, which would else have been nuclei of epithelial cells; and the suppurative process, which is a similar abortion of cell-growth, indicates the operation of like influences in its origin.

ζ. In the true glands, the formation of a complete cell is at once recognised as the regular type for secretory nutrition: The exceptions are very frequent, yet they admit of ready explanation on principles here stated; they are fallings short of the mature process, by the omission only of that which is in-essential; they are instances of unfinished development, under circumstances of local excitement or general ill-supply.

Blood-vessels. 5. The *vascular apparatus* is nearly identical in all organs of secretion; its main requisite being a distribution of blood in such delicate vessels, as may readily permit the transudation of its fluid ingredients.

Limitary membrane. 6. In most instances the cytoblasts are formed, and the particular products manifested on the surface of a *limitary membrane*, which divides them from immediate contact with the capillaries; but this tissue is absent under circumstances which exclude the possibility of its being essential to the process of secretion. It seems entirely subservient to the mechanical office of support: it is found in the true glands to be prolonged into the excretory apparatus, in those without ducts to be folded into closed tubes or vesicles; so as in the latter case to retain, in the former to conduct, the secretion.

7. A distinction, implied in this differing arrangement of the limitary tissue, divides the glands into the two classes, which I have compared and contrasted. The specific difference of the smaller group consists in their not excreting from the body those materials, which are shed into them from the blood. *Their secretion is into closed cavities.* GLANDS WITHOUT DUCTS.

8. The glands without ducts *vary in activity* according to varying circumstances; sometimes their cavities are distended, sometimes nearly empty. In the latter case, that, which they had withdrawn from the blood, must again have passed into it. Their common function.

9. The last fact strikingly distinguishes them from the Wolffian bodies, as shewing that their sequestration of peculiar materials from the blood is only for *temporary or occasional* purposes.

10. This metabolical action in regard of the circulation,—this alternate withdrawing and rendering up again of certain particular materials, may be called the *common function* of the class; they belong to the offices of vegetative life, and are accessory to the circulatory system; they act on the blood occasionally, in respect of its chemical constitution.

11. In that which relates to their *distinctive uses*, and to the particular products of each, the following are the steps of inquiry necessarily to be followed in the subject: viz., Their distinctive uses.

α. Since their functions are not of the same activity in all moments, what determines the variation for each? According to what circumstances of the general system is each most active? Do the fluctuations of activity extend over long, or over short periods? Do their respective functions sympathise with those of other organs—either co-operantly, or by alternation?

β. Since they secrete into closed cavities, and consequently, when exercising their functions, become filled with their own specific products to an extent that enables these to preponderate considerably over the secretory structure,—chemical analysis may be applied to their examination (the spleen of course excepted) with more advantage than to the true glands: it will furnish us (allowance being made for the presence of blood-vessels, areolar tissue, and the like) with so near an approximation to the nature of their several secretions as may suffice for physiological purposes, and enable us to express the function of each in the strict language of physical science.

γ. Comparative anatomy—in indicating how far in the animal kingdom the presence of each organ extends, and with what variations of development—will almost certainly either suggest a theory for its use, or serve to test and correct opinions derived from other sources.

CHAPTER VI.

PHYSIOLOGICAL CONCLUSIONS.

In the present Chapter I purpose briefly to review and combine the leading facts set forth in the earlier portions of my essay; but, previously to doing so, will beg the reader's attention for a moment to a verbal distinction, which can scarcely be considered unnecessary.

The terms "use" and "function" are often employed indiscriminately by physiological writers, as if synonymous and convertible. In strict language their meanings are widely different, and it will be convenient throughout the following pages, wherein the words frequently recur, to employ each in its exact, distinctive signification: taking "function" to mean merely that *which an organ does*, viewed absolutely and alone,—taking "use" to denote this action viewed *in its relations to the entire system;* "function," the organ's *method of fulfilling* an use; "use," nature's *application* of the function.[1] The difference, too, is more than verbal: for, as regards the physiological investigator, *function* is matter for direct observation; it is matter of fact: *use*, on the other hand, is often a subject for inference and theory.

Applying this verbal distinction to the instance before us, I would say that the preceding chapters of my essay (if their object is fulfilled) have shewn the Functions of the Thymus gland, and that the present one has to unfold its Use.

FUNCTION OF THE THYMUS: The Function of the Thymus may be stated in these words: by means of an apparatus strictly analogous to that of true glands, it secretes into a closed cavity certain particular elements of nutrition. Further, the secretion has been shewn to occur differently under different circumstances; viz.,

where a temporary organ; (1) In most animals it occurs only temporarily. The secreted matter then presents itself in a *fluid form*, and is related to the universal material of nourishment, the liquor sanguinis, by the closest affinity of ultimate chemical composition.

where a permanent organ. (2) In some animals, after discharging this temporary function, the gland gradually passes into the permanent exercise of a different, but analogous, act of assimilation, and manifests its secretion in the *solid form of fat.*

The latter condition of the gland may help us to the elucidation of its former state, for the general physiology of the formation of fat is sufficiently well known to us.

[1] For example, the FUNCTION of the stomach (*that which it does*) is to secrete a certain acid mucus; its USE (*the application of its function*) is to reduce the food to a condition in which its nutritive principles may be absorbed: or again, the FUNCTION of the lung is, to be the medium of a certain chemical interchange of gases; its USE, to provide for the supply of a vital stimulant and the maintenance of an independent temperature in the animal.

There are abundant grounds for affirming that where fat is normally set aside, the process occurs with a view to some further use in the œconomy, and the secretion is designed—like starch in the vegetable kingdom—for ultimate subservience to the nutritive processes of the organism.

In both cases cited, the function is essentially the same, and consists in the sequestration of nutrient material. How is this material hereafter to be applied?

Under what circumstances is the function exercised?

In recapitulating the circumstances under which the functions of the gland are most actively exercised, we have occasion to notice the following instances: first, that of *young animals* during the period of their growth, and especially during the earliest part of that period: secondly, that of *hybernating animals*, previously to the commencement of their winter torpor. On a comparison of these instances, it is easy to say what the conditions of hybernation and of early life have in common: *in both, the waste of animal tissue is reduced to a minimum.*

By principles developed in our morphological analysis, we are enabled to explain the twofold difference observed in the secreted products of the gland,—that they are sometimes fluid and albuminous, sometimes solid and fatty. In the instance of the hybernators, the accumulation has reference to a state extending over many months: during half the year the nutritive material is being gathered into its receptacles, during the other half is becoming slowly exhausted: so gradual are these processes, that the ultimate organisation of the gland assumes a form expressive of *permanence;* namely, the cytoblasts undergo their extreme development, and the cells originating from them become filled with a more elaborated secretion than that of the temporary Thymus. In the other instance (that of the young animal) the functions of the gland are exercised amid conditions of hourly change: as the amount of ingesta, on the one hand,—as the breathing and muscular movements, on the other, may respectively be more, or less; so will the Thymus have at its disposal a larger, or smaller, surplus from the general expenditure,—so shew a richer, or a poorer, sinking-fund of nourishment. Since the circumstances, which render the Thymus an index of the general nutrition, vary from hour to hour, we are prepared to expect that the peculiarities of the ultimate organisation of the gland in young animals should be those of *im-permanence.* Such is the fact: the low degree of cell-growth in the gland expresses the transitory and imperfect nature of the combination effected between its ultimate elements and the material gathered round them: the process of appropriation is effected by mere cytoblasts, falling short of the completion of cells; the secretion (when compared with the accumulated fat-cells, which distend the cavities of the gland in hybernating animals) is found less removed from the condition of the circulating blood, and capable of returning to it more readily. That it does so pass back, and that the repletion of the Thymus fluctuates from hour to hour, is obvious from many considerations; the readiness and frequency of the metabolic actions so occurring are well illustrated in the fact mentioned by Mr. Gulliver,[1] "that in overdriven lambs the Thymus will soon shrink remarkably and

[1] Gulliver's translation of Gerber's General Anatomy; Appendix, p. 98.

be nearly drained of its contents, but will become as quickly distended again during rest and plentiful nourishment."

USE OF THE THYMUS.

Knowing, then, that the Thymus presents an apparatus for the retention of nourishment in organic combination,—knowing too that this combination is temporary, and is made by nature (with varying degrees) so loose, that it may readily yield in proportion to the needs of the system,—we still have the task before us of assigning an object to these contrivances. What use in the living œconomy is fulfilled by the temporary sequestration of nutrient material? In obedience to what exigencies of the system, must the Thymus render up again that which it has accumulated?

Its relations to the respiratory process;

It is here requisite to glance back again at previous chapters in which we have found the following suggestions of a reply:

1. An abrupt limit defines the extension of the gland in the animal series. Its presence is regulated by the development of the respiratory system: it is precisely conterminous with pulmonary respiration. It is absent not only from fishes, but even from the caducibranchiate larvæ of those batrachia which obtain it in their mature state. It never co-exists with gill-breathing, except among those anomalous ichthyoid reptiles where lungs are likewise present: and, even among these, it is easy to see that in proportion as the reptile comes nearer, in respect of its respiration, to the characters of the fish,—in such measure its Thymus dwindles, or is absent.

and to the motional habits of the animal.

2. The period of its persistence bears inverse proportion to the muscular activity of the individual. In animals of torpid life, it continues to discharge its function longer than in others: in the restless and energetic beasts of prey, its existence is remarkably transient. The contrast of animals in the single class of mammalia is hardly sufficient to illustrate this law by extreme instances of its operation. Such, however, may be found in birds and in reptiles: for in comparing these classes we find the most opposite conditions of muscular energy—in the former its highest development, in the latter its lowest; and so, in contrasting the two classes with regard to the persistence of the Thymus, we observe that in birds the gland vanishes at the earliest period, while in reptiles it cannot even be called a temporary organ.

While the former of these laws clearly tends to annex the Thymus to the organs of respiration in their most perfect development, the latter introduces a modification in the dependence thus suggested. Namely: whatever use the gland may fulfil in reference to the respiratory apparatus, is more or less superseded, when the muscular system is fully evolved, and when its functions are in high activity. We have to search, then, for some possible relation to the offices of the lung, which may be borne conjointly by both Thymus gland and muscular system. This leads to the following question; viz., What have the motions of the individual, and its general energy—what have those acts which are called (κατ' ἐξοχὴν) the *animal* functions, to do with the respiratory process? The relation is palpable and notorious: in proportion to motility there is waste of tissue; in proportion to waste there is fuel for breathing.

In pursuance of this subject we may observe, that there are two ordinary sources of the material which combines with oxygen in the respiratory process: viz., first, there are the effete products of muscular action and change—products augmented in proportion to the motions, and energy, and liveliness of the animal; secondly, there are likewise presented for oxidation certain matters not previously appropriated into any of the more permanent organic combinations of the body—matters, either remaining in the blood from the period of their ingestion to that of their use in respiration, or, if not actually remaining in it, at least only so far set aside that they may, if required, revert to it with the utmost facility. Some importance in the physiology of respiration must be assigned to this latter source of supply, when we consider that there are certain conditions of the system, in which it officiates singly; conditions, under which the wear and waste of the organised fabric are so scanty, that, if respiration had been left contingent solely on them, it must speedily have terminated. I have already adverted to instances of this kind: to the case of very young animals, where the decay of tissue is either absolutely none, or in the smallest proportion to the process of assimilation; and to that of the hybernators, where the voluntary movements are utterly extinguished during periods of many months. It seems indispensable for the continuance of respiration under circumstances like these, that there should exist the second source of oxidable material—a source independent of muscular activity and its effete products. But we may easily believe that inconveniences would arise, if occasional large additions of nutritive matter, furnished for this purpose, remained concentred in the blood till gradually exhausted by respiration. At all events, we find nature providing against any such possible accumulation: in every instance, normal or abnormal, where the waste materials for oxidation are scanty,—in every instance where the supply of *exspirabilia* is ill furnished by the more permanent tissues of the body, and is chiefly maintained by successive additions of new nutritive matter, we invariably notice a setting-aside of some portion of these supplies—an œconomical sequestration from the blood. An abnormal illustration of this fact occurs in the obesity attendant on extreme indolence; the unused muscles undergo their minimum of decomposition; they yield little fuel and require little renovation; the fresh ingesta, precluded from their more legitimate office of renewing to the active tissues of the body what these should have rendered up for respiration—are themselves used as waste; but they are not suffered to accumulate in the blood till slowly exhausted in this application; they are set aside within ready reach, in a most oxidable form; they are converted into fat, and, as such, are constantly subservient to the respiratory process. It is in anticipation of similar circumstances normally arising, that Nature prepares an animal for the long immobility of hybernation, by copious fat-deposits; these are gradually accumulated by successive per-centages of the summer's nutrition; they are gradually subservient to respiration during the wasteless inaction of the winter. It is under these very circumstances too, be it remembered—that the Thymus gland appears as a persistent organ.

Physiology of œconomical secretion.

The tendency of all the preceding observations is, to range together the physiology of

Functions and Uses of the Thymus included in the theory of fat-formation.

the Thymus and that of fat-formation generally, as parallel instances of the temporary sequestration of nutritive material, designed for identical objects. The structural metamorphosis, already often alluded to, gives infinite corroboration to this view of the physiological affinities of the gland. Acting quickly and transiently—effecting diurnal or hourly interchanges with the circulation, *it secretes an albuminous fluid:* acting leisurely and with comparative constancy—its metabolæ extending over months, *it forms fat-cells.* Surely there can be no essential difference between two given vital processes, where *one lapses into the other by mere retardation of its pace.*

General conclusion.

Guided by the preceding general laws, by the evidence they furnish, and the analogies they suggest, it seems difficult for us to avoid the conclusion, that the THYMUS GLAND FULFILS ITS USE AS A SINKING-FUND OF NOURISHMENT IN THE SERVICE OF RESPIRATION. For—whereas the operations of the gland are essentially œconomical, and its loosely-combined products are ever held at the call of the system; whereas its presence is distinctly conterminous with the highest form of respiratory function; whereas its actions obviously pertain to periods having a common physiological peculiarity;—how can we avoid identifying its use with the exigencies of these periods and of that function? The nature of those exigencies has already been stated; and I can conceive no manner in which the functions of the Thymus may be applied to meet them, other than this,—that what the gland sequestrates from the circulation does, in gradually reverting thither, accomplish those chemical purposes in respect of respiration and temperature, which under other circumstances are fulfilled by the effete products of active animal tissues.

In other words;—An object (probably the single essential object) of the respiratory process is the maintenance of an independent temperature for the animal. . . . In order to this end, the particles of the body are gradually yielded to the oxidising influence of the atmosphere; they slowly burn. . . . In the active tissues the rapidity of oxidation is in the ratio of exercise. . . . There are times and circumstances when these tissues waste infinitely little. . . . For such occasion how is oxidable matter provided? Surely by prior œconomy, by prior sequestration. . . . And this may occur in a two-fold manner; most usually in the form of fat the material is diffused throughout the body, filling its interstices and clothing its surface; more rarely it is gathered within a single organ, and retains the albuminous form in which it was first added to the blood. The requisite link for uniting these two instances is furnished by the fact, that under certain circumstances the second merges in the first; the Thymus deviates from its more special function—it passes into the general method of œconomical secretion—it fills its cavities with fat-cells—it becomes, indeed, a mere glanduliform collection of fat.

On this theory, every fact that has come to my knowledge in the history of the Thymus admits of ready explanation;—the larger anatomy of the gland, and its minute structure; the chemistry of its products; its morphetical analogies; the laws regulating its presence, and assigning its abrupt termination; the phenomena of its development and decrease; its invariable augmentation after birth; its occasional persistence through life; the evident proportioning of its functions to special and individual circumstances of nutrition and muscular activity. General conclusion.

And, while the theory here defended serves to combine, harmonise, and explain the various facts developed in the preceding pages, it seems no less clear that many of these facts are inflexibly opposed to the several other theories previously enumerated. For how can any doctrine[1] of the gland's mechanical use be reconciled with the facts of its varying position, inconstant outward relations, and elaborate organisation? What theory,[2] implying any permanent function, will suit an organ so essentially transient? Yet how can its office be identified[3] with uterine life, all peculiarities of which it so long out-lasts? Having seen that whatsoever it effects during embryonic life, is only preparatory to a marked increase of functional activity after birth,—knowing too the chemistry of its fœtal contents—how can we suppose, even with Meckel and Tiedemann, that it is an organ of vicarious respiration? What theory of its being a conglobate gland, or of its serving as a hydraulic diverticulum, or modifying agent, to streams of lymphatic absorption,[4] will bear the test of anatomical inquiry? What immediate local purpose[5] can be assigned to a secretion, which would only attain its end after re-entering the common circulation? Or what general aim, barring that here ascribed? For, with what straining of the fancy can we imagine that the whole body is fed by an organ of its own; or that a material can be secreted from the blood fitter for nutrition than that mother-fluid?[6] And what possibility remains for the gland's usefulness[7] in nourishment by lactation, when we find it existing in birds and reptiles no less than in mammalia? Or what service in forming germs for the tissues, or for the blood, can the corpuscles of the Thymus, as such, fulfil[8]—when obviously incapable, in their corpuscular form, of traversing the imperforate limitary membrane of the gland?

As further disproof, or discussion, of these opinions could do little towards establishing the validity of my own, I here leave them. It remains for the reader to determine whether those views, which I offer in their stead, have stronger claims for reception—whether they better explain the facts of the case—whether they more nearly accord with the known laws of the living œconomy.

[1] Such as that of Galen and his followers.

[2] As Wharton's, and (by implication) many of those which explain the Thymus as a lymphatic gland.

[3] As was attempted in the theories of Morand, Boeckler, Bellinger, and Martineau; and more or less, in all but one of the remaining hypotheses on the subject.

[4] Doctrines variously supported by Cowper, Haller, Lucæ, Caldani, Bartholin, Schenck, Heister, and a host of others.

[5] Such as the uses assigned by Muralt, Verheyen, Petit, and Steller.

[6] One or other of which suppositions is involved in the theory quoted by Palliani, and in those of Glisson, Sir Astley Cooper, and others.

[7] As believed by Haugsted.

[8] According to the hypotheses of Hewson, Bischoff, and Gulliver.

APPENDIX.

NOTE ON THE PATHOLOGY OF THE THYMUS.

THE diseased conditions of the Thymus are very rare, and have been little investigated. In order to collect such a number of original cases, as might add somewhat to existing information on the subject, a far longer period would be necessary than that allowed for the completion of the present Essay. Haugsted gives an excellent compilation of the cases scattered through various periodicals and monographs; and as I could add little in this respect to the gatherings of his industry, it is better that I should refer to his pages, than extract from them. APPENDIX.

I have never noticed *absence of the Thymus* except in cases of true acephalism; and from these rare instances, no physiological inference can be drawn; for the Thymus is absent—not on account of the mere acephalism—but as one sign, out of many, of the general malformation of the body. In a case which I have recently dissected, the heart and lungs were deficient as well as the Thymus. Least of all can we infer from these deformities, that any essential sympathy subsists between the great nervous centres and the gland: for in anencephalous fœtuses—where the brain is no less absent than in those which are truly acephalous, but where the residual development of the body is infinitely higher,—the Thymus attains at least its usual growth. The absence of the gland, then, obviously belongs to acephalism as to an extreme degree—not as to a specific and essential kind—of monstrosity.

In a single case of *synthoracia* (thoraco-didymi) which I have dissected, there was, as might be anticipated, a Thymus for each fœtus; the glands were small and pyramidal; they rested below on the opposite corners of the common pericardium, and extended a short way upwards—one into each neck. The lungs were double.[1]

Tubercular deposit is the only disease I have met with, in dissecting the gland; and this I have found only in subjects past the period of infancy. Cruveilhier, however, reports a case of congenital abscess in the gland: but he, as well as Rokitansky, considers it to be very rarely affected with disease.

A most interesting point in the pathology of the Thymus is the relation alleged to subsist between its *hypertrophy* and certain other diseases of infants. Mr. Hood, of Kilmarnock, published some years ago a collection of cases, from which he argued that "the sudden death of a child, which has been preceded by no morbid sign of ill-health, but arising immediately from surprise, or violent irritation, accompanied with great efforts to cry without being able to raise the voice, may in general be attributed to an enlargement of this gland."[2] Shortly afterwards other pathologists expressed somewhat similar opinions; and Dr. Kopp[3] particularly, having investigated the disease of young children known in this country as *laryngismus stridulus* (which disease probably includes the two or three cases of Mr. Hood's collection bearing on the subject) confirmed the belief of its frequent connexion with the post-mortem appearance of an enlarged Thymus. Under the impression that the fatal dyspnœa in such cases depends on the pressure of the overgrown gland, he named the disease *asthma thymicum*. There are several objections to the unqualified admission of this theory.

First,—although the coincidence is unquestionably frequent, yet it is by no means invariable or necessary: for, not only do the symptoms of laryngismus stridulus often exist without any enlargement of the gland; but likewise undoubtedly this enlargement may exist unaccompanied by the symptoms of laryngismus stridulus; it has been noticed in connexion with other maladies of the respiratory system, as frequently as with that disease.

[1] Drawings, illustrating this dissection as well as two cases of anencephalous monstrosity, were included in the collection which accompanied this Essay in its earlier form. I have not thought it necessary to engrave them; but may refer to the originals, which are in the Library of Guy's Hospital.

[2] Cases of sudden death and affections of the head originating from diseases in the Thymus-gland and Chest; by Alex. Hood, in Edinb. Journal of Medical Science; Jan. 1827.

[3] J. H. Kopp; Denkwürdigkeiten in d. ärtzl. prax. 1830.

Secondly,—as the peculiar mark of the disease is the *paroxysmal* nature of its symptoms, and as it has sometimes proved fatal in a first attack, it is difficult to conceive its exclusive dependence on a permanent mechanical cause, such as the supposed one would be. Assuming that, in the recorded cases, the Thymus was sufficiently large to cause inconvenient pressure on adjoining organs,—how can we explain the long intervals in which this inconvenience remained latent? how can we conceive of a cause, so gradual and so constant in its operation, that it should (as in some of the supposed cases) manifest itself by no discomfort till one fatal moment, and then strangle its victim with the rapidity of a bow-string? We may judge of such cases on the analogy of aneurisms: where these act mechanically, encroaching on the strait of the thorax, and flattening the trachea by their pressure—the symptoms, whether of venous obstruction or of tracheal irritation, are more or less persistent, and are always progressive; there may be intervals of comparative ease, but some indications of a constant cause must likewise themselves be constant; nor does death, so far as I know, ever occur till such indications of pressure are infinitely more decided than in these alleged cases of thymic suffocation.[1]

Thirdly,—even on the supposition of an enlarged Thymus producing the effects pretended, the disease would still be unexplained. For, why should the Thymus be enlarged? That it may be the seat of various idiopathic changes, I am well aware; it is of course liable to inflammation and its consequences; I have often seen tubercles deposited in it; and authentic cases are related of malignant growths arising in its substance. But the instances in question are of a different order; the Thymus appears, in a vast majority of them, to have been simply enlarged—over-grown. Now, idiopathic hypertrophy is a very questionable possibility: primâ facie, we should as little expect it in a gland as in a muscle. Just as the blacksmith's arm grows in proportion to its task,—just as the muscular fibres of the heart and bladder become hypertrophied, when they have to struggle against the unnatural resistance of a constricted outlet,—just so (and, I suspect, only so) may a gland become over-grown where it is over-worked. Thus it is, that the liver answers to the necessities of its vicarious function: thus, that a testis, or a kidney, may be enlarged in compensation for atrophy of its fellow; or that both testes, or both kidneys, may grow in obedience to the increased functional demands of salacity or diabetes. Enlargement of the Thymus, however, differs a little from these cases: it appears to consist not in an hypertrophy of the secreting structures, but in an accumulation of the secreted product:—such accumulation depending, of course, either on too rapid formation, or on too indolent absorption and application of the fluid.

It appears to me that the large number of cases, cited by authors, of alleged interference with respiration by an enlarged Thymus gland, may be arranged in two classes. First, there are a few—a very few—instances in which the gland has really thus acted: in such, the enlargement has been considerable, originating in some idiopathic structural disease, (usually tubercular or malignant,) and shewing its mechanical effects on the veins no less than on the windpipe. Secondly, there are very many cases in which the gland has merely been large from accumulation of its natural secretion; cases, in which, (according to the authors citing them,) the amount of enlargement has been quite insufficient to account for the symptoms as results of pressure, and in which the increased bulk of the gland must have been an accidental coincidence with the protracted dyspnœa, if not rather an indirect effect of it.

[1] I am indebted to the kindness of Sir Benjamin Brodie for some particulars of a case, attended by him with Dr Holland, which confirms the view here stated. A young lady, seven years of age, had suffered for a considerable time from occasional attacks of difficulty of respiration—sometimes so severe as to threaten suffocation,—in one of which she at length expired. On inspecting the body, a large tumor presented itself immediately beneath the sternum, and occupying the situation of the Thymus-gland in the anterior mediastinum. It was composed partly of solid substance, and partly of cells containing a fluid of a white colour; the latter not less than six or eight ounces; and the solid tumor, when the fluid had escaped, about as large as a small orange. Now, in this case, the existence of such a tumor was rendered probable during life, and was actually anticipated in the necropsy, from the fact that, with the frequent interruptions of breathing, there was conjoined a tumid condition of the lower part of the neck, depending on a turgid state of its veins. It seems quite impossible for a mediastinal tumor to attain such a size as to affect respiration, without likewise manifesting, as in this case, its obstructive effects on the venous circulation. There is a case of fungoid disease of the gland given at the end of Sir Astley Cooper's book, (p. 44); and I would beg the reader to compare it with some of Mr. Hood's cases. "I witnessed her," says Sir Astley of his patient, "making daily approaches to dissolution, without being able to afford her any permanent benefit; she died, not from any sudden attack of suffocation, but from being worn out by the constant irritation excited by the difficulty in respiration." This is very different from *Asthma Thymicum.*

And I suspect that the latter has not infrequently been the case; for, if we examine other recorded cases of simple enlargement of the gland (vid. Haugsted, p. 182 et seq.) we find this unnatural condition associated, in almost every instance, with some chronic impairment of respiration, occurring in infants, and *not inducing marasmus*. The distinction intended in the last three words is an important one: if the disease of the respiratory organs be one, which—like phthisis—proves fatal by exhaustion and emaciation, we should of course expect, on the analogy of our previous observations, that the Thymus would be wasted, even out of proportion to the rest of the body. But the cases in question are from the opposite class: the disease, which fatally interferes with the oxygenisation of the blood, is attended by no wasting. And in this class of cases (cyanosis, laryngismus stridulus, and the like) it is, that the enlargement of the Thymus has been observed, and has in some instances been over-hastily considered an idiopathic disease—the mechanical cause of the fatal dyspnœa. APPENDIX.

Now, the theory, which I have suggested for the functions and use of the gland, would fully include and explain this remarkable connexion between its enlargement and the non-emaciative derangements of the respiratory function: it would interpret the increased size of the gland, as a phenomenon of *retained secretion*, and as a *consequence* of the diminished respiration. For, if it be the function of the Thymus to secrete and hold within its cavities matters in readiness for oxygenisation,—if it be (as almost certainly it is) a sinking-fund of nourishment in the service of the respiratory process; then surely we may anticipate, that any protracted interference with this process would cause an apparent hypertrophy of the gland, by suffering an unemployed secretion to accumulate within its cavities. Such, I have little doubt, is the pathological explanation of the coincidence in question; and the exact manner, in which it harmonises with my previous conclusions, may perhaps justify some confidence in both.

ON THE AIR-BLADDER OF FISHES, AND ON THE RESPIRATION OF THE LOWER REPTILES.

I AM indebted to Mr. Gray for directing my attention to an apparent omission at the close of my fourth chapter, which I shall here endeavour to supply.

Among Fishes, as I have stated, no Thymus is found; but in most of the class there is observed a peculiar organ,—unknown in other divisions of the animal kingdom—described as often possessing a remarkable glandular appendage—and, above all, alleged to bear some relation to the respiratory process: I refer to the air-bladder and its gland. Does this apparatus shew any signs of analogy, in structure or function, to the Thymus of the other classes? apparently not the least.

Configliachi's singularly careful and complete researches,[1] corroborated as they are in all essential particulars by the contemporary observations[2] of Biot, Delaroche, Humboldt, and Provençal,—leave no doubt on my mind as to the use of the organs in question. After analysing the contents of the air-bladder in 120 specimens of various genera, Configliachi found that hydrogen never existed in it; nor carbonic acid—except in rare instances and in the smallest proportions; that nitrogen and oxygen were the essential products of the cavity; the former usually existing in very considerable excess, sometimes even to the entire exclusion of the other; that sometimes, though with comparative rarity, the oxygen would preponderate over the nitrogen, even considerably; that these variations, though generally subject to a particular law,[3] were at times apparently capricious, occurring in individuals of the same species caught under identical circumstances; thus in *Gadus Merluccius*, the

[1] Configliachi; Memoria sull'analisi dell'aria contenuta nella vescica natatoria dei Pesci; in Brugnatelli's Giornale di Fisica, &c., vol. ii.
[2] See Schweigger's Journal für Chemie u. Physik; Vol. i.
[3] The law referred to is the very singular, but unquestionable one, that the proportion of oxygen in the air-bladder increases, as the particular fish examined belongs to deeper water. Those fishes, which contain almost unmixed nitrogen in their bladders, are accustomed to the superficial strata of water; those which contain the largest preponderance of oxygen are inhabitants of the deep. There are occasional exceptions to this law, sometimes apparent contradictions of it; but a glance at Configliachi's table (p. 370) will convince the reader of its general accuracy: it is at present quite unexplained.

APPENDIX. proportion of oxygen to nitrogen varied from 2:98 to 32:68—from little less than a fiftieth to almost the half; thus too, in *Sparus Mormyrus*, from an insensible quantity to 17 per cent. This extreme diversity in the gaseous contents of the bladder clearly evinces that no primary object lies in the *nature* of the gas; and further, when we consider that the products of respiration are never found there except in the minutest proportion,—that the predominance of oxygen is exceptional—and that nitrogen, which is absolutely indifferent to the respiratory process, is the most usual and most abundant product of the cavity,—we are impelled to search for the use of the secretion rather in its mechanical than in its chemical properties. Thus we are prepared for the conclusion, furnished not only by popular observation, but by scientific experiments on living fishes;—that the use of the bladder depends merely on the specific gravity of its aëriform contents; that these are secreted by the mucous lining of the sac, and may be increased or diminished, condensed or rarified, at the will of the animal—according as it would sink or rise in the medium which surrounds it; that in many fishes the power of hastily evacuating their air, in order for sudden descent in the water, is facilitated by the presence of a *ductus pneumaticus* opening into the pharynx; but that this tube is in no manner calculated for allowing the ingress, as it suffers the exit, of air.

As regards the so-called "gland" of the air-bladder, my dissections have led me to the same anatomical results as those which Mr. Quekett has recently published;[1] the red body in question is a mere congeries of parallel looped blood-vessels, and is quite destitute of parenchymatous cells; clearly then it is no gland. Its existence is not essential to the function of the cavity; it is not the organ of secretion; there are many air-bladders having no trace of it. From the known exceptions to its presence, and from the statement that it usually exists where the *ductus pneumaticus* is absent, one might rather conjecture that its use may be for the occasional quicker absorption of air,—a process not so necessary where the *ductus pneumaticus* is open, since in this case the animal is able by muscular effort to empty its air-bladder in a moment, and thus to increase its specific gravity, whenever required to do so for sudden vertical descent.

From the close similarity between the distribution of vessels in the lungs of reptiles and that in the air-bladder of fishes (a fact perfectly displayed in his beautiful injections), Mr. Quekett draws an inference, that this organ forms part of the respiratory system; that its uses are such as those of a lung or gill. This opinion does not, I think, quite necessarily result from the fact mentioned. The natural deduction from an analogous arrangement of blood-vessels in the two organs, is merely this; that the method of effecting their respective processes is the same for both; that their spheres of operation are alike; that the mucous membrane of the air-bladder, like that of the lung or gill, has to do with the absorption, and secretion, and interchange of gases. But surely we cannot from this single fact infer their identity of use,—contradicted as it is by every chemical and physiological argument,—any more than we could ascribe identical functions to the parotid and lachrymal glands, or to the tubules of the testis and kidney, from the similarity of their vascular plexuses.

In following Nature's transitional steps, it is necessary to mark every significant distinction, even where of some apparent subtilty; and I would remind the reader that there is an important difference between *functional* and *organic* parallelism. It is a necessary consequence of development from simple types—one, to the reality of which all rudimental parts bear testimony—that Nature should cling to shape longer than to function, and should continue a formal similarity in organs beyond the limits of their identical use.

Now, it is impossible to study the air-bladder of fishes, without a conviction that it is the *organic representative* of the lung; undergoing successive degradations in form from those species where, as in the Lepisosteus, it opens into the pharynx by a large and regular slit of communication, —down to those where the *ductus pneumaticus* is lengthened, or is absent or obliterated. But again, it is equally impossible, in the face of Configliachi's experiments, to maintain any identity of use, or any mutual subservience, between the two organs. The air-bladder is a lung converted to a non-respiratory purpose.

[1] On a peculiar arrangement of blood-vessels in the air-bladder of Fishes; by John Quekett: in the Transact. of the Microscopical Society; 1844, p. 99.

But, where does this conversion begin? So far as we may draw inferences from mere anatomical arrangement, I would express great misgivings as to the correctness of the line of demarcation, now generally recognised as abrupt in respect of the respiratory apparatus, between fishes and reptiles. APPENDIX.

Unluckily we have no chemical analyses of the contents of the air-sacs in the lower reptiles; but there is a point which has forcibly struck me in dissecting the perenni-branchiata, and which has not, I believe, been much noticed hitherto: I allude to the extreme ill-adaptedness of their organisation for fulfilling the pulmonary respiration, which they are supposed to exercise conjointly with the branchial. To fill the lungs by a sort of intercepted deglutition of air is, under the best of circumstances, not a very convenient method of breathing: it clearly requires for its facilitation that the air-pipe should be at least as accessible and pervious as the œsophagus. Accordingly in the frog, we find the lung almost beginning at the glottis; and in serpents and saurians, though the trachea is long, it is furnished with cartilaginous rings, as perfect and as permeable as our own. Not so in the perenni-branchiate reptiles. The *proteus*, for instance: its so-called lungs are but scanty pyriform enlargements of constricted semi-pervious tubes, which have run two thirds the length of the body before undergoing this ampullation. So narrow are these tubes, that, when after death obstructed by their own epithelium, they may seem absolutely closed. In a specimen now before me, where the sacs are distended, I am unable, even by very firm compression, to force the air from them in a retrograde course. This is perhaps an extreme case; but in the *siren* and *menobranchus* the tube is arranged with scarcely less inconvenience for permeation; it lies flat in the posterior wall of the pericardium, its opposite surfaces in close contact, its pharyngeal opening so oblique as to be almost valvular, its walls presenting only the faintest indication of cartilage. In ascending to the abranchial reptiles—even to the lowest, the *menopoma* and *amphiuma*—we at once observe a change in the latter respect: the duct becomes a genuine trachea, and is kept patent by the elasticity of cylindroid cartilages.

The peculiarities here adverted to intimate a declension in the respiratory apparatus; and, coincident as they are with the persistence of branchial breathing, lead me to believe that the air-sacs of the animals in question are but little nearer to the function of a true lung, than are the corresponding organs of fishes. I may add, that there is insufficient evidence of the double respiratory function ascribed to the perenni-branchiate reptiles: the *siren*, in which the air-sacs are more developed than in any of its congeners, dies (I am informed by Professor Owen) if its branchial tufts are allowed to dry.

So little is positively known with respect to the *axolotl*, that I should hesitate to found any argument on so insecure a basis. But I may be allowed to remind the reader, that, as this animal approaches the true lung-breathing reptiles in the larger size of its Thymus, so likewise does it distinguish itself from the remaining perenni-branchiate batrachia, by the same development of its air-tube as we have found in the menopoma and amphiuma: it has a patent and cartilaginous trachea.

It appears that there are two distinct types of construction for the respiratory organs; the membrane may be *inverted*, with more or less ramification, as a lung; or it may be *everted*, with more or less plication, as a gill. These types correspond respectively to two degrees of the respiratory process: the former to the higher grade of direct aërial breathing; the latter to a less active interchange of material, effected through the medium of water. Each type repeats itself to a certain extent (either in rudimentary form, or with transient duration) in that part of the animal kingdom which naturally has the other type for its own. Thus the gills are indicated in the early embryonic state of the highest animals: thus, too, the lungs are continued, with more or less degradation of shape, beyond the limits of their actual usefulness. Such being the case, it is exceedingly difficult to draw any exact line of demarcation; though probably no animal possesses so precisely balanced a development of both organs as to be genuinely amphibious. The axolotl (supposing it to be a permanent, and not —as many naturalists have believed—a larval, form) and, perhaps, the menobranchus would offer most likelihood of exercising the two functions conjointly; yet, should the line of separation be drawn with rigour between those animals which owe their respiration chiefly to air, and those which gain it through the medium of water, I suspect, from the higher development of its trachea, that the axolotl would be found above the line; while close under it would throng the anomalous forms of the more ichthyoid reptiles, and of fishes with open air-bladders.

ADDITIONAL NOTE ON THE PHYSIOLOGY OF THE GLANDS WITHOUT DUCTS.

APPENDIX. THE general opinions expressed in the preceding pages, with reference to the Glands without Ducts, chiefly relate to the mere anatomy and structural affinities of these organs. So many data are still wanting for the establishment of positive conclusions as to their uses, that I shall scarcely attempt more in the following note than to suggest the direction for future experiments.

The most important points, deducible from the anatomy of the Glands without Ducts, are these; that their functions are not constant; that (whether they be permanent organs, as are the renal capsules, the thyroid gland and the spleen,—or temporary, as is the Thymus) their mode of operation is essentially remittent and occasional; that their activity alternates with periods of repose, during which their specific secretions re-enter the stream of circulation. Add to this the unquestionable fact, that their uses are economical; and the deduction almost necessarily ensues, that these must bear reference to certain periodical variations in the nutrition of the body generally, or in that of particular organs.

This physiological inference applies equally to all the organs in question; it expresses what may be called their common principle of action. But beyond this point their physiology subdivides itself: a separate problem belongs to each organ,—a separate course of observation and experiment. What determines the repletion of each? what its emptiness? if activity and repose alternate in each, what regulates the rhythm of alternation?

1. With respect to the *Thymus*, I have already endeavoured to answer these questions. I have shewn that it is according to alternations in the general nourishment, that this organ now sets aside its proportion of nutritive matter, now renders it up again; and I have adduced some evidence to the effect, that the latter of these alternate processes is especially for the sake of the respiratory function.

2. In the case of the *thyroid gland*, there are strong reasons for believing that these alternations of nourishment may reciprocate with similar differences in the nourishment of the brain—itself, of all organs, the most evidently periodic in its operations. Pathology might have suggested this belief; but Comparative Anatomy, as I have elsewhere[1] shewn, furnishes the strongest arguments in its support. The simplest analogue of the gland in the animal series—the first suggestion of its future existence—is a mere vascular diverticulum to the stream of the cerebral circulation. This arrangement is not superseded in the higher development of the gland; universally among vertebrate animals, the thyroid arteries rise in such close proximity to the cerebral, that they may, with the utmost facility, fulfil their original diverticular function, whenever the latter vessels either spontaneously reduce their calibre, or become surcharged with blood.[2]

No organ of the body is so systematically remittent in its actions as the brain; in the human being, sleep suspends every manifestation of mind, during at least a third of the total period of existence; in many animals this inaction of the brain endures for still longer seasons, and in still larger proportions, than in man. It would be contrary to every physiological analogy to suppose that the organ is equally nourished in its activity and in its quiescence. Recent physiological researches,—which have taught us the existence of muscular fibre in the texture of arteries, and their consequent power of regulating their own capacity in obedience to certain unknown laws,—leave no room for rational doubt that the cerebral vessels do determine for themselves, according to necessity, the passage of a more or less abundant circulation. In order to facilitate these (as it were) *optional* changes of capacity and current in a particular vessel, no better contrivance could be devised than the annexation of a variable waste-pipe, branching off in such relation to the first, as the thyroid arteries with respect to the cerebral.

[1] On the Comparative Anatomy of the Thyroid Gland; Philosoph. Transact. 1844, Part. ii.

[2] No better illustration of this point can be required, than that afforded in the human subject. As there are two cerebral arteries on each side of the body, so are there two thyroids—one rising in close proximity to each cerebral; the superior just on the distal side of the internal carotid, the inferior just on the distal side of the vertebral. In the latter case, too, the origin of the artery is so far from its distribution, and its course is so unusual (crossing as it does the axis of a very large artery, which — but for the definite end in view — might as well itself have furnished it) that we cannot suppose the arrangement accidental. It is scarcely necessary to remark that they take the very origin which would best qualify them for diverting, in case of need, the stream of the cerebral circulation.

I am far from supposing, however, that the function of the gland, except in its most rudimentary form, is so merely mechanical as some of the phrases just used might imply. For, as the organ developes itself in the ascending scale of animals, it assumes all the requisites for secreting into closed cavities; there is an intercalation of gland-cells amid its capillary blood-vessels. Yet surely the intention of this super-added secretory apparatus must harmonise with that of the prior vascular arrangement. How?

What *diversion* is to the *stream* of blood, viewed quantitatively—*alternative secretion* would be to the *composition* of blood, viewed qualitatively: and I should conceive that the use of the thyroid gland, in its highest development, may depend on the joint exercise of these two analogous functions. I should suspect, not only that the thyroid receives, under certain circumstances, a large share of the blood which would otherwise have supplied the brain,—but also that the secretion of the former organ bears some essential relation (which chemistry may hereafter elucidate) to the specific nutrition of the latter; that the gland—whether or not it appropriates its elements in the same proximate combination, as the brain does,—may at all events affect in a precisely similar degree the chemical constitution of the blood traversing it; so that the respective contents of the thyroid and cerebral veins would present exactly similar alterations from the characters of aortic blood.

Finally, I should suppose that these actions occur only, or chiefly, during the quiescence of the brain; and that when this organ resumes its activity, the thyroid may probably render up again from its vesicles to the blood, in a still applicable form, those materials which it had previously diverted from their destination.

3. The *spleen*, like the Thymus, appears to exert its functions for systemic purposes. It is an organ of the utmost passive erectility; an organ, that very readily becomes turgid, not from arterial impulse, but with venous congestion. After each large ingestion of food, with the attendant increase in the volume of the circulation, the spleen swells considerably; it gradually resumes its former dimensions, in proportion as the newly-assumed blood expends itself in various acts of nutrition. These alternations in size depend on a mechanical cause; almost the entire bulk of the spleen is constituted by a vast plexus in which the splenic vein commences, and, according to the ease with which the vein evacuates its contents, the plexus (and therewith the entire organ) will collapse, or will be distended. To the latter state there hardly seems any other limit than the capacity of the abdomen: the elastic tissue in the capsule and septa of the spleen, on which depends the ordinary evacuation of its plexus, will bear almost infinite extension. The usual and healthy cause of its temporary turgescence is the slight mechanical hindrance to its circulation—the minute increase of pressure on its effluent blood,—which the greater repletion of the general venous system affords, for a certain time after each full meal. Thus, by mere mechanical properties, it acts as a diverticulum or safety-valve to the systemic circulation.

Now, the Malpighian bodies in the spleen appear to me a very ready—though not a very essential —supplement to the mechanical contrivance just mentioned: they are the most rudimentary form of glands without ducts. In respect of their use,—as I have argued of the thyroid body, so I would argue here; that an apparatus of secretion, super-added to a mechanical contrivance, must probably have been designed in harmony with it.

Many circumstances induce me to consider the Malpighian bodies as low analoga of the vesicles of the Thymus: rudimental, as deficient in a limitary tissue; and presented in a discrete form, as wanting the tubular stem, or axis, which that tissue furnishes to the vesicles of the more complete organ; but still fulfilling the same function, and destined for a similar purpose. The secretion appears substantially the same in both organs; in the glandules of the spleen, as in the young Thymus, there seems a mere setting-aside of albuminous nutritive material; a process, similar in its nature to the formation of fat, and differing from it only thus far, that the matters so set aside are perhaps more easily re-absorbed and re-applied in the system. I can conceive no manner wherein the minute secretory actions, occurring in parts of the spleen, might better harmonise with the mechanical functions of the whole, than as in the theory here suggested: the glandules seeming to effect for the *quality* of the blood, what the entire organ does for its *quantity*. And thus, I would suggest, while the spleen serves *mechanically* as a diverticulum to the replenished systemic circulation, holding

APPENDIX. much blood only where much is in temporary excess,—so likewise it may *vitally* withdraw from this lingering blood some of its most plastic elements, and retain them for a time within its own interstitial chambers, at the call of the system;—a readier, a more quickly available, though scantier, sinking-fund of nourishment, than is afforded in the adipose tissue.

4. The structure of the *supra-renal glands*, equally with that of the Thymus or Thyroid, bears evidence of remittent function; and I have some reason for believing that the conditions affecting their activity are not (as with the spleen and Thymus) variations in the systemic nutrition, but are rather (as with the thyroid) some partial and special sympathies. My own researches on the subject are at present too incomplete, for me to aim at defining exactly the nature of these sympathies; nor will I pretend to offer any theory of my own, on the use of the organs in question. It may be not irrelevant, however, in the great uncertainty of the subject,—while the speculative physiologist still doubts whither to direct his experiments, still asks what *possible* relation these organs may hold, still hesitates as to what remittent and occasional functions yet remain in the economy, with which the greater or less activity of these *might* alternate,—it may be not unwise, to recall Meckel's guess of some essential affinity between the supra-renal glands and the generative system. Periodicity of function is so remarkable a character of this system, that the connexion suggested has at least apparent possibility in its favor, and certainly deserves examination.

To conclude, I append in a tabular form the chief results of the preceding researches and speculations; that the reader may more readily see, what parts of the subject still remain incomplete or untouched.

Glands without Ducts.	Arrangement of their Cavities.	Form of their contents.	Chemical constitution of their contents.	Their dependence and sympathies.
THYMUS.	tubulo-vesicular; with limitary membrane, more or less symmetrical, and continuous throughout each half of the gland.	cytoblasts and albuminous fluid; or fat-cells.	essentially protein, or that of ordinary fat.	systemic.
GLANDULES OF THE SPLEEN.	discrete vesicles; without limitary membrane; in an azygous organ.	cytoblasts and albuminous fluid.	essentially protein.	systemic.
THYROID GLAND.	symmetrical; compacted vesicles; with limitary membrane.	cytoblasts surrounded by, or nucleated cells containing, albuminous fluid and salts.	incompletely known.	with the brain.
SUPRA-RENAL GLANDS.	more or less symmetrical; parallel tubules; with limitary membrane.	cytoblasts surrounded by, or nucleated cells containing, molecular matter.	unknown.	unknown.

FINIS.

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PHYSIOLOGICAL ESSAY ON THE THYMUS GLAND.

ERRATA.

Page 8, note 10, *for* "Redbuck" *read* "Rudbeck."

Page 71, line 7 from bottom, *for* "hysical" *read* "physical."