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FUNCTIONS OF THE SUPRARENAL CAPSULES.

BY

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IN this paper no attempt will be made to give a review of the whole subject of the physiology of the suprarenal capsules, since this was done not so very long ago by Rolleston.¹ Moreover it will be impossible even to mention the greater part of the immense literature which has now been accumulated on this subject. I shall content myself with emphasising those points upon which I have been specially engaged, and those aspects of the question which are of most practical importance.

Comparative Anatomy, Histology, and Development of the Suprarenal Bodies.—In the very lowest animals in the vertebrate scale suprarenals are not known. We find them first for certain in Elasmobranch fishes where there are a series of paired bodies arranged segmentally on the intercostal arteries and extending the whole length of the abdominal cavity. They are situated in close proximity to the sympathetic nervous system. These correspond in structure^{2, 4} and function¹² to the medulla of the suprarenal capsules of higher vertebrates. Secondly we find a single or paired, yellow, rod-shaped organ lying between the two halves of the kidney, and near the dorsal aspect of the organ. This is the "interrenal" of Balfour and corresponds to the cortex of the suprarenals of higher vertebrates.² The "medullary glands," as we may call them, consist of an irregular or wavy fibrous stroma with irregular protoplasmic cells and mostly oval nuclei. Some of these cells are branched, and are stained brown by treatment with potassium bichromate. These pigmented cells are mostly in the interior of the body. The "cortical glands" (interrenals) on the other hand consist of definite solid columns, having the form of the alveoli of secreting glands, and containing elongated cells.²



In Teleostean and Ganoid (?) fishes we appear to have only cortex represented, and the "cortical glands" are small rounded bodies lying on the ventral or dorsal aspect of the kidney or in its substance. The histological features are very like those of the "interrenal" or "cortical gland" of Elasmobranchs, but in some cases (eels) there appears to be a lumen in the centre of each alveolus, and progressive physiological changes in the cells as they elaborate their secretion can be made out. (Pettit).³

In Amphibians the suprarenal capsules form yellowish streaks on the kidneys. Cortex and medulla are united into one organ. The greater part of the gland is made up of columns of cells, which are of very varying size and shape and interlace in all directions. The cells are mostly elongated and tapering, and contain a large round nucleus. This is the "cortical" part. But in addition to the above-described structure we get masses of a different kind of cell. These appear to be irregularly distributed. The cells stain very deeply with hæmatoxylin and become brown after treatment with potassium bichromate; the nucleus is not so easily seen as in the cortical cell columns, but is most often oval. This is the "medullary portion of the gland." It will be seen that the terms "cortex" and "medulla" are quite misnomers in amphibians, for the "cortex" often occupies the central as well as other regions of the gland, and the "medulla" is, as often as not, cortical in position. But it will be advisable for the present, to avoid confusion, to retain these names.⁴

In Reptiles and Birds the minute structure is not very different from that in amphibians, but in these groups the suprarenal capsule is in anatomical relationship to the reproductive organs and not the kidneys.⁵

It is not until we come to mammals that the terms "cortex" and "medulla" are really appropriate. The description of the anatomy and histology in mammals need not detain us.

Developmentally, it would seem from the best authorities that the medullary part of the suprarenals is derived in some way from the sympathetic nervous system, and that the cortical portion is derived from the germ epithelium; but it must be

noted that, whatever their origin, they are both "glandular," so that we must look upon the mammalian suprarenal capsule as a double glandular organ, developmentally related to the reproductive and nervous systems.

I have thought it desirable to repeat some of the statements concerning the comparative aspects of the subject in this paper, because since I wrote my previous article in this Journal,¹¹ I have accumulated further evidence, all of which points in the same direction. Thus it is found that the homologies of the paired bodies in Elasmobranchs and the interrenal gland in the same order to the medulla and cortex of mammalian suprarenals are borne out by subcutaneous injections of extracts made from them.^{12A} The same applies to the homology of the teleostean suprarenal body to the cortex of the suprarenals of the higher vertebrates.^{12A} Further, in conjunction with B. Moore, I have investigated the comparative chemistry of the suprarenal capsules, with results entirely harmonising with those I had previously obtained.^{73, 74}

Extirpation experiments upon the eel⁷⁵ have entirely corroborated my opinion that the suprarenal bodies of Teleosts consist entirely of cortex.

It is perhaps desirable to urge still further the separate importance of cortex and medulla, as observers may be led to investigate the subject upon what I believe to be the only safe lines. This would scarcely appear necessary, except that medical men and some physiologists have not yet sufficiently grasped the most fundamental points in the comparative anatomy and physiology of the subject. Thus Dr. Rolleston⁶ so recently as 1895, says, "At the present time the cortex and the medulla of the suprarenal body are generally considered to be distinct in origin, structure, and function. The cortex is regarded as being glandular or hæmatopoietic, and the medulla as being nervous and connected with the sympathetic." If this second sentence were to read, "The cortex is regarded as being glandular and probably derived from the germinal epithelium, and the medulla as being also glandular, but apparently derived from the sympa-

thetic," this would express with some accuracy what I believe to be the correct view. The medulla of the mammalian gland, whatever its origin, is certainly not in its essence and function "nervous." But Dr. Rolleston proceeds to quote Creighton⁷ to the effect that the distinction between the cortex and medulla of ordinary anatomy is quite arbitrary, as there is no real difference between their constituent cells. "The central part or medulla is only more spongy than the rest." I have, in former papers, given sufficient evidence^{8, 9, 10, 11, 12} to shew that there are no grounds whatever for such an opinion. *The cortex and medulla are as distinct as possible throughout the whole of the vertebrata.* One has only to look at a series of slides of the suprarenals in Fishes, Amphibians, Reptiles, and Birds to be convinced of this. Rolleston concludes, "From these considerations I should be inclined to regard the suprarenal as a functional whole, the medulla and cortex performing the same work, though possibly in unequal degrees, since the cortex very commonly undergoes considerable fatty change. This speculation, based on anatomical grounds, receives strong support from the observation that the medulla alone provides an active extract." Surely this is illogical. The fact that the medulla provides an active extract while the cortex does not, would rather tend to emphasise the distinction between them. Besides, as I have had occasion to urge in previous papers, it is rash to assume because no active principle has yet been found in the cortex, that there is no such active principle.

Dr. Auld¹³ holds similar views, but as I have already published replies to these,¹¹ I will not further discuss them here. The facts I have given in former communications will, I imagine, speak strongly for the separate origin, structure, and function of the cortex and medulla.

Since, as above pointed out, two primary groups of fishes (including by far the great majority of living species) appear to have no "medulla," but only "cortex," it might be urged that the cortex is more important than the medulla, for, whereas in certain vertebrates the medulla can be dispensed with, the cortex is universally present.¹²

Results of ablation experiments.—The investigation of the functions of the suprarenal capsules has been carried on in various ways. The chief of these will be briefly dealt with.

The earlier views on the functions of the suprarenals need not be discussed, as they were based for the most part on the wildest hypotheses and had no scientific value whatever. The history of the subject commences in 1855, when Addison published his famous memoir "On the Constitutional and Local Effect of Disease of the Suprarenal Capsules."¹⁴ Some months later Brown-Séguard,¹⁵ as the result of a series of 300 experiments, concludes that the suprarenal capsules are absolutely essential to life. Later, however, this eminent physiologist seems to have modified his views. Philippeaux^{16, 17, 18} came to the opposite conclusion and was supported by Harley,^{19, 20} Gratiolet,²¹ Berûti²² and Schiff,²³ who were inclined to attribute death to causes other than the mere removal of the suprarenal capsules. Harley, for example, considered the fatal result was due to damage of the semi-lunar ganglion.

In 1884—1888, Tizzoni^{24, 25, 26, 27} published a series of papers in which he holds that the removal of the glands always brings on death by causing pathological changes in the nervous system. Stilling^{28, 29, 30} recognised that removal of both capsules was always fatal, while removal of one entailed a compensating hypertrophy of the other.

The next researches of importance date from 1891, when Abelous and Langlois commenced their series of ablation experiments upon frogs.³¹⁻³⁹ These experimenters used the cautery to effect destruction of the capsules. They found that complete destruction of both capsules was always followed by death of the animal. When one organ only was removed the results were negative, the animal remained perfectly normal, and no hypertrophy of the remaining capsule was observed. After removal of one capsule and part of the other, the symptoms varied with the extent of the destruction. Death was accompanied by convulsions and dyspnœa.

After destruction of the two capsules the animal appeared

normal for a time. The duration of survival was variable, this variation depending upon season, according as the experiments were carried out in summer or winter. Hibernating frogs lived 12 to 15 days, summer frogs never more than 48 hours. The symptoms observed were apathy, inco-ordination of posterior extremities, muscular weakness and paralysis, first of hind limbs then of fore limbs. Respiration became slow, pupil contracted, heart weak and infrequent, and death ensued. These results could be hastened by causing the frog to sustain muscular exertion.

These authors further found that if one takes some of the blood from a frog which is dying as the result of the destruction of its suprarenal capsules, and injects this into the abdominal vein or the dorsal lymph sac of a second frog whose capsules have only just been destroyed, one observes a rapid paralysis and death.

From these experiments Abelous and Langlois conclude that after the removal of the suprarenal capsules, the animals die of an "auto-intoxication," an accumulation in the blood of some substance or substances which it is the duty of the capsules to get rid of.

Many other observers have removed the suprarenal capsules from various animals, and the conclusion arrived at has been that this always induces death, that the animal cannot live without some suprarenal tissue. Langlois,⁴⁰ as the result of a series of ablation experiments in mammals, concludes that the blood of these also is toxic after the operation. Of course it is possible that the blood of an animal dying from other causes might be toxic, especially following operations where some septic condition might easily be induced. The French physiologists however maintain strongly the auto-intoxication theory.

Without deciding finally, we may say that the evidence is strongly in favour of the view that the suprarenal capsules are organs essential to life. While concluding in this fashion from the results of operations entailing entire removal of the organs,

we must not forget that the surgical difficulties are very great, and it is not possible to remove the capsules without doing considerable injury to other structures.

THE SPECIFIC PHYSIOLOGICAL EFFECTS OF EXTRACTS OF
THE SUPRARENAL CAPSULES.

The method of research which has been most fruitful of results has been the injection of extracts made from suprarenal capsules into the blood-vessels of living animals. This method has been employed by Oliver and Schäfer,^{41, 42, 43} resulting in discoveries which have made an epoch in the history of the subject. After intravenous injection of very small quantities of suprarenal extract, these observers noted *marked contraction of the arterioles, causing an enormous rise of blood-pressure within the arterial system.* That the contraction of the arterioles is due to the direct action of the active principle of the gland upon the muscular tissue of the blood vessels, is shown by the experiment of perfusing a weak extract of the glands through the blood-vessels of the frog after brain and spinal cord have been destroyed; it is also demonstrated by the fact that it occurs equally well after section of the spinal cord, and after section of the nerves going to the limb. On the heart suprarenal extract was found to exert a powerful inhibitory effect so long as the vagus was intact. After cutting the vagi the heart beat more quickly and more powerfully. These authors found the active principle to be present only in the medulla. They conclude—"It may fairly be concluded therefore that one of the main functions, if not the main function, of the suprarenal capsules is to produce a material which is added in some way or another to the blood, and the effect of which is to assist by its direct action upon the various kinds of muscular tissue in maintaining that amount of tonic contraction which appears to be essential to the physiological activity of the tissue."

This conception is one of "internal secretion," and is usually stated in opposition to the "auto-intoxication" theory of the French school. But we must bear in mind the possibility that

both views may be correct; it is possible that the secretion of the capsules has for its duties the destruction of the waste products of the muscular metabolism and the formation of an active material by means of which an increased tone of the muscles is brought about.

Szymonowicz and Cybulski⁴⁴⁻⁴⁹ have since obtained similar results, but believe that the extract acts, not directly upon the blood-vessels, but upon the vaso-motor centre. They also find that the cortex is partially active. The experiments of Velich⁵⁰ as well as my own upon the suprarenals of the lower vertebrates⁵¹ tend to confirm the statements of Oliver and Schäfer. Indeed there can now be little doubt that the Polish physiologists are incorrect upon both these points.

THE GENERAL PHYSIOLOGICAL EFFECTS
PRODUCED BY SUBCUTANEOUS AND OTHER INJECTIONS OF
EXTRACTS OF SUPRARENAL CAPSULES.

Various authors have from time to time attributed toxic properties to the suprarenal capsules, as a result of experiments involving subcutaneous injection of extracts into animals. Foa and Pellacani^{52, 53, 54} seem to be the earliest of these. These observers injected fresh aqueous solutions into dogs, rabbits, and guinea pigs. The animals were usually found dead the next day. Marino-Zucco, Dutto, and Guaruceri^{55, 56, 57} attributed these results to neurine, while Alexander⁵⁸ and Alexais and Arnaud⁵⁹ considered the experiment of little value, believing the effects to be artificial, and that the suprarenal capsules in the fresh state do not contain any toxic principle. Oliver and Schäfer⁶⁰ produced no obvious effects by injection of large doses into the dog, the guinea-pig, and cat. But in the case of the rabbit, a large dose of suprarenal extract administered subcutaneously appeared invariably to produce death. Cybulski⁶¹ does not think these effects are toxic, but attributes them to an effect principally upon the vaso-motor centre. Gourfein⁶² notes the variability in the toxic effect obtained in different cases. Glaczinski,⁶³ Caussade,⁶⁴ and Dubois⁶⁵ have also contributed to this part of

the subject. The last of these authors has attempted to classify the causes of the variations in the toxic effects produced.

My own conclusions^{77, 78} are :—

1. It requires comparatively very large doses of suprarenal extract to cause death in any animal when injected subcutaneously. At the same time it seems clear that the substance of the capsules does certainly contain an active toxic principle, which is specific to the glands, and not present in other tissues.

2. Rabbits, guinea-pigs, rats, and mice, can all be killed by the injection if the dose be sufficiently large.

3. The characteristic symptoms after injection are slow muscular movements, paresis and finally paralysis of the limbs (hind limbs always becoming affected first), hæmaturia or hæmoglobi-nuria, bleeding from mouth and nostrils, and ecchymoses. The breathing is rapid and shallow at first, finally becoming deep and infrequent, and there are occasionally convulsions resembling those of asphyxia preceding death. Before this event the temperature very frequently falls to a very low point.

The blood-coloured urine was found in one case to contain no corpuscles. In other cases corpuscles have been present. The hæmaturia has, in my experiments, not occurred with fresh material, but the other hæmorrhages occur alike with fresh decoctions, glycerine extracts, or extracts made from dried material which has been kept some time. The paralysis is central, not peripheral, as shown by the effect of stimulating the sciatic nerve, when the condition is fully established.

4. The injection of glycerine extract causes local sloughing and ulceration of the skin and subcutaneous tissues.

5. The cortex of the gland is inactive as regards any appreciable general effects, just as Oliver and Schäfer found it to be in its effects on blood-pressure.

6. Other gland extracts (liver, spleen, kidney, etc.) are likewise inactive.

7. Even after several of these symptoms have supervened, and the animal is considerably paralysed, the effects may pass off and complete recovery follow. This shows that the toxic principle is easily eliminated.

8. The precise dose which will be fatal to an animal of given species and weight cannot be predicted, as idiosyncrasy plays a large part in the conditions.

9. After a sub-fatal dose a partial immunity seems to be set up, so that it is difficult to cause a fatal result by subsequent injection.

The first effect noticeable in *dogs* is excitement. There is increased muscular activity, which passes into a stage of agitation with tremors, until paresis and finally paralysis come on. Thirst is also a striking symptom in dogs. There is abundant micturition, but I have observed no hæmaturia. A peculiar statuesque attitude has characterised all the dogs experimented upon after the first stage of excitement passed off. Before paralysis sets in, muscular effort appears to be accompanied by pain; the dog frequently raises a limb from the floor as if the contact were painful. There appears to be no hyperæsthesia of the skin. The paralysis which comes on before death is similar in all respects to that which occurs in other animals. The temperature in one case fell before death to 26.7°C .

In *cats* by far the most noticeable feature was an enormous rapidity of the respiratory movements in the early stage. Thirst and loss of appetite were also noted. The paralysis of the limbs was not so definite as in other animals, but the breathing became gradually less and less frequent towards death.

As such large doses (26 to 60 grammes) had to be given to dogs and cats to produce symptoms, I was anxious to make myself certain that other tissues and organs would not produce any toxic effect when prepared and administered in the same way. Accordingly an extract was prepared (by boiling for a short time and filtering) of 37 grammes of rabbit's liver, and injected subcutaneously into a dog weighing 4.5 kilos., without producing the slightest effects. Again, I injected into the same dog an extract of 37 grammes of sheep's brain with similar results. Pituitary extracts were also found to produce no symptoms. It thus appears that the suprarenal gland (with the possible exception of the thyroid) is the only mammalian tissue which produces

toxic effects when a boiled and filtered extract is administered subcutaneously.

The extracts employed were prepared in different ways. Some were obtained by boiling the chopped fresh gland with normal saline for a short time, filtering, and using the filtrate for injection. Some of the glands were cut up and dried at a low temperature, and the dried material subsequently boiled in a similar manner, the decoction being as before carefully filtered. In other cases cortex and medulla were separated as far as possible and employed in the above manner, either fresh or dried. Again, some of the extracts were alcoholic and others glycerine extracts. Numerous control experiments have been performed. Thus, when a glycerine extract was injected, the same amount of glycerine diluted to the same extent was injected into another animal of as nearly as possible the same weight.

Taking together the results of experiments upon the arterial system and those which have for their object the elucidation of the general effects upon the economy of suprarenal extract, we see that *the active principle has a peripheral effect on muscular tissues and also a central effect manifested by the paralyses above described.* Of course it is possible that there may be more than one such active principle.

Both these effects are due to the medulla. What functions shall we ascribe to the cortex? Two views are open to us. (1) That it is in some way accessory to the medulla, *e.g.* it may prepare the active material for final elaboration in the medulla, or (2) it may have nothing whatever to do with the medulla, the union of the two being in a sense accidental. This latter view is the one I am myself disposed to take, since it is supported by the very different origin of the two parts of the organ (see *Comp. Hist. and Development, supra*).

CHEMISTRY OF THE SUPRARENAL CAPSULES.

Having thus briefly reviewed the effects obtained by administering extracts of suprarenal capsules to animals, we must direct our attention to the chemical nature of the gland, and substances which can be obtained from it.

The chemistry of the subject has been studied by Vulpian,⁶⁶ Fränckel,⁶⁷ Mühlmann,⁶⁸ Krukenberg,⁶⁹ Moore, and others. The following account is taken chiefly from the last named author.

In his first communication ⁷⁰Moore concludes :—

The active principle is soluble in water, and in dilute alcohol ; its solubility decreases with the percentage of alcohol present, until with absolute alcohol it is almost insoluble. It is insoluble in ether, chloroform, amyl alcohol, carbon bisulphide, or benzene.

It is not attacked by acids nor by boiling for some minutes, but is destroyed by alkalies, by oxidising agents, and by continued boiling.

It is not precipitated by excess of alcohol, by saturation with ammonium sulphate, mercuric chloride, potassio-mercuric iodide, or tannic acid.

It does not reduce Fehling's solution alone, nor after boiling with mineral acids, nor does it form a crystalline compound with phenylhydrazine.

It is not volatile either alone or with water vapour. It dialyses freely through parchment paper, and the highly active dialysate obtained is completely free from proteids.

In a later communication⁷¹ Moore concludes that the active principle is not identical with a powerful reducing substance first described by Vulpian⁶⁶ in the same situation. This material gives various colour reactions on being oxidised : *e.g.*, with ferric chloride it gives a dark green or blue colour, and with chlorine, bromine, or iodine water, or caustic alkalies, a rose-red colour. He concludes that Fränckel's opinion that the active substance is a derivative of pyrocatechin is incorrect, and also that it is not identical with the chromogen of the organ. He found that the substance or organic radical which gives the colour tests has no action on blood-pressure. He considers it probable that the chromogen is a complex compound somewhat resembling the tannins of coffee and tobacco, each of which gives a green colour with ferric chloride, turning to red on the addition of an alkali. There are certain indications that the

substance or group on which the physiological activity depends is probably a pyridine derivative. If suprarenal extract be cautiously fused with caustic potash so as to avoid charring, the characteristic odour of pyridene is obtained. But pyridene itself lowers blood pressure, while reduced pyridene or piperidine raises it in a marked degree. Moore provisionally concludes that probably the suprarenal material like piperidine is a pyridine derivative, which contains a reduced or partially reduced pyridine ring, differing somewhat from piperidine.

In 1888, MacMunn⁷² made some valuable observations on the suprarenal capsules. He found that the suprarenals show the presence of the bands of hæmochromogen or reduced alkaline hæmatin, when examined spectroscopically. These bands he found to be specially well marked in the medullary portion of the gland. In man, dog, cat, rabbit, rat, guinea-pig, ox, and sheep, the result was practically the same. Wherever hæmochromogen had been previously detected MacMunn had found it to be excretory, so he concluded that here also it must be excretory. He drew the obvious conclusion that in the adrenals a downward metamorphosis of worn-out pigments—hæmoglobins and the histohæmatins—is taking place, and the function of these organs is to pick out of the circulation these worn out or effete colouring matters with their accompanying proteids. "When the adrenals are diseased, these effete pigments and effete proteids circulate in the blood; the former, or their incomplete metabolites, producing pigmentation of skin and mucous membranes, and appearing often in the urine as uro-hæmatoporphyrin; the latter producing toxic effects, and leading to further deterioration of the blood with its consequences."

This is practically an "auto-intoxication" theory, though differing somewhat from that of the French authors. There is at present no satisfactory evidence that the blood of an animal dying after removal of its suprarenal capsules, or the blood of a patient suffering from Addison's disease, contains any specific toxic substances.

Pathological and Therapeutical.—Undoubtedly the greatest interest in regard to the function of the suprarenal capsules

centres around Addison's disease. In this disease the most striking symptoms are the pigmentation and the extreme muscular prostration. The pigmentation may or may not be due to derangement of the functions of the medulla which, as we know, contains a chromogen. The muscular weakness is tolerably well understood if we adopt the theory put forward by Oliver and Schäfer that the medulla of the capsules normally manufactures and pours into the blood a secretion which maintains the tone of the various muscular structures of the body. When this secretion is absent, as in Addison's disease, the muscles are quite incapable of any but the briefest exertion. This excessive loss of muscular energy is indeed considered by many to be diagnostic of Addison's disease. It is of a peculiar character, inasmuch as there is not so much inability to perform a single muscular act, as an almost complete loss of resistance to fatigue. If tracings be taken with Mosso's Ergograph it is found that the curve falls away suddenly, differing totally in its character from that of other wasting diseases, such as phthisis.

The indication for treatment obviously is to supply in some way or other the active substance which is lacking to the economy, owing to disease of the capsules. There are three ways in which this may be done. (1) The patient may be fed upon suprarenal capsules, or may take by the mouth some form of extract made from them. (2) Extracts may be injected subcutaneously. (3) Extracts may be injected directly into the blood-vascular system.

With regard to the treatment by the mouth, there is little evidence at present as to its utility. Dr. Oliver, Dr. Rolleston, Dr. T. Oliver and others have employed this method, but the results have been disappointing. There is, indeed, no direct evidence before us that the slightest physiological effect can be induced by taking suprarenal capsules, or extracts made from them into the stomach. It has so far been considered as correct treatment on the strength of the observation made by Oliver and Schäfer that the active principle of the gland was not destroyed by gastric digestion *in vitro*.

I have myself failed entirely to produce the characteristic symptoms of suprarenal poisoning by giving by the mouth suprarenal capsules of the sheep, and extracts made from them to cats, dogs, and rabbits. One of the dogs I employed devoured 200 grams. of suprarenal capsules without any appreciable effects,⁷⁶

Subcutaneous injections seem more likely to produce good effects. A boiled and filtered normal saline decoction would be the most readily prepared, and most convenient mode of administration. The following formula is given by Langlois :—

Suprarenal capsules of guinea-pig	0.80	gram.
Boiled water	10.00	„
Sodium chloride } Sodium sulphate }	0.07	„

Pound in a mortar, and leave to macerate for 24 hours, then filter through sterilised cotton wool. The dose is from 2 to 5 cc.

The formula of D'Arsonval is as follows :—

Suprarenal capsules 10 grams.

Cut up into small pieces and leave to macerate for
24 hours in glycerine at 30° C.

Water containing 25 grams. per litre of NaCl, 5 grams.

This is left to macerate for half-an-hour, then filtered through paper and sterilised by means of carbonic acid under pressure. For subcutaneous injection, the liquid is to be diluted with equal parts of boiled water, and the dose is 3 to 8 cc.

Alcoholic extracts may also be employed for subcutaneous injection.

If suprarenal capsules from the sheep be employed for making the extracts, much larger doses can be safely employed.

In the last stages of Addison's disease much benefit might be derived from *intravenous* injection of suprarenal extracts. The dosage in this case must be very small. Oliver and Schäfer ascertained that a milligram per kilogram of body-weight is sufficient to produce physiological effects. On the other hand, it must be remembered that the effect is very temporary, the blood pressure soon returning to the normal, and the heart to its former force and frequency.

Schäfer has recently suggested *intracardiac* injection of extracts of suprarenal glands as a last resource in heart-failure from administration of chloroform.

But Addison's disease is probably not the only condition in which suprarenal extracts may be found useful. As our knowledge of the physiology of the glands advances, so will our knowledge of the pathology, and it is more than likely that before long, distinct diseases will be recognised as due to distinct pathological conditions of the suprarenal capsules. It is probable that various anomalous diseases characterised by muscular weakness or wasting may be due to functional disorder of the capsules. Again, some blood-conditions may some day be ascribed to lesions of these organs. In the meantime, it seems more than likely that good results may accrue by the administration of suprarenal extracts in cases of excessive muscular fatigue, of low blood-pressure, and feeble heart's action. But we must bear in mind that there are several distinct effects produced at the same time, so that the dosage should be very cautious. There seems every reason to believe, from Dr. Oliver's and Prof. Schäfer's experiments, that suprarenal extract may turn out to be a useful hæmostatic.* Dr. Oliver mentions purpura, hæmophilia, and diabetes, as conditions in which it is likely to be useful. Dr. Stanley states that in a case of pernicious anæmia, he has found the administration of the extract increases the number of red blood-corpuscles.

But it may be that more than one active physiological substance is present in suprarenal capsules, and we must await further chemical investigation on this subject.

To sum up briefly the most recent views about the suprarenal capsules. These organs consist of two separate and distinct glands, cortex and medulla. The medulla contains a chromogen, possibly allied to the tannin in coffee, and an active principle which appears to be closely connected chemically with piperidine. This latter has a remarkable effect upon the muscular

* Prof. Schäfer has recently found that the extract acts as a powerful local styptic in epistaxis.

tissues generally, increasing their tone, and producing when injected intravenously, an enormous rise of blood-pressure. There is also a central effect manifested by the production of paralysis, but whether this is due to the same or a different active principle, is not yet determined. The function of the cortex remains to be elucidated.

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The Comparative Histology of the Suprarenal Capsules.

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(With Plates XVI—XVIII.)

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I. Introductory.

In this paper an attempt will be made to give a review of the minute structure of the suprarenal capsules in those groups of the Animal Kingdom where they can be shewn to exist.

I have previously described the anatomy and histology of these organs in Pisces [116] and have also given a preliminary account of their structure in Amphibia and Reptilia [117]. Having been engaged for some time in researches upon the comparative physiology and

¹⁾ The numbers in square brackets throughout the text refer to this bibliographical list.



chemistry of the suprarenal capsules [118—121, 81, 82] I thought it would be interesting to employ the results obtained from these modes of investigation to form a basis for a widely comparative survey of the structure of the representatives of the capsules throughout the Vertebrata.

The literature of the subject is very extensive, and although I have tried to obtain access to every paper bearing upon it, I fear there may yet be some omissions, which will I hope, be pardoned.

A full account of the history up to date as regards Pisces, will be found in the paper above referred to [116], and some account of the literature in Amphibia and Reptilia in 117. The results here put forward embody the labour of five years, and some repetitions of former published results have been necessary for the sake of uniformity in a review of the whole subject.

I have examined a very large number of species. As in previous histological work, I have relied entirely upon perfectly fresh material, except in the case of some of the rarer animals. Some preparations were made quite fresh, others after freezing. Still others after hardening, were stained in bulk imbedded in paraffin, and cut with the "Rocking Microtome". The fixing and hardening fluids I have employed most frequently are Müller's fluid, and other bichromate solutions, alcohol, formol, mercuric chloride, and osmic acid. Methods of dissociation have been employed for studying the separate cells, and the most frequently used of these was maceration in Ranvier's $\frac{1}{3}$ alcohol. The most useful fluid for hardening is undoubtedly Müller's, because by this means we have a universal method of distinguishing cortex from medulla.

I take this opportunity of expressing my thanks to Professor E. A. Schäfer, LL. D., F. R. S., for advice on many points connected with this research, and for the generous manner in which he has placed the resources of his laboratory at my disposal. I am also indebted to Professor G. B. Howes, LL. D., F. R. S., and to Dr. H. O. Forbes for their kindness in furnishing me with material. I have further to record my gratitude to the British Medical Association, by whose munificence I have been enabled to carry on my researches during the past two years.

II. The Suprarenal Bodies in Invertebrata.

Leydig, [73] in a most interesting passage, discusses the possibility of the existence in some Invertebrata of the equivalents of the suprarenal bodies. He says: "Es sind in verschiedenen Wirbellosen am Nervensystem Zellen beobachtet worden, die von den gewöhnlichen Ganglienkugeln differierten. So habe ich schon früher von *Paludina vivipara* mitgeteilt, dass an den vegetativen Nerven 'eigentümliche Zellen vorkommen, die vielleicht Ganglienkugeln eigener Art sind; sie sind gelblich, haben im Innern verschiedene Bläschen und stehen in keinem directen Zusammenhang mit den Nervenprimitivfasern'. Auch an den Ganglien von *Pontobdella verrucosa* machten sich besondere Zellen mit gelbkörnigem Inhalt auffällig." He quotes also a description of Meissner concerning similar cells in *Mermis* and concludes: "Meine Meinung bezüglich dieser Zellen von unbekannter Bedeutung an *Paludina*, *Pontobdella*, *Mermis* (und wahrscheinlich wird ein näheres Nachsehen die Zahl der Beispiele sehr vermehren) geht dahin, sie als Analoga der Nebennieren vorläufig zu betrachten."

I had long considered the possibility of the existence of suprarenal bodies of some sort in the Invertebrata, but had not myself succeeded in finding any organ or tissues which seemed likely to represent them. But recent physiological researches have put it into our power to test any organ to see if it be medullary suprarenal (Oliver and Schäfer [87], Swale Vincent [120]). Accordingly, I dissected out the nervous system as completely as possible from about a dozen fair-sized specimens of *Paludina vivipara*. The material (in which of course was included the groups of cells described by Leydig) was then made into a decoction by boiling for a short time with normal saline and carefully filtering. This was then injected into the venous system of a cat while a record of the blood-pressure was being taken. The result was quite negative, there being not the slightest rise of the blood-pressure.

If these cells of Leydig represented any part of the suprarenal capsules at all, this would be the medulla, since it is the medulla which is found in Vertebrata to bear a close relationship to the

nervous system. But medullary substance when injected into the venous system of a living mammal even in the smallest quantity, always causes a marked rise of blood-pressure. I feel justified, therefore, in dismissing these groups of cells from consideration as the analogues of the suprarenal medulla, at any rate as the physiological analogues. Whether or no there are any suprarenal bodies in Invertebrata must remain an open question for the present.

III. Acrania. Amphioxus.

Nothing is known of the suprarenal bodies in Amphioxus. There is no mention of them in the text-books or in the monographs upon this animal. I have myself examined several individuals without finding anything which suggested the existence of either the cortical or medullary representatives of these organs. It would however be rash in the present state of our knowledge to assume that Amphioxus has nothing corresponding to the suprarenal bodies.

IV. Cyclostomata.

As early as 1827 Rathke [93] described certain "white-specks" on the cardinal veins of *Ammocoetes* which he thought were suprarenals. In the following year a note appears in the text of "Burdach's Physiologie" (Bd. XIX. No. 2. p. 601) signed by Rathke in which he suggests that the pronephros or head-kidney and suprarenal bodies may be homologous. In 1843 appeared the well known description of J. Müller's "Clustered gland" in Myxinoids. Later this Author changed his opinion and thought it was the thymus.

Ecker [32, 33] in 1846 described a new structure in *Petromyzon* as a suprarenal body, an organ triangular in section on the inner wall of the posterior cardinal sinus. Stannius [107—110] and Leydig [70] considered the bodies pointed out by Rathke and J. Müller to be the suprarenal bodies.

In 1884, Weldon [124] described the head-kidney of *Bdellostoma* and believed that in this animal the pronephros has become modified so as to form an organ functionally analogous to the suprarenals. Later this writer expands this view [125] and in Wiedersheim's text-book [126, 127] we find Rathke's original suggestion revived:—

“Bei Teleostiern sind die Nebennieren nicht überall in klarer und überzeugender Weise nachgewiesen; wo dies aber der Fall ist, handelt es sich, wie früher schon angedeutet wurde, um Beziehungen zu der in lymphoides (adenoides) Gewebe umgewandelten Kopfniere. In anderen Fällen aber sind sie enge mit der Niere verbunden” — referring to a foot-note which runs as follows. “Dies gilt nach W. Weldon auch für die Cyclostomen” (*Bdellostoma Forsteri*).

A paper by Miss Kirkaldy (65) in 1893 leads to the same conclusions.

In conjunction with W. E. Collinge [20] I have attempted to determine whether suprarenal bodies are present or no in the Cyclostomata. We succeeded in finding both Rathke's and Ecker's bodies, but were not convinced that either of them had anything to do with the suprarenal bodies.

More recently Pettit [89] has re-examined the structure described by Ecker in the Lamprey. He says: “J'ai pu retrouver chez *Petromyzon marinus*, L, les corps signalés par Ecker; ce sont deux masses irrégulières mesurant dans leur plus grande largeur 10 millimètres, dont l'aspect pancréatiform rappelle assez exactement les capsules des Batraciens. Elles occupent une position qui me semble être celle des glandes décrites par Müller chez la Myxine.

En tout cas, ces deux organes sont situés en arrière des branchies, de part et d'autre de la ligne médiane, à la hauteur du péricarde cartilagineux. L'aspect de ces glandes n'a, il faut le reconnaître, rien de caractéristique; ce sont des masses irrégulières, jaunâtres, parsemées de taches pigmentaires; néanmoins elles affectent des connexions constantes qui permettent de les trouver facilement; il faut fendre la face ventrale de la veine cardinale à la hauteur du coeur et écarter les deux lambeaux. Les glandes apparaissent alors au travers de la paroi vasculaire, entre la veine cardinale et l'artère aorte; d'ailleurs grâce à leur coloration jaunâtre elles se détachent assez nettement sur le fond sombre des tissus environnants. (La glande adhère intimement à la veine cardinale et il est difficile de la séparer de ce vaisseau sans la détériorer.)

Au point de vue histologique cet organe se montre constitué par

une série d'acinés tapissés par un épithélium colonnaire et pourvus d'une lumière; en outre il existe quelques cellules pigmentaires éparses çà et là."

Pettit is unable to decide whether this structure is homologous with the suprarenal bodies of Teleosts or not.

V. Pisces.

1. *Elasmobranchii*.

In Elasmobranch fishes two distinct sets of structures are found, both of which have from time to time been described as suprarenal bodies. These two structures correspond the one to the medulla and the other to the cortex of the suprarenal capsule in the higher Vertebrata¹).

Paired Suprarenal Bodies. The following account differs in some points from that which I gave in April of last year [116]. Since that time I have determined that these bodies correspond physiologically to the medulla of the suprarenals of the higher Vertebrata [120, 121] and that they contain the same chromogen [81]. We shall see that the histological structure also is analogous.

The gross anatomy of these bodies need not detain us. They are situated on branches of the aorta, segmentally arranged, and extend on each side of the vertebral column from the front part of the sinus of Monro to the posterior end of the kidney. The anterior pair are elongated and correspond usually to three or four segments²).

The structure of these bodies is very complex and difficult to describe even when the preparations are successfully made. It will be desirable, however, to enter into as much detail as possible, since these organs represent the primitive type of suprarenal medulla in Vertebrates.

It will be convenient first of all to describe the structure of the first pair, the so-called "axillary hearts" and then to proceed to the description of the bodies which lie posterior to them.

¹) This view was first put forward by Balfour [6] p. 664.

²) For drawings of these bodies see 114 of bibliography.

If a longitudinal section be taken through the centre of an "axillary heart" of *Scyllium canicula*, it is seen that the whole structure consists of two distinct parts. First, there is an elongated nerve-ganglion antero-externally, and secondly, there is the proper suprarenal medullary substance postero-internally. The ganglionic structure needs little comment. It is composed of typical large nerve-cells with nerve-fibres running longitudinally. The nerve-cells are on an average 55μ in diameter.

The typical arrangement of the proper glandular structure of the axillary heart is as follows:—

Running through the centre of the body is an arteriole. On each side of the artery (surrounding it, forming a central zone) is seen the layer of cells which are stained brown with the bichromate of potassium. These are irregular and branched, and frequently more or less triangular. Their size is difficult to state, owing to their irregularity; they vary, however, in their greatest lengths from $10-30 \mu$; the nucleus is usually about $6-8 \mu$ in diameter. These cells appear to communicate freely together by their processes.

The outer zone consists of an external layer of irregularly columnar cells one row deep and beneath this one or two layers of polygonal cells. Externally is a fibrous capsule $4-7 \mu$ in thickness which sends off septa accompanied by capillary plexuses into the interior of the organ.

There is no trace of an alveolar arrangement of the cells in these bodies.

In many cases there are groups of nerve-cells in the central portion of the structure, and scattered nerve-cells are not infrequent in many parts of the organ. In addition, there are to be seen here and there the intermediate form of cell to be described below. There are many variations in the arrangements in regard to nervous structures, and the amount of connection with the ganglia differs in different genera and also to some extent in different species. The above account, however, having reference to *Scyllium canicula* may be taken as on the whole, fairly representative.

The "axillary heart" is more "mixed up" with nervous structures than any of the more posteriorly placed bodies. As we proceed

further and further backwards, there is less and less nervous admixture, till the most posterior bodies present the type of suprarenal tissue, with the ganglia quite separate from them. A fibrous capsule sends in irregular septa, and capillary plexuses follow these. The arteriole above mentioned always occupies the centre of the section, and surrounding this is the "medulla" containing the chromogenic cells. These have already been described in connection with the first pair. Pl. XVI. fig. 1 and Pl. XVIII. fig. 3 represent these cells from the middle region of the body of *Raja clavata*. External to these is a layer several rows deep of irregular polygonal cells which shew no brown coloration in bichromate preparations, and immediately beneath the capsule is a layer of very irregular, elongated, almost columnar cells, likewise shewing no pigmentation (Pl. XVI. fig. 2). The nuclei of all these cells shew distinct nuclear figures.

Chevrel [18] differs from Balfour [3] in failing to find any distinction between the character of the cells in the external and internal zones of the paired bodies. This Author indeed goes so far as to state that no definite cell-outlines can be made out in any portion of the bodies. "On ne voit ni cellules columnaires à la périphérie, ni cellules polygonales au centre; il n'y a que des apparences. Et ces apparences sont dues vraisemblablement au contours des mailles de la trame conjonctive des corps. Les dissociations nous donnent également des résultats négatifs."

In my former descriptions I was inclined to agree on the whole with Chevrel, but I have since then, as the result of continued investigation, seen reason to alter my views. Even before the paper was printed I had stated in a footnote "Since the above was written I have succeeded in making out the cell outlines in the 'axillary hearts' and by renewed preparations by different methods I have now no difficulty in determining the outlines of the cells in nearly all the bodies. Moreover, "definite cells in some parts" were described . . . "mostly triangular or multipolar in shape, and of a uniform sepia-brown tint, and they contain large, very darkly stained, round nuclei . . . The cells appear in some places to communicate

together by their processes". And more recently¹⁾: "These pigmented cells are mostly in the interior of the body".

So that we have certainly two zones, a "cortical" and a "medullary" in these bodies; the cortical is devoid of chromogenic cells, the medullary consists almost entirely of them. The pigmentation in the central cells is only seen after hardening in, or treatment with, some fluid containing bichromate of potassium.

On further examination too, it is clear that one must agree with the view of Balfour that the cells in the outer layer are columnar. This is depicted in Pl. XVI. fig. 2. But, after all, the chief distinction between the two kinds of cells is that those in the central portion contain the characteristic chromogen of suprarenal medulla (Eberth, 30), while those in the external layer do not. This distinction does not seem to have been noted by Balfour.²⁾

Undoubted nerve-cells are found included in the substance of many of the paired medullary bodies, both in the "axillary hearts" and those which follow, indeed in all, except perhaps a few of the most posterior. But in addition to these there are to be seen, especially in the axillary hearts, some cells as large as the nerve-cells, but whose protoplasm has become stained brown with the potassium bichromate. There are still other cells which are rather smaller, but have the same characters. *These I believe to be transition forms between nerve-ganglion cells and the proper medullary cells of the organ.* Balfour [3], suggests the possibility that such cells might exist, but was unable to determine their presence.

It has been shown in previous communications [118, 120] that these paired bodies really correspond physiologically to the medulla of the suprarenal capsule of the higher Vertebrata. It has also been demonstrated that the chromogen is of the same nature as in the suprarenal medulla of higher animals [81].

The intimate relations which subsist between these paired bodies

¹⁾ Birm. Med. Review, April 1898. p. 214.

²⁾ It may be that the physiologically active principle is secreted only by the central (chromogenic) cells. It is of course impossible to settle this point by direct experiment.

and the sympathetic nervous system have been sufficiently emphasised. Leydig [70 and 71] and Semper [106] have laid great stress on this aspect of the question. It remains to say a word about their relations to the blood-vascular systems. We have seen that each body is placed on an intercostal artery which is a direct branch of the aorta. This artery pierces the centre of the body and is always seen in the middle of the section. But much more striking is the fact that several of the anterior bodies (the number differs in different species) are placed in the venous sinus, and during life are bathed in its blood.

Interrenal Body. The interrenal body is an "ochre-yellow" rod-shaped structure, paired in the Rays, unpaired in the Sharks, lying usually in the region of the posterior part of the kidney, but sometimes extending as far forward as its anterior extremity. It bears a striking resemblance in its colour, general appearance, and relations to the kidney to the suprarenals of the Anura, and in the first two of these features, to those of the Reptilia.

This organ is the primitive type of the suprarenal cortex and corresponds in structure with the cortical part of the suprarenal body in Amphibians, Reptiles, Birds, and Mammals. It will be seen that it is very similar in structure to a secreting gland, as shewn by its definite arrangement into alveoli and its markedly granular protoplasm (see Pl. XVI. fig. 4).

The alveoli are arranged in many places in a radiating manner round large veins or venous sinuses. In many of my sections are seen structures very like "demilunes" in Mammalian mucous glands (Pl. XVI. fig. 4 *dc*). The appearance of the interrenal body when examined microscopically is so like that of the "corpuscles of Stannius" — the known suprarenal bodies of Teleostean fishes — that there can scarcely be a doubt of the homology between them (cf. Pl. XVI. figs. 4 and 7). This homology has been worked out in a separate memoir by Diamare [25 and 26].

The organ is made up of masses of cells, apparently solid, which we may designate the glandular alveoli (Pl. XVI. fig. 4). These vary in size and shape in different groups of Elasmobranchs and even in different species. Thus in the Rays they have a more rounded form than in

the Sharks. As seen in section the alveoli appear more or less oval in form, about 50μ thick and reaching $140-150 \mu$ in length. Each is surrounded by a fibrous membrane about 2μ in thickness. The cells are mostly elongated; some of the longest of these are $30-50 \mu$ in length, and reach quite across the thickness of an alveolus. The nuclei of the cells have an average diameter of 10μ . The cell protoplasm is coarsely granular and contains in a fresh state fatty looking globules. The nuclei shew nuclear figures in most cases. A rich capillary plexus surrounds the alveoli, separating their connective-tissue walls from those of neighbouring alveoli at nearly every point. Here and there in the section these capillaries widen out so as to constitute veritable sinuses.

It may with advantage be noted here, before leaving the subject of the Elasmobranchs, that the cortex of the suprarenal capsules is not much altered in the ascending series from Pisces to Mammalia, but that the medulla gradually undergoes a development, till from cells which differ little from pigmented nerve-cells devoid of axis-cylinder processes, arranged in irregular masses, we get the glandular form of the Mammalian medulla. The specific secretion and chromogen appear however even in Elasmobranchs.

2. *Ganoidei.*

The Sturgeon (*Acipenser sturio*) is the only member of this order about which I can make any positive statement. The suprarenal bodies of this fish are yellow masses of varying size and shape, scattered in the renal substance. I have nothing to add to the description I have already given of the histology of these organs. My former figure is reproduced (Pl. XVII. fig. 10) and it will be well to quote the description from my former paper [116].

"The rounded or elongated-oval alveoli ($50-60 \mu$ in diameter, or even 100μ long by about 60μ broad) are bounded by bold thick walls, averaging 3μ in thickness (Pl. XVII. fig. 10 al. w.) and the cell outlines are admirably preserved. The preponderating shape of the cells is round or oval, and in some parts they are seen to overlap, as the section is thick enough to contain several layers (*x*). In other parts

the cells are more polyhedral or irregular. Like the alveoli, they vary somewhat in size; their average diameter is about 20μ . The nuclei (n) are deeply stained and somewhat irregular in shape, having a diameter of $3-6 \mu$. The protoplasm is very finely granular as a rule, occasionally more coarsely granular. There are small nerve ganglia in connection with some of the bodies."

It was concluded:—"I have no doubt, from the above structure, that these bodies are the representatives of the suprarenal gland in Ganoids, and in my opinion they correspond to the cortical portion in higher Vertebrata". I have not had the opportunity of putting the matter to the physiological test in the case of the Ganoids.

3. *Teleostei*.

I have found suprarenal bodies in all fresh specimens examined. They are usually paired, round or oval, pale pink bodies, placed on the spinal or ventral surface of the kidney. They are near the posterior extremity of the renal mass, and are either free on its surface or more or less imbedded in its substance.

Histologically examined, the organs are found to be surrounded by a fibrous capsule which varies in the species examined from about 4 to 70μ in thickness. Externally to this capsule the intertubular adenoid tissue of the kidney is more abundant than in the other parts of the renal mass. The capsule is always thicker where the suprarenal adjoins the kidney substance, because here we have a double layer consisting of the capsule of the suprarenal body fused with the proper capsule of the kidney. The suprarenal glands are thus quite distinct and separate from the kidney substance. They are in fact simply placed in depressions upon the surface of the kidney.

The fibrous capsule sends in trabeculae, which divide and subdivide in the interior of the gland, and divide this up into vesicles or alveoli, which bear a striking resemblance to those of the interrenal body of Elasmobranchs. It is difficult to determine from sections the precise form of these gland vesicles in the different species, but it seems that in some cases they are tubular structures (see Pl. XVI. fig. 7 and Pl. XVII. figs. 8 and 9), while in others they closely approximate

to spheres (Pl. XVI. figs. 5 and 6). In most cases these vesicles appear to be completely filled with cells, but in some cases, as in the Anguillidae, they contain a distinct lumen (Pl. XVI. figs. 5 and 6). In the Anguillidae, perhaps, we have the most typical arrangement. In these animals the suprarenal body consists of a mass of a closed cylinders, of varying form (Pl. XVI. figs. 5 and 6). On section many of them appear rounded or polyhedral from pressure of neighbouring cylinders, while others are more elongated, but never reaching any very great length. The cylindrical alveoli are separated by a loose connective-tissue in which runs a rich capillary plexus and numerous lymphatic vessels. The alveoli are lined with cells usually one row deep. These are columnar and contain a distinctly granular protoplasm, and one, or sometimes two, nuclei. The cells are usually 18—20 μ in length by 2—10 μ in width. They are of unequal heights and have the appearances which are usually interpreted as indicating a breaking down of the cell substance to form a secretion. But it is doubtful if this is the true significance of what one sees. It is more likely that the cells in their central portions are more friable than elsewhere and more easily break down under the razor.

In some species (*Orthogoriscus mola*) the alveoli have the form of branching tubules running in all directions (Pl. XVII. figs. 8 and 9). Thus the general appearance of the suprarenal bodies on section offers a considerable variation throughout Teleosts, but when closely examined the differences are found to consist (in addition to the form of the acini already described) chiefly of variation in amount of fibrous tissue, and variation in blood supply.

From histological considerations I previously came to the conclusion that *the suprarenal bodies of Teleosts consist entirely of cortex* [116, 117]. I have further tested the matter physiologically and chemically, and find that the opinion then formed was correct [118, 120, 121, 122]. *There seems to be in Teleosts no equivalent to the paired bodies of Elasmobranchs or to the medulla of the suprarenal capsules of the higher Vertebrata*¹).

¹) The question of the relation of the degenerated pronephros or so-called "head-kidney" to the suprarenal bodies of Teleostean fishes I have sufficiently

4. *Dipnoi*.

Until 1896 nothing had been known of the suprarenals in the Dipnoi, and even now our information is very limited. My own investigations upon preserved specimens yielded entirely negative results, but I stated [116]:— "Nevertheless, from *a priori* considerations, I believe that adrenals of some sort are almost certainly present in the Dipnoi. These fishes closely approach the Amphibians in many respects and I am persuaded that could one obtain perfectly fresh specimens of large size, suprarenals of a type resembling that of the Amphibians would be found."

Since the above was written, Pettit [89] has claimed to have found the suprarenal bodies of *Protopterus annectens*. He says that in general form and relations they resemble those of the Teleostei, while in minute anatomy they are rather like those of the Batrachians. But he gives no histological details and says nothing about cortex and medulla.

Since this account of Pettit is the only one extant of the suprarenals in Dipnoi, it will be advisable to quote it in full:—

"Aucun auteur à ma connaissance n'a indiqué l'existence des capsules surrénales chez les Dipnoïques; c'est là une lacune regrettable que Wiedersheim déplore dans le remarquable chapitre de son *Anatomie comparée* qui est consacré aux glandes surrénales.

Grâce à l'extrême amabilité de MM. les professeurs Filhol et Vaillant, j'ai pu constater l'existence de ces organes chez le Protoptère (*Protopterus annectens*, Owen).

Sur le spécimen que j'ai disséqué, ces organes étaient représentées (Pl. III. fig. 8) par deux petites masses de volume inégal qui

treated elsewhere [116, 117, 118, 119, 120, also 20]. It is sufficient here to repeat that there is no anatomical or physiological relationship of any kind between the two (vide supra, pages 4 and 5).

In the "Comptes Rendus" for last year, No. 25 (Seance du Lundi 21 Juin) is a communication by Huot on the suprarenal bodies of Lophobranchs in which he expresses the opinion that in these fishes the suprarenal capsule has nothing to do with the lymphoid tissue of the kidney.

In a later communication (Compt. Rend. CXXVI l. p. 49), Huot says that the suprarenal bodies of Lophobranchs are developed as 2 hollow diverticula from the hinder end of the Wolffian duct.

étaient accolées à la face ventrale de la veine cardinale au point où celle-ci pénètre dans le canal hémal; ils sont par conséquent en rapport, non plus comme chez les animaux précédemment étudiés avec la face ventrale du rein, mais avec la face dorsale; il résulte de cette disposition qu'elles perdent toutes connexions avec les glandes génitales.

Par leurs rapports et par leur forme, les glandes surrénales du Protoptère ne rappellent en aucune façon les mêmes organes des Batraciens desquels on le rapproche volontiers: au point de vue morphologique il y a là un véritable hiatus entre les deux classes. En réalité, il n'en est rien. En effet, les capsules de ce Dipneuste ont une structure intime qui est assez voisine de celle qu'on constate chez les Batraciens; elles sont composées par un parenchyme beaucoup plus compact que chez les Poissons osseux, avec lesquels elles n'ont guère de commun que la forme extérieure et les rapports anatomiques.

Resumé.

En somme, les glandes surrénales du Protoptère, par leurs rapports et par leur forme, rappellent, assez exactement, comme nous le verrons bientôt, les mêmes organes des Téléostéens; d'autre part, par leur structure histologique, ce sont plutôt des capsules de Batraciens."

The author gives a drawing (Pl. III. fig. 8) in which not two small unequal bodies are represented but one fair-sized body, and no relations to the viscera are indicated. He does not state whether the specimen he dissected was a fresh or a preserved one. If the former, then the paucity of histological detail which he gives is very surprising. If the latter, one would have expected him to announce the fact as an excuse for histological deficiency.

VI. Amphibia.

1. Urodela.

In a previous communication [117] I have given a brief account of the gross anatomy and histology of the suprarenal bodies in *Salamandra maculosa*, but since that paper was written I have re-investigated the subject, and have not seen reason to seriously modify my

views. In the above-mentioned paper I wrote: "I find, in fact, that the suprarenal of *Salamandra maculosa* agrees in every respect as to its histological structure with that of the Anura." The chief difference between the tailed and the tailless amphibians in respect to the suprarenal organ is undoubtedly that in the former the body is divided up into a series of small masses, while in the latter it is more or less continuous.

Leydig [71] describes a very intimate relation between the sympathetic ganglia and the suprarenal bodies in *Salamandra maculosa*. He states, in fact, that there are to be found transitions between the ganglion-cells of the sympathetic, certain yellowish cells in connection with them, and the suprarenals on the kidney. But he does not make it clear that the *medulla* of the suprarenal is alone in relation to the sympathetic ganglia. In my former paper [117] I found "no nerve-cells whatever in close relation to the suprarenals". In this I was in error. Recent investigations have convinced me that the medullary representative of the adrenal in *Salamandra* is very intimately related to the ganglia of the sympathetic chain, and *I am able to verify the statement of Leydig that transition forms exist.*

Much confusion has arisen as to the exact conditions of the suprarenal capsules in the Urodela. Thus in a paper by Velich [115] in 1897, it is affirmed that in the opinion of Kölliker, there is no medullary suprarenal in Birds, Amphibians, and Fishes! This author gives no reference to Kölliker, but relies on the authority of Kahlgen [64] who says: „Die Nebennieren der Vögel, Amphibien und Fische, welche kein Mark und keine Nerven haben, entsprechen nach Kölliker nur der Rindensubstanz der Säugetiernebenniere.“ Kahlgen likewise gives no reference, and I have been unable to find that Kölliker expresses any such opinion (see 66 and 67).

My own researches have been made upon *Salamandra maculosa*. The kidneys were hardened in Müller's fluid and sections were cut from end to end. At the anterior end one finds more medulla in relation to cortex than at the posterior end, and it is in the anterior portion that the relations to the sympathetic can best be made out. When the material is placed in bichromate solution no apparent

darkening of the specks of suprarenal can be observed by the naked eye¹). It was found impossible also to get the tests for the chromogen by making an extract. The extract, further, did not raise the blood-pressure when injected into the blood-vessels of a living mammal²). For these reasons extreme care has been employed in the histological examination.

There can be no doubt that my former description of the two kinds of tissue was in the main correct. I found, on looking up my old slides that I had apparently relied entirely upon the characteristic staining of the medullary cells with haematoxylin (vide infra pag. 302 and 306), having no specimens which had been hardened in bichromate. This being rather unsatisfactory I have since employed Müller's fluid to detect with certainty the relations of the two substances. These two constituents, the cortical and the medullary, are as distinct as in Anura, Reptilia, Aves, and Mammalia, but the medulla is not present in such large proportion as in any of these³).

The cortical substance presents the same histological features as in the frogs and toads (q. v. *infra*), being composed of delicate solid columns of cells interlacing in all directions. The structure of this portion needs no further description.

The medullary portion is represented by small masses of brown⁴) cells, or even single cells, sometimes actually situated *in the ganglia of the sympathetic*, sometimes further away from the ganglia and in closer contact with the cortical cell-columns. The anatomical condition is in fact an intermediate one between that found in Elasmobranchs, where the two constituents are quite independent of one another, and that found in the Anura and Reptilia, where cortex and medulla have come into close contact, but have only just commenced to be mixed up together⁵). In the ganglia or close to them one can sometimes

¹) This is in marked contrast to the behaviour of the suprarenals of the frog.

²) This result can only be attributed to the insufficient amount of material which one could obtain.

³) Except perhaps in *Hyla arborea*, where I find the amount of medullary substance to be very small.

⁴) i. e. after bichromate treatment.

⁵) This intermingling is complete in Aves (q. v. *infra*).

find large cells resembling nerve-cells, except that the protoplasm is full of the brown pigment produced by the action of the bichromate of potassium¹). Then there are some smaller cells, less like nerve cells and more like the proper medullary cells. *These would appear to be transition forms between the two.* The proper cells of the medullary substance are so like those of the Anura and Reptilia that they do not deserve a separate description.

2. Anura.

There is practically no difference between the various species of frogs and toads as regards the minute structure of the suprarenal capsules. In these animals the suprarenals are golden-yellow streaks on the ventral surface of the kidney, of about 15 mm. in length in the common frog to about 28 mm. in a good sized toad. Their width varies in a similar manner from 1 to about 3 mm. But their dimensions vary very considerably according to the size and development of the particular individual. In a good sized specimen the suprarenals present on the ventral surface of the kidneys a very beautiful appearance forming on each side a series of irregular arcs with their convexity outwards, and varying in width from place to place. Their colour is of a bright yellow, of a somewhat fatty aspect, and their surface is marbled with veins running in all directions. Their average dimensions are given above, but it is noteworthy that in both frogs and toads although the suprarenal reaches nearly up to the anterior end of the kidney, it always ceases at a point anterior to the posterior fifth of that organ.

The adrenal is not quite continuous, but is broken up on each side into a varying number of portions, separated by slight intervals. With a lens, or sometimes even with the naked eye, they are seen to consist of a series of parallel lines presenting a distinctly lobulated appearance.

The blood-supply appears to be the same as that of the kidney substance, i. e. it receives arterial blood from the dorsal aorta and

¹) These medullary cells and those of Reptilia possess a slight yellowish-brown coloration even in a fresh state.

venous blood from the Renal Portal vein. But there are no capsular arteries direct from the aorta; whatever arterial blood the bodies receive, they get indirectly from the arterioles distributed on the kidney. The tributaries of the Posterior Vena Cava, bringing impure blood from the kidney, run for some distance longitudinally along the anterior surface of the organs and around this part of their course the suprarenal substance is collected. There are some three or four of these branches on each side. It would almost appear as if the suprarenal had had its exact location on the surface of the kidney determined by these veins, for the discontinuity above mentioned corresponds fairly well with the occurrence of the venous tributaries. In some cases the suprarenal capsule appears to be little more than a kind of glandular wall to the vein, and this explains the interesting fact first noticed by Gruby [50] that when the blood-vessels are distended, the suprarenals become less distinctly visible.

The suprarenal body forms a distinct bulging on the ventral surface of the kidney as shewn in transverse section (Pl. XVII. fig. 11). It is enclosed in the capsule of the kidney and there is no sheath or septum of any kind between the cell-columns and masses of the former and the tubules and malpighian bodies of the latter. The line of demarcation between the two structures is however fairly definite, although there is no connective-tissue boundary.

The gland is seen at once to consist of two distinct kinds of structure. The greater part is made up of columns of cells which are of varying size and shape and interlace in all directions (Pl. XVII. fig. 11 and Pl. XVI. fig. 12). The constituent cells vary somewhat in shape but are mostly elongated or columnar, and contain a large round nucleus with nucleoli. This substance is the "cortical", which is homologous with the interrenal body of Elasmobranchs, the known suprarenal bodies ("corpuscles of Stannius") of Teleosts, and the cortical substance of the suprarenal bodies of Reptilia, Aves, and Mammalia.

But in addition to the above-described structure, we get masses of a different kind of cell (*me.*, Pl. XVII. fig. 11 and Pl. XVI. fig. 12). These are to some extent irregularly distributed, but there is usually a more or less continuous tract of them along the dorsal border of

the organ¹). If the tissue has been hardened in alcohol, the cells stain very deeply with haematoxylin, and the nucleus is not easily seen. The cells are more irregular and somewhat larger, and the nuclei have rather greater dimensions, than in the cortical cell-columns. The nuclei are often oval. But the most striking feature about these cells is that if the tissue has been hardened in Müller's fluid (or any other fluid containing bichromate of Potassium), they become stained brown just as do the chromogenic cells in the paired suprarenal bodies of Elasmobranch fishes. So that this structure is the "medulla".

The medulla is small in amount in proportion to the cortex. The organ has a very rich blood-supply (see Pl. XVII. fig. 11 and Pl. XVI. fig. 12). A network of capillaries runs between the alveoli (Pl. XVI. fig. 12), and large veins are abundant.

There seems to be considerable difference between the various species of the Anura in regard to the amount of medulla in proportion to the cortex. This proportion is always small, but is particularly so in *Hyla arborea*.

The physiological identity of the suprarenal capsules of the frog with those of mammals has been placed beyond a doubt by the researches of several authors. Thus Szymonowicz [112] has employed extracts from a frog's suprarenals in his experiments upon the alterations of blood-pressure produced by such extracts. Langlois [69] has devoted a separate paper to the subject. In conjunction with B. Moore [81], I have chemically tested an extract made from the suprarenal capsules of several frogs, and found that this gave the chromogen reactions in a perfectly definite manner. These physiological and chemical reactions of course only apply to the medullary substance. The evidence as to the homology of the cortical substance is morphological and histological.

VII. Reptilia.

While in Pisces and Amphibia the suprarenal bodies are in close anatomical connection with the kidney, in the Reptilia they are intimately associated with the reproductive apparatus. In the Lacertilia

¹) Forming a sort of irregular boundary between the substance of the kidney and that of the suprarenal body.

and the Ophidia the suprarenal body is situated between the postcaval vein and the reproductive gland (ovary or testis as the case may be). The position in the Chelonia is only apparently different, because in this order the kidneys and reproductive organs are on about the same antero-posterior level. I have not been able to examine any of the Crocodilia.

The histological structure of the suprarenal capsules in the Reptilia closely resembles that in the Amphibia. The cortical substance (which constitutes by far the greater part of the gland) consists of curved, irregular, branching, and interlacing columns of cells, about 50μ thick and reaching a length of 120μ (Pl. XVIII. fig. 13), consisting most often of a double row (as seen in section), but sometimes having three or even four tiers. The cells are $20-26 \mu$ in length and about $8-10 \mu$ in width and their protoplasm is very distinctly reticulated (*co*, Pl. XVIII. fig. 13); near the centre of each is a large rounded or oval nucleus (*n*) about $7 \mu \times 3 \mu$ or about 5μ in diameter, with a marked nuclear network (*n. net.*) and nucleoli.

The medullary masses (Pl. XVIII. fig. 13, *me*) are of various sizes and shapes, distributed through the gland. The greater part of the medulla forms a layer along the dorsal aspect of the organ, but groups of five, six, or more cells are found in different regions of the organ. There are also smaller groups (see, Pl. XVIII. fig. 13) or even occasionally isolated single cells. The cells are larger than those of the cortex, as also are the nuclei; the cell protoplasm is very distinctly granular, the granules being of large size, rounded, and regularly distributed throughout each cell (*g. p.*, Pl. XVIII. fig. 13). They become very deeply stained with haematoxylin if the tissue has been hardened in alcohol, but brown if in Müller's fluid. The haematoxylin in the latter case only stains the nucleus, leaving the cell-granules brown.

Between the columns of cells are blood-spaces lined with a vascular epithelium, i. e. capillaries (Pl. XVIII. fig. 13 *i*). In some parts the cell-columns are arranged in a radiating manner round one of these large blood-spaces, just as one sometimes finds in the internal body of Elasmobranchs (vide supra pag. 291).

The above description applies to *Uromastix Hardwickii*, but may be considered as fairly typical of the Reptilia generally. Descriptions of several other species and drawings of some few will be found in an earlier paper [117].

The medulla, then, in the Reptilia is for the most part arranged side by side with the cortex along the dorsal aspect of the organ, but there is already a commencement of that intimate intermingling of the two which is so characteristic of Aves.

Braun [11] describes transition forms of cells between nerve-cells and medullary suprarenal cells in certain lizards. I have not succeeded in verifying this, but I consider it probable that such forms are present.

VIII. Aves.

Very little need be said about the gross anatomy of the suprarenal capsules in birds. They are bright ochre-yellow bodies, in very close contact with the reproductive glands, so that with them they appear to form almost one organ. This intimate relationship (which is seen also in the Reptilia), is of peculiar significance as bearing upon the development of the cortical portion of the organ. The glands are also in close connection with the vena cava and the aorta. Large nerve-ganglia are found near the surface of the organ. The nerve-supply is derived from the ovarian or spermatic plexus.

In birds the cortex and the medulla of the suprarenal capsules are more intimately mixed than in any other animals. The medulla is decidedly more abundant in proportion to the cortex than in any other class.¹⁾ The medullary columns are distributed fairly uniformly throughout the gland. The medullary cells have every appearance of having been pushed in, as it were, between the cortical columns, and in *Gallus bankiva* this appearance is very marked, as there is an almost complete layer of medullary cells surrounding the outside of the organ, just within the capsule, with points of irruption here and there, whence start the branching and interlacing cords which are found throughout the organ.

¹⁾ It is interesting to note in this relation that birds have a very high blood-pressure.

The medullary masses in the outer portion of the suprarenal body are always more abundant in the neighbourhood of the nerve-ganglia.

The cortical substance (*co.*, Pl. XVIII. fig. 14) has the form of gland vesicles of very varying size and shape. The cells (*e. c.*) form a regular row of columnar shape, constituting a peripheral layer round each alveolus. In the small peripheral cylinders, there is often only one layer, which bounds a distinct, round or oval, lumen. But in most cases the structure is that of solid masses of polyhedral cells surrounded by a layer of columnar ones and having no lumen (Pl. XVIII. fig. 14). The cells are finely granular and contain in a fresh state numerous fat-globules.

The medullary cell-columns (Pl. XVIII. fig. 14 *me.*) are smaller than the cortical, and shew no regular glandular arrangement of the cells. These are considerably larger than the cortical cells and more irregular in shape. After treatment with hardening fluids containing bichromate of potassium, they shew a tendency to separate from each other, leaving clear spaces between them. The most distinct feature of these cells is the brown pigmentation which occurs after such treatment. This is sometimes uniform throughout the cell protoplasm, sometimes in the form of distinct granules. Henle [54] first called attention to this universal mode of distinguishing medulla from cortex, But as Rabl [91] points out, and as I have already indicated for lower forms, other modes of staining show a marked distinction between the two structures. Thus with haematoxylin the cell-protoplasm stains almost as deeply as the nucleus. The same applies to several other nuclear stains. This indicates that the cell-protoplasm of the medullary substance approximates either in chemical or physical properties to nuclear material. At the same time, the bichromate test is extremely useful and quite unique, as no glandular tissue except the medulla of the suprarenal capsule gives the same reaction. The medullary cells contain no fat.

Rabl (*loc. cit.*) has applied the very appropriate names "Hauptstränge" and "Zwischenstränge" to cortex and medulla respectively in birds, but it is difficult to find terms which are applicable to the two kinds of tissue throughout Vertebrates. For this reason it is better

to retain the names cortex and medulla, always bearing in mind that they are quite misnomers in all animals below mammals.

The above-named observer made the very interesting discovery that there are intermediate forms of cells between the ganglion cells of the sympathetic nervous system and the proper cells of the suprarenal medulla. Braun (*loc. cit.*) had previously described such in Reptilia. I have indicated above that these are to be found in the medullary glands of Elasmobranch fishes, and I can corroborate the statement of Rabl with regard to Aves.

IX. Mammalia.

In the Mammalia the two separate glands of which the suprarenal capsule is composed are not irregularly mixed up as in birds, but the medulla is placed internally, being completely surrounded by cortex. Indeed it is only in Mammals that these terms are appropriate to the two portions.

If one cuts across a fresh suprarenal capsule of any Mammal the cortex and medulla are always quite readily distinguishable from one another. But there are wide differences in the general appearance of the section in different species. Thus in some cases the cortex is narrow and the medulla extensive, but in most cases the opposite is the case, and the rule is that by far the greater bulk of the capsule is made up of cortex. The guinea-pig has proportionately a large medulla.

In tint too there is considerable variation; thus in the sheep there is a yellowish white medulla, surrounded by a dark red cortex. In the dog there is a dark pink medulla and an ochre-yellow cortex. The rabbit has a very slight core of a greyish medulla surrounded by a yellow cortex. In the guinea-pig much of the chromogen in the medulla is developed into a pigment, and the substance appears dark brown or purple when cut across.

These differences are undoubtedly associated in some way with the functional activity of the organs in the different species according to their different habits of life, but more than this one cannot at present affirm. The point which I wish to emphasise here is the marked and

universal distinction between the cortex and the medulla. This is obvious enough without the application of any reagents, but can be beautifully shewn by placing the gland, after being cut across, in a solution of bichromate of potassium for a time, when the medulla always becomes dark brown. As has been stated above for other vertebrates, various staining re-agents mark the distinction quite well for histological examination. Thus, if the gland has been hardened in alcohol and stained with picro-carmin, the cortex has the protoplasm of its cells stained yellow and the nuclei red, but the medullary cells are scarcely touched by the picric stain. The same applies to eosin and safranin. Thus the medullary protoplasm appears to stain deeply with nuclear stains, but faintly with general stains.

Medulla. In Mammals the evolution of the medullary gland has become completed. There is little or no trace in its structure of anything which would make us suspect its nervous origin. We find certainly an abundance of nerve-cells in the medulla of some animals, but, so far as I have been able to ascertain, there are none of those transition forms which obtain so high up in the scale as birds.

The cortex and medulla are always distinctly marked off from each other, and have every appearance of being what they really are, two separate and distinct glands of different origin, and probably totally different functions. There is in some species a septum of connective tissue separating the two portions from one another. In other cases the distinction is rendered obvious by the above-mentioned staining reactions.

The medullary cells are arranged in most Mammals in elongated solid cords, in the form of a plexus. (Pl. XVII. fig. 15), the inter-spaces of the meshwork being occupied by a rich network of capillaries, with here and there a large blood sinus. In man the arrangement is practically that which has just been described except that the cords are shorter, so that in section the cells of the medulla appear to be arranged in rounded groups.

There has been a considerable amount of confusion as to the form of the cells of the mammalian medulla. They have frequently been described as irregular in form, as having processes, and as leaving

irregular spaces between individual cells. These appearances are figured by Eberth [30, 31] and his drawing has been extensively copied into the text-books, but I am convinced that it is fallacious. It is certain that after some methods of preparation these appearances are seen. Thus, the arrangement seen in Pl. XVIII. fig. 16 is often obtained. But I am persuaded from the study of several species and the employment of many different modes of fixing and hardening, that this appearance does not represent the true structure. I was at first of the opposite opinion because the appearances so much resemble the homologous structure in Elasmobranch fishes (cf. Pl. XVI. fig. 1 and Pl. XVIII. fig. 3 with Pl. XVIII. fig. 16). The peculiarity seen in these cases I attribute to two causes [1] shrinkage from the employment of bichromate of potassium [2] a softer and more delicate structure of the medullary cells, which causes them to break up under the razor.

When alcohol or formol is employed as a fixing agent, one always gets appearances closely resembling those depicted in Pl. XVII. fig. 15, which represents a small portion of the medullary substance of the sheep. Here the medulla has the general arrangement described above, which I believe to be the typical one, and the cells are regular in form. Even after hardening in Müllers fluid, if care be taken in the preliminary processes and in the cutting of the sections, one frequently gets the cells regularly disposed in close contact with one another as in glands generally, and with no signs of shrinkage of the individual cells.

The general arrangement of the medullary cell-columns does not differ very much in the different species of mammals which I have studied. In man, the cat, the dog, and some others, the appearance is almost precisely like that drawn in Pl. XVII. fig. 15 for the sheep.

V. Brunn [13] finds smooth muscular fibres in the medullary substance in man, and in much smaller numbers in the horse, rabbit and cat, but states that they are absent in most animals. They occur, according to this observer, round the great veins in the medullary portion of the gland, and are longitudinal in direction only, no circular fibres being discoverable. De Mattei [75] also appears to have described these fibres, but I have not been able to obtain access to his

paper. In the ox these bundles of muscular fibres are very striking. As far as my own observations extend, they appear to be present only in the larger capsules (i. e. in ox, horse, man &c.).

The nerve-terminations in the suprarenal capsules have been investigated by Dogiel [27] and Fusari [41, 42]. The nerve-fibres come for the most part from the solar plexus. After a course of variable length in the connective-tissue capsule, they penetrate perpendicularly the cortical substance and bury themselves in the medulla. The nerve-supply to the medulla is much more strongly developed than that to the cortex, and in the former the relations of the nerves to the glandular cells are much more intimate. In the medulla of large capsules such as those of the ox, large nerve-fibres cut in various directions, and groups of nerve-cells of differing sizes are frequently to be seen. But nerve-cells are rarely to be found in the substance of the suprarenals of smaller animals.

Cortex. In many aspects the cortical portion of the suprarenal capsule is to be looked upon as the more important constituent of the organ in the Vertebrata. Thus from Elasmobranchs upwards this part is always present, while in Teleosts (and most probably Ganoids) the medulla is wanting. Then, again, in most animals the cortex is much more abundant than the medulla, and has a very regular glandular aspect even in Elasmobranchs. The medullary portion on the other hand appears to undergo a progressive evolution as we ascend the scale of the Vertebrata, and it is not until we reach the Mammalia that it partakes of the nature of a true internal-secreting gland.¹⁾

So that we may look upon the cortical gland as the principal or primary constituent of the suprarenal organ, to which certain cells derived from the sympathetic nervous system have become related. As this relation becomes more intimate the medulla gradually becomes included within the substance of the cortex and takes on a distinctly glandular form.

The structure of the mammalian cortex is tolerably easy to make

¹⁾ That is, as regards its histological structure. This characteristic secretion is already elaborated even in Elasmobranchs [120, 121].

out and is fairly well-known. But it will be desirable to give a brief account of it, so that it may be compared with its homologues in the lower Vertebrata.

In man, as was first pointed out by Arnold [2], the cortex is seen on section to consist of three layers, more or less distinct from each other, but not nearly so much so as are cortex and medulla from each other. The outermost layer is called the *zona glomerulosa*, as the cells are aggregated into rounded masses. Beneath this is the *zona fasciculata*, so-called from the elongated columns of cells which form it. Internally, adjoining the medulla, is the *zona reticularis*, this name indicating an approximation to a network arrangement of the cortical columns in this layer.

These three layers are however only arbitrarily separated off from each other. It seems clear that the "zona glomerulosa" is nothing more than the columns of the "zona fasciculata" which turn round when they come near the surface of the gland and run for a greater or less distance parallel to the capsule. In a radial section these portions are of course cut transversely and appear as rounded masses of cells.

This arrangement into three layers can be tolerably well made out in the guinea-pig, the ox, and the dog. In the rabbit the "zona fasciculata" sometimes runs to the surface, or there is only a very narrow "zona glomerulosa" with a wide "zona reticularis".

The *zona fasciculata* is always more faintly stained than either of the other layers.

In some animals, as the horse and the ox, the cells in the outermost layer of the cortex do not always appear as circular masses, but are sometimes arranged as crescents or horse-shoes, and sometimes the ends of the crescent become fused and a ring of cells is formed, presenting an appearance closely resembling that of a gland alveolus with a large lumen. But this is not a true lumen, as appears from the fact that it sometimes contains tissue of the same nature as the stroma of the gland, and occasionally even blood-vessels may be observed in it.

The cells which make up the masses and columns of the cortex

are mostly polyhedral, but in the most external of the outer layer in the horse and in the dog they are elongated columnar.

In young animals one sometimes finds that the medulla has not yet become completely surrounded by cortex, but comes to the surface at some point. In the case of the suprarenal capsule of a young rabbit I noted a very interesting appearance. Near that part of the circumference where the medulla reached the surface was a sympathetic ganglion outside the capsule of the organ. Near to it, also outside the capsule was a mass of cells resembling those of the suprarenal medulla only not so uniformly stained by the bichromate. But no cells which could be called transitional forms were to be discovered.

X. Development of the Suprarenal Capsules.

As I have not myself investigated this part of the subject I shall content myself with a brief *résumé* of the conclusions arrived at by observers up to the present time. This is the more necessary since the study of the development throws so much light upon the minute structure of the adult organ.

Bergmann [9] and Remak [96] seem to have been the earliest observers of the close relation subsisting between the suprarenal capsules and the sympathetic nervous system. Leydig [70] in 1852, pointed out the very intimate connections between the sympathetic and the paired suprarenals of Elasmobranchs and the suprarenal bodies of the Urodela. But Leydig misunderstood the nature of the cortex, stating that it is derived from the medullary cells by the deposition of fat-globules.

Leydig's views as to the nervous origin of the medulla were strengthened by the researches of Balfour [3] in 1878, who concludes provisionally at this date that the paired bodies in Elasmobranch fishes are the true suprarenals while the interrenal "does not belong to the same system"¹). Later, this author changes his opinion [6, 7] and definitely expresses the view that: "In Elasmobranch Fishes we thus

¹) By this, Balfour meant presumably that the interrenal body had nothing to do with the suprarenals.

have [1] a series of paired bodies, derived from the sympathetic ganglia, and [2] an unpaired body of mesoblastic origin. In the Amniota these bodies unite to form the compound suprarenal bodies, the two constituents of which remain however distinct in their development. The mesoblastic constituent appears to form the cortical part of the adult suprarenal body and the nervous constituent of the medullary part".

This brilliant hypothesis has been fully confirmed by the investigations of most subsequent embryologists who have worked at different classes of animals, as well as by my own observations upon the comparative physiology and chemistry of the suprarenal capsules [118—122, and 81, 82].

In Reptilia, Braun [11] has fully established the development of the medullary cells from the nerve-cells of the sympathetic ganglia.

In Birds, Rabl [91] states: "Es bleibt also nichts übrig, als die Markzellen für abgetrennte Ganglienzellen zu nehmen, welche insofern einen, dem embryonalen nahestehenden Zustand zeigen, als ihr Kern nicht den Charakter des Zellkernes einer ausgebildeten Ganglienzelle besitzt und das Protoplasma keine Nervenfortsätze entwickelt hat" and he gives abundant evidence of this view. The cortical substance is derived, according to this author, from the distal end of the pronephros. Fusari [39, 40] also supports the view that the medullary part of the suprarenal gland in Birds is derived from the nervous system, and points out in these animals that the groups of "nervous cells" remain distributed between the "epithelial lobules" while in the mammal, the nervous portion assumes a central position. Fusari, however, maintains that the interrenal body of Elasmobranch Fishes is not homologous with any part of the suprarenal capsule, but with a certain adipose tissue found round the suprarenals in some mammals. Von Brunn [12] has also supported the nervous origin of the medulla in Birds.

In the Mammalia there have been numerous observations, all of them clearly pointing out the totally distinct origin and nature of the cortex and medulla. Thus Mitsukuri [79] worked out the development in the rabbit and the rat. He concludes that the cortical substance

arises from the mesoblast, while the medullary substance is derived from the peripheral part of the sympathetic nervous system, and is at first placed outside of the cortical substance, becoming transported into the middle of the suprarenal body in the course of development. Inaba [57] who studied the development in the mouse, found that the cortex develops as a proliferation of the peritoneum at the angle of the mesentery and laterally continuous with the beginning of the generative organ, while the medulla is derived from the sympathetic elements, which enter the organ in the 14th day embryo. They increase and form a reticulated mass at the centre, from which the cortical cells are gradually pushed aside. The connection with the sympathetic system is usually cut towards the close of gestation but in some may be retained till after birth.

Mihákovics [77] has traced the cortical blastema from the Germinal epithelium of the coelome, and this conception, viz: that the cortex of the suprarenal capsule and the genital glands have the same origin is the one now usually admitted.

Gottschau [45] and Janosik [58] deny the nervous origin of the medulla and state that this is formed from the cortex. Creighton [22] even goes so far as to say that "the distinction between the cortex and medulla of ordinary anatomy is quite arbitrary, as there is no real difference between their constituent cells. The central part or medulla is only more spongy than the rest". This view, contrary to all sound evidence on the subject and only requiring the most casual observation in order to be refuted, has nevertheless been supported by Rolleston [100] so recently as 1895.

Valenti [114] thinks the suprarenal is a "rudimentary organ" (!).

Summing up what is known about the development of the suprarenal capsules, it seems probable that the cortex is derived from the germinal epithelium, while the medulla is derived from the nerve-cells of the sympathetic ganglia¹).

¹) If the medulla of the mammalian suprarenal capsule be derived phylogenetically from the series of paired suprarenal bodies of Elasmobranch fishes, it is probable that only those bodies in the region of the kidneys and reproductive organs have actually entered into the formation of the gland in higher animals. What has become of the rest? Are they unrepresented in Mammalia? It is in-

XI. Summary and Conclusions.

1. *The Suprarenal capsule in Vertebrates is made up of two separate and distinct glands — the cortex and the medulla.* In Elasmobranch Fishes these two are quite independent. In Amphibia and Reptilia the medulla is placed close to the cortex but only to a comparatively small extent mixed up with it. In Birds the two are irregularly combined, while in Mammals the medulla occupies a position in the centre of the cortical substance.

2. *Far from being in any sense "rudimentary organs", the two constituents of the suprarenal capsule show a progressive development as we ascend the Vertebrate scale, the medulla especially becoming more and more glandular in structure as we reach the Mammalia.*

3. Developmental researches show that the medulla is derived from the nerve-cells of the sympathetic ganglia. This origin is revealed also by the histological structure in the adult in Elasmobranchs, Amphibians, Reptiles, and Birds, where *transition forms are found between nerve-ganglion cells and the proper cells of the medullary substance.*

4. According to the best evidence the cortex in Mammals is derived from the germ epithelium.

5. *Although the medullary gland is nervous in origin, in the adult it seems to be no longer nervous but glandular, having a characteristic internal secretion.*

6. *The medulla of the suprarenal capsule in the higher Vertebrates corresponds to the paired suprarenal bodies along the sympathetic in Elasmobranch Fishes.* This is shewn by physiological means, i. e. these paired bodies contain the same active principle as the medulla of the suprarenal capsule in higher Vertebrates, and also

interesting to note that certain cells are described in connection with the abdominal sympathetic ganglia which are not nerve-cells and closely resemble the medullary suprarenal cells. Kohn [68] states that these become stained brown with potassium bichromate.

With regard to the paired bodies anterior and posterior to these, it is not impossible that they may be represented in the Mammalia by such glands as the "carotid" and the "coccygeal". I would rather throw this out as a suggestion than hazard it as an opinion.

by chemical means, i. e., these bodies contain the same characteristic chromogen as the medulla in higher animals.

The cortex in the higher orders corresponds to the interrenal body in Elasmobranch Fishes. The physiological and chemical evidence is negative, but the histological and morphological evidence is very convincing.

7. *In Teleostean Fishes the known suprarenal bodies ("corpuscles of Stannius") consist solely of cortex.* This is shown by the absence of a physiologically active principle, by the absence of a characteristic chromogen, by the fact that extirpation does not cause death [122] and by their histological structure. They are thus homologous with the interrenal body of Elasmobranchs.

8. In Ganoids the same is probably true, but I am guided here entirely by histological evidence.

9. *In Mammals the cortex and medulla, although anatomically united into one organ, are still quite distinguishable from each other.* This distinction between the two is not arbitrary, but rigorously marked out by a layer of connective tissue (in some animals), by staining reaction, and by the arrangement of the alveoli, and the shape of the constituent cells.

The medullary cells not only stain deep brown with potassium bichromate, but the protoplasm stains as if it were a nucleus with most nuclear stains while it stains less deeply with ordinary protoplasmic stains.

10. *The totally distinct origin and structure of cortex and medulla renders it probable that their functions have no relation to each other.* No one would imagine that the functions of the paired suprarenals in Elasmobranchs have any relation to those of the interrenal, and since the two organs seem to be only as it were accidentally combined, their functions have most likely remained distinct. The function of medulla would appear to be, so far as we know at present, to manufacture an internal secretion which it pours into the blood and which, being distributed throughout the body, maintains the normal tone of the muscular structures (Oliver and Schäfer [87]).

As for the function of the cortex, little can be said at present

No physiologically active principle can be obtained from it. Pettit [89] has ascribed an antitoxic function to the suprarenal bodies of the eel, which I have shewn to consist only of the representative of the cortex¹).

11. The suprarenals are very intimately related to the blood-vascular system. This relationship is most striking in Elasmobranchs, but is still evident in Mammals from the very large blood-supply to the organ and its close anatomical connexion with the great veins.

12. *The cortex, from a morphological stand point would seem to be the more important or essential element of the suprarenal gland.* For it is always more abundant in amount than the medulla, and is universally present in all animals above the very lowest Vertebrates, whereas the medulla appears to be absent in some orders of fishes²).

The following table is intended to represent in a compact form the variations in occurrence and arrangement of the suprarenal constituents throughout the Vertebrata, so far as is known at present:—

¹) This harmonises well with some interesting results obtained by Myers (Brit. Med. Journ. 1898. April 9. p. 946) with regard to the action of tissue extracts on cobra poison. His experiments were made with the organs of guinea-pigs, and with the result that the suprarenal body was alone found capable of neutralising the cobra poison. Positive results were also obtained with the suprarenal of the sheep, the only other animal tried. The interesting feature of these experiments is that *the medulla was found to be inactive, the cortex and the entire gland active.*

²) In the present state of our knowledge the medulla must undoubtedly be considered as the more important from a physiological standpoint.

Comparative table of Suprarenal Capsules in Vertebrata.

<i>Cyclostomata</i>	<i>Pisces</i>						<i>Amphibia</i>		<i>Reptilia</i>	<i>Aves</i>	<i>Mammalia</i>							
	<i>Elasmo-branchii</i>	<i>Ganoidei</i>	<i>Teleostei</i>	<i>Dipnoi</i>	<i>Anura</i>	<i>Urodela</i>	Cortex	Medulla										
Cortex	Medulla	Cortex	Medulla	Cortex	Medulla	Cortex	Medulla	Cortex	Medulla	Cortex	Medulla							
	Internal body	Paired suprarenal bodies in connection with sympathetic	Suprarenal bodies in substance of kidney	Suprarenal bodies ("corpuscles of Stannius") upon surface of kidney	Absent	Definitely stated to exist, but nothing yet known about cortex and medulla	Cortical cell-columns in suprarenals on kidney	Cell-masses in suprarenals on kidney	Much the same as in Anura, except that the suprarenal capsule is divided up into separate specks along kidney and vena cava	More medulla in anterior region	Cell columns in suprarenals which are placed near the genital glands	Cell masses in suprarenals, mostly dorsal in position, but partly intermingled with cortex	"Hauptstränge" (Habl)	Intermingling with each other throughout the organ. Suprarenal close to genital gland	"Zwischenstränge" (Habl)	External	Internal	Completely surrounded by cortex in adult

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Explanation of the Plates.

Reference-Letters common to all the figures.

ad., adenoid tissue of kidney between the tubules; *al.w.*, walls of alveoli; *bld. c.*, blood-corpuscles; *ca.*, capsule; *c. sp.*, central space in alveoli; *d. c.*, cells resembling "demilune" cells; *co.*, cortex; *e. c.*, elongated cells; *n.*, nuclei; *n. c.*, nerve-cells; *n. net.*, nuclear network; *nl.*, nucleoli; *k t.*, kidney tubules; *p. c.*, branched pigment cells; *pr.*, granular protoplasm; *me.*, medulla; *s.*, septa; *str.*, fibrous stroma.

Pl. XVI.

- Fig. 1. Portion of central part of paired suprarenal body from the middle region of the animal (*Raja clavata*), shewing branched chromogenic cells, as seen under a magnifying power of 480 diameters.
- Fig. 2. Part of peripheral zone of paired suprarenal body from the middle region of the animal (*Scyllium canicula*) shewing columnar cells. Same magnification as preceding fig.
- Fig. 4. Section through a small portion of the interrenal body of *Raja clavata* As seen under a magnifying power of 480 diameters. Outlines drawn with the camera lucida.
- Fig. 5. Section taken through portions of kidney and suprarenal body of *Conger conger*, shewing the intertubular adenoid tissue of the kidney with tubules here and there, and the general structure of the suprarenal body as seen under a low power.
- Fig. 6. From same slide as preceding, shewing the detailed structure of the suprarenal vesicles. Outlines drawn with camera lucida.
- Fig. 7. Section of small portion of suprarenal body of *Salmo trutta*. Seen magnified 480 diameters. Compare with fig. 4.
- Fig. 12. From same slide as preceding. To shew cortical cell columns and medullary masses of cells. Higher power.

Pl. XVII.

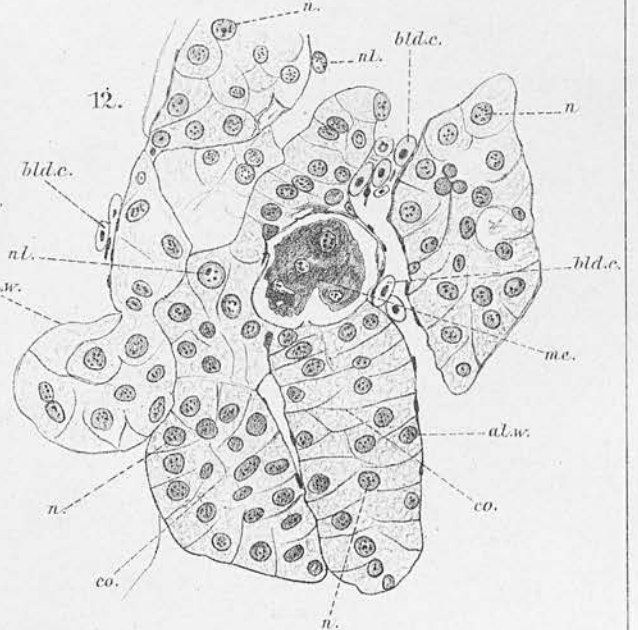
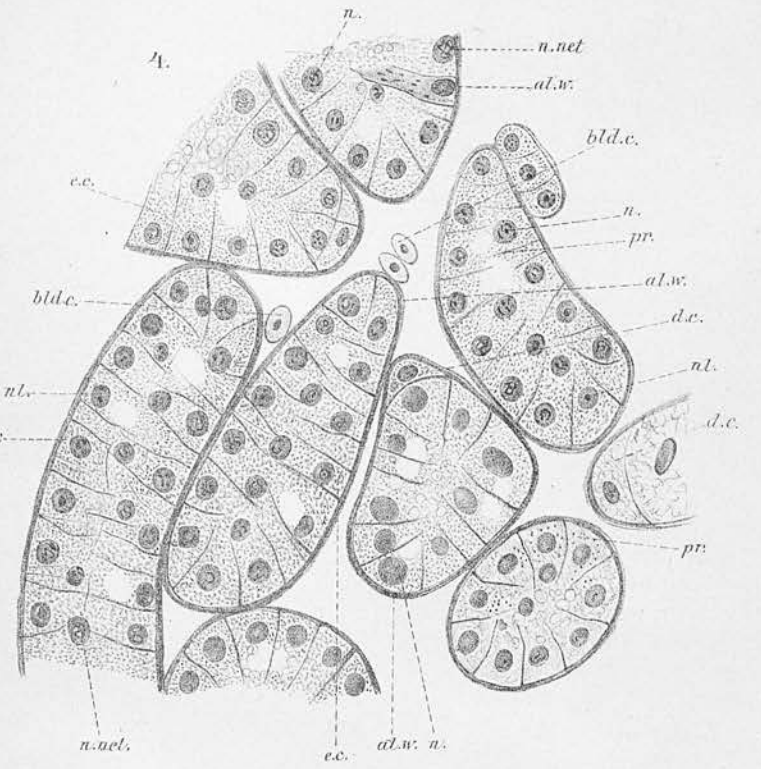
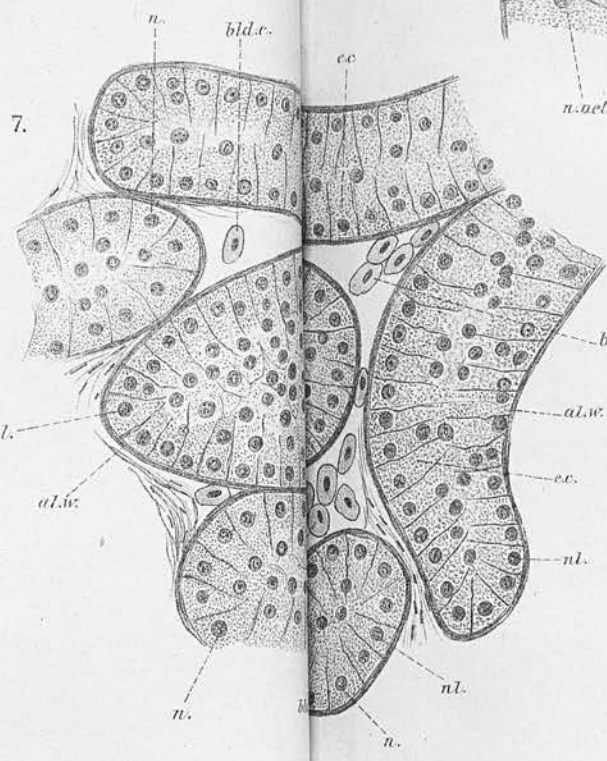
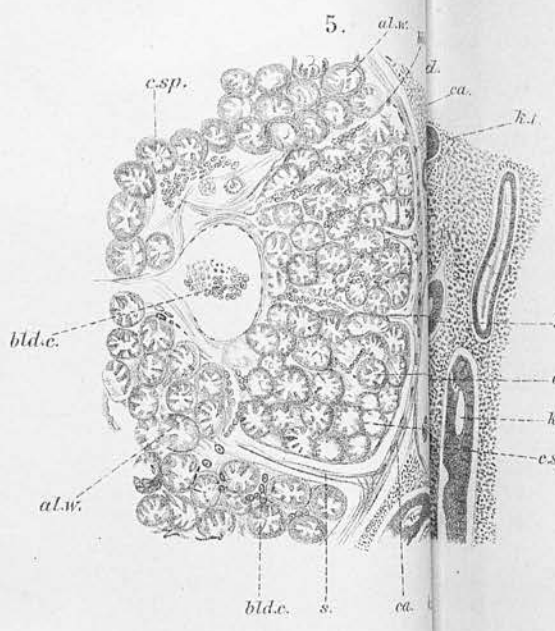
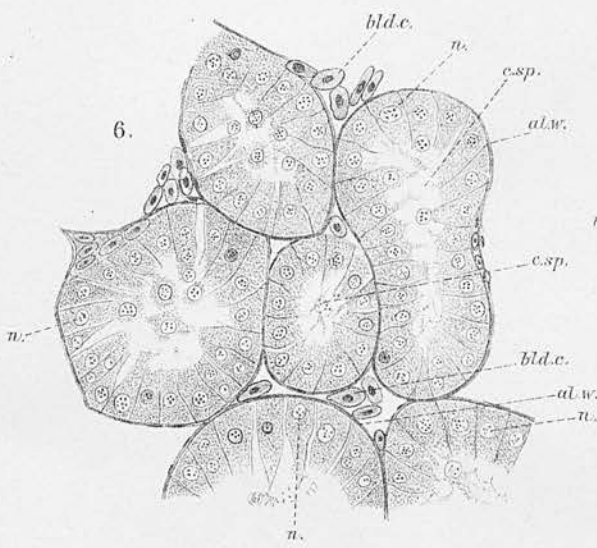
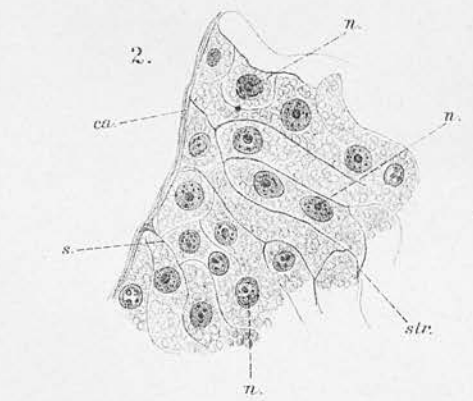
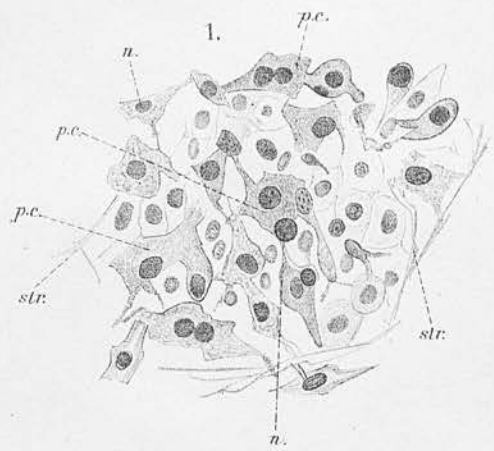
- Fig. 8. Section of external portion of the suprarenal body of *Orthogoriscus mola*. Low power.
- Fig. 9. From same slide as preceding. Higher power.

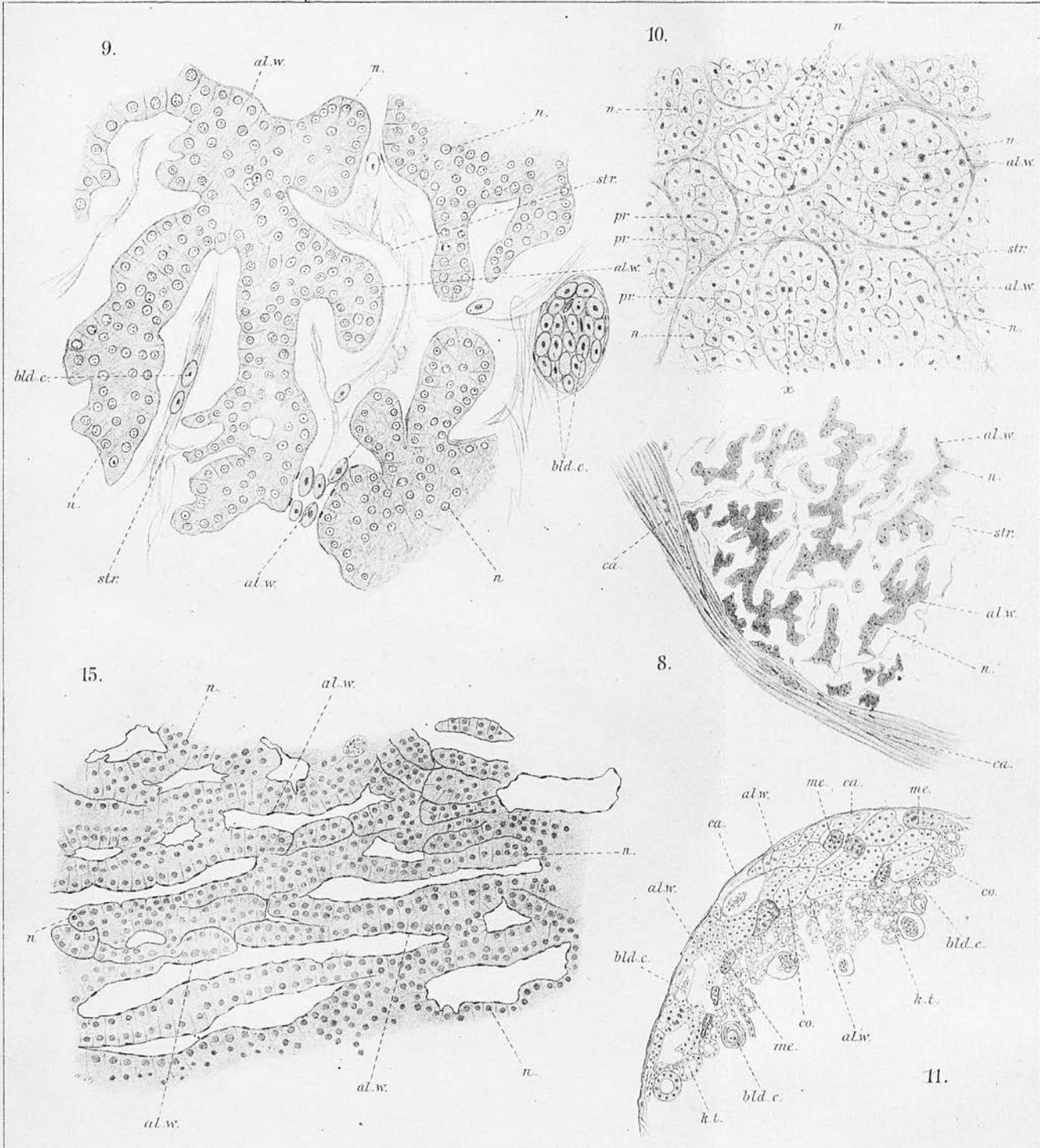
- Fig. 10. Section of suprarenal of *Acipenser sturio*. The body was put into osmic acid about 12 hours after death, and sections were cut with the freezing microtome on the following day. The alveolar arrangement is well seen, and the cell-outlines are admirably preserved. Zeiss H. immers., E. P. 2. Camera lucida.
- Fig. 11. Section through the suprarenal capsule of *Bufo vulgaris*, shewing relation of suprarenal to kidney substance. Low power.
- Fig. 15. Small portion of the medullary substance of the suprarenal capsule of *Ovis aries*. The section demonstrates the solid cords interlacing in all directions. The interspaces consist almost entirely of capillaries. The body was hardened in methylated spirit, and stained with picrocarmine. The Cell-Outlines are distinctly shewn.

Pl. XVIII.

- Fig. 3. Chromogenic cells from central part of a suprarenal body (middle region of Body, *Raja clavata*). As seen magnified about 700 times. Figs. 1 and 3 shew a groundwork of cells which are not chromogenic, probably of the same character as those in fig. 2.
- Fig. 13. Small portion of suprarenal of *Uromastix hardwickii*, Leitz. Pantachromat. 30 mm. Drawn with Abbé's Camera lucida. The preparation was a most successful one and my drawing does not adequately represent the clearness and delicacy of the details. The material was hardened in alcohol so that the medulla is not brown, but the protoplasm of its cells has become stained with haematoxylin.
- Fig. 14. Section of suprarenal capsule of *Meleagris Gallopavo*. The material was hardened in Müller's fluid and stained with haematoxylin and eosin. A strand of medullary cells, stained brown with the pot. bichrom. is seen running between the cortical column. As seen under a magnification of 480.
- Fig. 16. This fig. represents the appearance of the medulla of *Bos taurus* after hardening in Müller's fluid, and staining in bulk with picro-carmin. It is doubtful whether the appearances of these medullary cells are not fallacious and due to shrinkage.

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A DISCUSSION OF SOME POINTS IN CONNECTION WITH THE SUPRARENAL GLANDS—CORTICAL AND MEDULLARY. By SWALE VINCENT, *J. Francis Mason Scholar, Research Fellow of the University of Edinburgh.*

(From the Physiological Laboratory, University of Edinburgh.)

GASKELL, in a recent number of this Journal (1), has incidentally discussed certain points connected with the morphology of the cortical and medullary constituents of the suprarenal capsules. He relies chiefly upon the work of Weldon (2 and 3) and Aichel (4 and 5) to support certain details of his theory as to the origin of the vertebrata. Now subsequent observations have shown that Weldon was in error in regard to the relation between the suprarenals and the 'head-kidney' of Teleosts (6 and 7). This author stated: "In Teleostei, suprarenals are at all events frequently absent, or, as I would suggest, they are represented by the greatly metamorphosed head-kidney described by Balfour. In other cases *where suprarenals have been detected*,¹ they have always been attached to the surface of the kidney." In the same paper he refers to "the very general absence of suprarenals as separate structures in Teleosteans."

In the course of investigations on the comparative anatomy of the suprarenal bodies, I examined forty-three species of Teleosts and found the suprarenal bodies constantly present (*i.e.*, the cortical gland; the representative of the mammalian suprarenal medulla has only recently been discovered by Giacomini: *v. infra*), and came to the conclusion that there was no kind of relation between them and the lymphatic head-kidney (6 and 7). This conclusion was confirmed by Huot (16).

But Weldon, so far as can be gathered from his observations in the memoirs referred to, does not go so far as to deny the derivation of the medullary substance from the sympathetic system. In his second paper (3) he says: "The substance

¹ The italics are mine.—S. V.



which from its position in the mammalian suprarenal is known as 'medullary,' is now almost universally admitted to consist of metamorphosed nerve cells, which arise from one or more of the ganglia of the sympathetic system." Again: "Balfour was of opinion that the bodies of the anterior set, though they show in the adult a division into cortical and nervous portions as distinct as that which exists in the suprarenals of higher vertebrates,¹ were yet derived entirely from sympathetic ganglia. The presence, in the anterior end of the body, of a blastema such as I have described seems to throw doubt on the correctness of such a view,² though I have unfortunately been unable, owing to want of material, to prove by examination of later stages the share which this blastema takes in the formation of the paired anterior suprarenals."

Some points in Aichel's papers I have already criticised (12), but perhaps it will not be amiss to point out again how little evidence this author has for the views he has put forward. For example, he believes that the paired bodies in connection with the sympathetic in Elasmobranch fishes are homologous, not with the medulla of the mammalian suprarenal, but with certain bodies he describes as constantly occurring in connection with the reproductive organs. This homology he infers from developmental investigations.

Aichel states that his "neues normales Organ" consists of cortex and medulla just as does the proper suprarenal body. But he gives no details. He says: "Es würde zu weit führen, dies

¹ Balfour says "each body . . . exhibits a well-marked distinction into a cortical layer of columnar cells, and a medullary substance formed of irregular polygonal cells." I cannot find that he says the division is as distinct as that which exists in the suprarenals of the higher vertebrates. The division into two parts described by Balfour has been since shown to be due to faulty fixation.

² Giacomini (20 and 21) has recently declared himself opposed to Aichel's views.

Kohn (in a letter to the present writer, dated 19th March 1903) says in regard to Aichel's views: "*Aichel's* Angaben über die *Entwicklung* der Marksubstanz muss ich ebenso bestreiten wie seine Folgerungen über die *Homologa* der Nebenniere in der Thierreihe. Er hat vielfach die centrale Zone der Nebennierenrinde als Marksubstanz, bezeichnet, ohne sich darum zu kümmern, ob die Zellen chromaffiner Natur sind oder nicht. Er hat die Chromreaction, das verlässlichste Merkmal der 'Markzellen' ganz vernachlässigt. Er hat die Suprarenal-Körper der Selachier, die fast nur aus chromaffinen Zellen bestehen, den Marchand'schen Nebennieren homologisiert, die gar keine chromaffinen Zellen enthalten." I have obtained Dr Kohn's permission to publish this or other portions of his letter.

durch Zeichnungen von Nebennieren in den einzelnen Altersstufen hier vor Augen zu führen. Man kann sich durch die Untersuchung älterer menschlicher Früchte und Neugeborener von der Richtigkeit meiner Behauptung sofort überzeugen." Of course, if Aichel's observations on this point are correct, they are capable of corroboration. But it would have been more convincing if the author had been somewhat more explicit and given at least a sketch showing the cortex and medulla in a Marchand's body. This is a particularly important point, because Marchand's 'accessory suprarenals' have always been considered to consist entirely of cortex.¹ So far as his description goes, the structures in the mesorchium and the mesosalpinx of the higher vertebrates are not characterised by the presence of the characteristic 'chromaffin' cells of suprarenal medulla, nor has he shown that the bodies he describes contain the well-known physiological principle which probably always accompanies these cells in vertebrate tissues. It may be that these bodies *do* contain both chromaffin cells and the pressor substance, but even then the evidence for the homology of the paired suprarenals of Elasmobranchs with the mammalian medulla would not be diminished one jot. It would simply mean that we must add to our list still another group of chromaffin cells.

If there is one point which is perfectly clear in the whole subject, it is that the paired suprarenal bodies of Elasmobranch fishes correspond histologically,² chemically (14, 15), and physiologically (9, 10) to the medullary portion of the mammalian suprarenal capsule. That is, they are both made up of 'chromaffin cells,' which have been fully described in different places by Kohn (24, 27), Kose (28, 29), Stilling (30, 31, 32), and others.

If the medulla of the suprarenal capsule is derived from the mesonephros, then must also the carotid gland, the groups of chromaffin cells of the sympathetic ganglion, and the 'Nebenorgane des Sympathicus' of Zuckerkandl (38) be similarly derived. The topography of these various structures renders such a view extremely improbable.

Kohn is indeed so thoroughly persuaded that the medullary

¹ Kölliker, *Gewebelehre*, iii. s. 388, 6th Aufl., 1899.

² I had been convinced of the histological identity of the two tissues before Prof. Schäfer suggested that I should test the matter physiologically (*v.* 23).

substance is of sympathetic origin, that he even goes so far as to restrict the term 'suprarenal' to what is usually called the 'cortex of the suprarenal,' while he looks upon the 'medulla' as simply a part of the system of 'chromaffin cells.' This is as a matter of fact not very different from the view¹ most workers on the subject would be inclined to accept. Aichel agrees that the interrenal body of Elasmobranchs is homologous with a part at any rate of the mammalian suprarenal;² and Kohn sees in the mammalian medulla nothing more than certain chromaffin cells, of which the paired suprarenals of Selachii are examples.

I would point out to Dr Gaskell that it was the new homologies that constituted my chief point of attack upon Aichel's work, though I certainly do consider that this author has not given satisfactory proof that the paired bodies in Selachians are not derived from the sympathetic. The evidence on this point at the present time is overwhelmingly against Aichel.³ There is no need in this place to enumerate the long list of authors who have definitely described a developmental connection between the sympathetic nervous system and the medulla of the suprarenal capsule in the different groups of vertebrate animals. Kohn is the most recent of workers upon this subject, and his views are very positive as to the origin of the suprarenal medulla and the rest of the chromaffin cells. He says:⁴ "Die Marksubstanz der Nebenniere besteht in Wesentlichen aus *chromaffin* Zellen. Diese sind nach ihrer Genese, Morphologie und Physiologie *gleichwertig* den übrigen chromaffinen Zellen." . . . "Die chromaffinen Zellen *entstehen* autochthon in embryonalen, sympathischen Ganglien . . . Anfangs enthalten die sympathischen Ganglien nur *eine* Art von Zellen. Diese sind klein, dichtge-

¹ The suprarenal medulla, however, may be regarded as a great accumulation of chromaffin cells *which have assumed a distinctly glandular arrangement.*

² The homology of the interrenal body of Elasmobranchs with the suprarenals on the surface of the kidneys ('Corpuscles of Stannius') in Teleosts, and the cortex of the suprarenal in higher vertebrates, is indicated by a striking resemblance in external features and histological structure. This was first clearly pointed out by Diamare (36, 37), and later and independently by myself (6-12).

³ It is interesting to note, in view of the fact that Gaskell couples together Weldon and Aichel as supporting his views, that Aichel himself puts Weldon in the list of those who support the sympathetic origin of the medulla. From what I have quoted above, he seems justified in doing so.

⁴ In the letter previously cited.

drängt, mit dunkelgefärbten Kernen. Später werden *innerhalb* des Ganglien Gruppen hellerer und grösserer Zellen richtbar, die zu chromaffines Zellen werden."

Kohn, then, derives the chromaffin Zellen direct from the embryonic sympathetic ganglion. But they do not develop as do the other cells of the ganglion into typical nerve cells with processes, but into a peculiar and special form of cell which he says constitutes a new type of cell—"Sie repräsentiert selbst einen *neuen Zelltypus*—den der chromaffinen Zelle." According to Kohn, "*Sie sind aber auch nicht nervenzellen,*" they are "eine besondere Zellform, die durch modification noch unentwickelter sympathischer Ganglienzellen entstanden ist."

But Kohn will not admit that the chromaffin cells, whether constituting the medulla of the suprarenal or situated elsewhere, are 'epithelial,' 'glandular,' or 'secretory' in any sense.

Gaskell considers that "no physiologist would accept the doctrine of the conversion of nerve cells into glandular cells." Nevertheless, it seems clear that the chromaffin cells *are* derived from the sympathetic ganglion cells at an early period. Whether they are ever glandular is, as we have seen, disputed. For my part, I cannot see any reason why nerve cells should *not* become developed into glandular cells. A few years back it was considered inconceivable that the lymphoid cells of the thymus should be immediately derived from the original epithelial elements, yet this is now admitted to be the case. That nerve-ganglion cells (in process of development) should in certain regions take on a special form and develop a peculiar substance which they 'secrete' into the blood-stream, does not appear by any means out of the question.¹

But there is the alternative possibility, viz., that, as held by Kohn, the chromaffin cells, derived from embryonic nerve cells, never *do* become glandular or secreting cells, and that the presence of the blood-pressure raising substance found in connection with chromaffin cells in certain places has no physiological significance, or a significance which is unconnected with

¹ Gaskell points out that I have changed my opinion on this point. This is true, though, from the passage he quotes, it will be seen that I did not deny the derivation of suprarenal medulla from the sympathetic. It was the relation between the two *in the adult* which I thought had been overstated. For this reason I used the expression, "whatever may be their developmental relations."

any specific 'secretory' activity on the part of the cells in question. This is in my opinion only a remote possibility; the peculiar nature of the chemical substance, and the nature of the symptoms produced by extirpation or disease of the organ, in comparison with the physiological effects of the active substance, make it practically certain that the function of the medullary cells, and probably of chromaffin cells, in other places, is to manufacture and pour into the blood-stream this powerful active principle.¹

Many authors have described appearances in the microscopic anatomy of the suprarenal medulla which distinctly point to a secretory function. Thus Carlier (40) describes the passage into the veins of granules of the substance secreted by the medullary cells. Srdénko (41), working upon the Anura, concludes that there is a secretion from the medullary cells into the blood-spaces. Hultgren and Andersson (42) consider that the particles of secretion pass through the walls of the blood-vessels. Fr. Lydia Félicine (43) describes small spaces between the medullary cells which communicate with blood-spaces, and believes that "die Marksubstanz der Nebennieren ist eine Drüse mit inneren Sekretion." Gottschau (44), Diamare,² Giacomini,³ and Biedl and Wiesel (53) are all adherents to the view that the suprarenal medulla is an internally secreting gland.⁴ That the active physiological substance of the medullary cells actually, in the normal state of the animal, passes out into the blood-stream, is shown by the observations of Gybulski, Langlois, and Biedl, who showed that the blood of the suprarenal vein contains the active principle in sufficient amount to produce a rise of blood-pressure when intravenously injected.

Kohn insists that these medullary cells are not 'epithelial,'

¹ It is interesting to note that in some experiments performed by Langley (39) as to the effects of suprarenal extracts upon glandular secretion, etc., results were obtained which pointed to the view that the suprarenal extract has a specific stimulating action on *sympathetic* nerve-endings.

² *Op. cit.*

³ *Op. cit.*

⁴ Thus there are some who believe that the medulla of the suprarenal capsule is undoubtedly derived from the sympathetic and cannot be looked upon as glandular. There are others who believe that it is so distinctly a secreting gland that they are glad to welcome any observations which tend to show that it may *not* be derived from the nerve cells of the sympathetic. Most probably the true view embraces both conceptions—the medulla is *glandular* and is *derived from the embryonic nerve cells of the sympathetic ganglia*.

and therefore cannot be 'glandular,' cannot 'secrete.' He places the cells, as we have seen, in a category by themselves. My own observations on the structure of the medullary substance, especially in mammals, would certainly induce me to call the cells 'epithelial.' The structure has been sufficiently described in previous papers, but it may be well to quote what a recent French writer says on this subject. Guieysse (45) thus describes the medulla of the suprarenal capsule of the guinea-pig: "Les cellules de la moelle sont disposées en cordons plein remplissant les espaces entre les sinus. Ce sont de belles cellules cylindriques disposées sur deux ou trois rangs. . . . Leur forme est celle de grandes cellules plutôt cylindriques que cubiques avec de beaux noyaux. . . . Les cellules de la moelle sont donc, ainsi que je viens de le décrire, des éléments épithéliaux cylindriques sans grande caractérisation; leur forme ne rappelle en rien leur origine nerveuse, origine d'ailleurs contestée. . . ." ¹ This description corresponds very closely with what can be observed in many mammals, and the appearances are certainly such as to warrant one in ascribing a secreting function to the tissue.

Diamare (39) looks upon the medullary structure as formed by a kind of arrest of development of the original epithelial Anlage, in consequence of which the anatomical appearance of an epithelial tissue is retained and the cells set apart for a special secretory function.

There are one or two other points in Gaskell's paper I should like to call attention to. He refers to the so-called adrenal or suprarenal body as if the organ were a simple one, and overlooks the fact that we have to deal with two separate and distinct structures, as is undoubtedly the case. No one would reasonably refer to the 'suprarenal bodies' in Elasmobranchs, meaning by this term both the paired bodies and the interrenal; further, the mammalian organ cannot in any way be looked upon as a morphological or a functional whole. ²

¹ This author strongly supports the view which I have so often urged, that the suprarenal capsule of mammalia really consists of two separate and distinct glands. He considers that the cortical gland has some function in relation to gestation.

² Referring to Kohn's work, Gaskell says: "He desires in fact to make a separate category for such nerve glands." Now Kohn does not consider these paraganglia, whether in the shape of suprarenal medulla or as carotid ganglia, to be glands at all. In fact, this is the main point of discussion between Kohn on the one hand, and Giacomini, Diamare, and myself on the other.

Of recent work upon the morphology of the suprarenal capsules, that of Giacomini (19, 20) deserves special attention. This author gives us the first definite description of the cortical and medullary elements in the Cyclostomata (20). In conjunction with W. E. Collinge, I attempted some years ago (13) to find the suprarenal bodies in this order, but, after examining several structures which had been called suprarenals by earlier observers, abandoned the attempt. Giacomini, in *Petromyzon*, describes and figures, in the caudal, renal, and cephalic regions, representatives of both cortical and medullary structures. The cortex is composed of numerous small lobules of varied form situated along the posterior cardinal vein and in the adipose tissue ventral to the aorta. The medullary substance, which, it is important to note, Giacomini describes as *of epithelial aspect*, has the characteristic chromaffin reaction and stains deeply with hæmatoxylin. This tissue is situated at the side of the aorta, separated from the lumen of the posterior cardinal vein only by the endothelium, and extends along the parietal arteries. The author lays stress on the fact that in *Petromyzon* we have two distinct series of *internal secreting glands, the medulla just as much as the cortex being of this nature.*

Giacomini also claims to have discovered the medullary suprarenal element in Teleosts (22). He has at any rate found chromaffin cells in all species examined. They lie in the wall of the cardinal vein in the cranial region of the body. They appear to be independent of the sympathetic nervous system, and Giacomini suggests that a study of the histogenesis of these cells in Teleosts would throw light on the origin of chromaffin cells in vertebrates generally. He does not give any illustrations, and it is not quite clear from his paper whether the groups of chromaffin cells are large enough to be seen with the naked eye. When I pointed out (6, 7, 8, 15) that the known suprarenals of Teleosts consisted entirely of cortex, I had looked for and failed to find bodies comparable to the paired suprarenals of Elasmobranchs. It has always seemed extraordinary that Teleosts should have nothing corresponding to the medulla of other vertebrates, and it is satisfactory that Giacomini has succeeded in finding definite representatives of such tissue.

It is now well known that the chromaffin cells of the suprarenal

medulla are not the only representatives of their kind. In the sympathetic ganglia of man and mammals (Stilling, 30, 32, 34; Kohn, 27, 26; Kose, 29), birds (Kose, 32), and other vertebrates, are found, besides the typical ganglion cells, cells of another kind, having the microchemical features of the cells in the suprarenal medulla. This fact led Cleghorn (46) to test the physiological action of extracts of sympathetic ganglia. But instead of obtaining the rise of blood-pressure characteristically produced by extracts of suprarenal medulla, this author got on the contrary a fall. This was afterwards shown by Osborne and Vincent (47 and 48) to be the usual physiological action of extracts of nervous tissues in general.¹ In sympathetic ganglia the chromaffin cells are not present in sufficient amount to produce their physiological effect. Recently, however, Zuckerkandl (35) has described what he calls "Nebenorgane des Sympathicus" in the human subject. These are two bodies resembling lymph glands in external appearance, lying in front of the aorta on either side of the inferior mesenteric artery. They are constantly found in the new-born child. Microscopic examination shows them to consist of chromaffin cells, and Biedl and Wiesel (53)² have demonstrated that extracts prepared from them have precisely the same powerful effect upon the blood-pressure as have extracts from the medulla of the suprarenal capsule.

It is probable that the physiologically active substance is always associated with chromaffin cells wherever these are found. Thus the carotid gland contains such cells (Stilling, 32; Kohn, 26); and if sufficient material could be obtained there is little doubt that the presence of the active substance could be demonstrated.³

The mere fact that cells stain brown with bichromate of potassium does not of course prove that such cells are of the same nature as those forming the medulla of the suprarenal. But the additional facts that the chromogen (at any rate in the

¹ See also Halliburton (51 and 52) and Vincent and Sheen (49 and 50).

² These authors believe that the chromaffin cells have an internal secretion, and that the Nebenorgane functionate in the same manner as the suprarenal medulla.

³ I have, however, repeatedly failed to obtain any physiological effect from the injection of extracts of carotid glands. The difficulty I believe to be merely the result of the impossibility of satisfactorily isolating the carotid body. One necessarily injects so much material extracted from surrounding tissues that the pressor effect of the carotid is marked by the depressor effects of the other tissues (*v. Vincent and Sheen, loc. cit.*).

paired bodies of Elasmobranchs) is of the same nature as that of suprarenal medulla (Moore and Vincent, 14), and that the Nebenorgane of Zuckerkandl contain also the active physiological substance characteristic of suprarenal medulla throughout vertebrates, combined with the close developmental relation of all these bodies with the sympathetic, make it almost certain that we are here dealing with one series of structures. The matter cannot be considered as quite settled, however, until the physiologically active substance can be shown to exist in the sympathetic ganglia and in the 'paraganglion caroticum.'

Thus we probably have to admit with Kohn that the medulla of the suprarenal capsule is part of the system of chromaffin cells in connection with the sympathetic nervous system. But in the adult mammal it is the larger and more important part, and will, I imagine, continue to be called "suprarenal medulla" from anatomical considerations and as a matter of convenience.

On the other hand, it is not easy to agree with Kohn that these cells, either in the suprarenal body or elsewhere, are not of an epithelial type and cannot have a secretory function. The description given by Giacomini of the chromaffin bodies in *Petromyzon* is distinctly indicative of a secretory function; and, as we have seen, there is every appearance in the structure of the medulla in mammalia to suggest a glandular nature and secretory activity.

Our knowledge of the subject at the present time can be presented somewhat as follows:—

The suprarenal capsule of mammals consists of two separate and distinct glandular organs, which are anatomically conjoined but developmentally and physiologically quite unrelated.

The cortical portion of the mammalian organ is represented by the corresponding cortical substance in birds, reptiles, and amphibians. In Teleosts the cortex is found in the suprarenal bodies lying on the ventral or dorsal surface of the kidneys ('corpuscles of Stannius'), and in Elasmobranchs by the interrenal body. In the Cyclostomata the cortical substance is according to Giacomini represented by small lobules of cells along the posterior cardinal vein and in the fat in front of the aorta. This cortical tissue is admittedly of glandular form and structure, but nothing is known of its function, and its development is the subject of some discussion.

The medulla of the mammalian suprarenal is part of the system of 'chromaffin cells,' and such cells are found also in various places in relation to the sympathetic nervous system. In birds we have the medulla not forming a compact central mass as in mammals, but interlacing with the cortex throughout the organ. Other masses of chromaffin cells are found in connection with the sympathetic ganglia. In Reptilia and Amphibia practically the same conditions hold, except that the cortex and medulla are not so intimately united. The medulla in Teleosts is, according to Giacomini, to be found in certain chromaffin cells lying in the wall of the cardinal vein in the cranial region of the body.

But it is in the Elasmobranchs that we get the representative of the mammalian medulla in its most typical form. Here the tissue consists of a series of paired bodies in connection with the sympathetic ganglia and extending practically throughout the whole length of the body ('Paraganglia' of Kohn). *There can be no doubt that these consist of the same substance, histologically and chemically, as the medulla of the mammalian suprarenal*; and any theory, whether based upon embryological or other kinds of investigation, which overlooks this fact, must be essentially defective.

In the Cyclostomata the suprarenal medulla is represented by masses of cells along the aorta and parietal arteries (Giacomini).

It must be confessed that we are not yet fully informed as to the physiological significance of these masses of chromaffin cells, whether in the suprarenal medulla or wherever else they may be found. The consensus of opinion, however, among most recent workers is that they are developed from the nerve cells of the embryonic sympathetic ganglia (or from the original neural epithelium), and that they are, when fully developed, highly specialised secreting cells which manufacture and pass into the blood-stream a very powerful substance whose function is to maintain the tone of muscular and other tissues throughout the body.¹

The following table will help to make the principal facts readily comprehensible:—

¹ Very probably acting to a large extent through the sympathetic system (see reference to Langley, *supra*).

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From the PROCEEDINGS OF THE ROYAL SOCIETY, VOL. 61.

THE COMPARATIVE PHYSIOLOGY OF THE
SUPRARENAL CAPSULES.

BY

SWALE VINCENT, M.B. (LOND.).

“The Comparative Physiology of the Suprarenal Capsules.”
By SWALE VINCENT, M.B. (Lond.), British Medical Association
Research Scholar. Communicated by E. A. SCHÄFER,
F.R.S. Received February 18,—Read March 11, 1897.

(From the Physiological Laboratory, University College, London.)

Notwithstanding the belief of Cuvier, “qu’il était probablement réservé à l’anatomie comparée d’expliquer le véritable usage des capsules surrénales,” this method of comparative investigation has been but little employed in the attempt to discover the functions of these organs.

It has, in fact, been doubtful as to what are to be regarded as suprarenals and what are not, in certain of the lower vertebrates, especially in fishes. Thus it has been suggested that the lymphatic “head-kidney” of Teleosts may represent these bodies (Weldon, 19, 20); even the presence or absence of suprarenals in any given order has often been a matter of considerable doubt. I have, in previous papers (15, 16, 17, 18) endeavoured to clear up some of these points, and have described the anatomy and histology of the suprarenal capsules in fishes, amphibians, and reptiles, and I hope in the present communication to give some experimental confirmation of the correctness of the opinions I had previously maintained from histological considerations.

It will be advisable to prefix a few words about the comparative anatomy of the suprarenal capsules. Suprarenals of some sort are probably present in most, if not all, vertebrate animals. In the Cyclostomata this is at present doubtful,* so that it is not until we come to the Elasmobranch fishes that we find with certainty anything in the way of suprarenals. Here we meet with two kinds of structure concerning which there has been much discussion. In the first place, we find a series of paired bodies arranged segmentally on the intercostal arteries, and extending the whole length of the abdominal cavity. They are situated in close proximity to the sympathetic nervous system. Secondly, we have a single or paired, yellow, rod-shaped organ lying between the two halves of the kidney and near the dorsal aspect of this organ. This is the “interrenal” of Balfour (1).

The histology of these two organs I have described elsewhere (*loc. cit.*), and also I have expressed my belief that the paired segmental bodies correspond to the medulla of the suprarenals of higher vertebrates, while the interrenal body corresponds to the cortex. That this was the case was surmised long ago by Leydig (6, 7), and it is

* See, however, Collinge and Vincent, ‘Anat. Anz.’ vol. 12, Nos. 9 and 10, 1896.

experimental evidence in favour of this view which I now wish to put forward. Before doing so, however, it will be well to state here that, so far as I have been able to make out, one only (viz., that which corresponds to the cortex) of the two suprarenal constituents is present in Teleostean fishes. The same probably applies to Ganoids.

With regard to the development of the suprarenals it is only necessary to note that many observers believe that the medullary portion is derived from, or at any rate, developed in connection with, the sympathetic nervous system (Balfour, 1), and it seems clear from the researches of Mihákovics (8) that the cortex is developed from the germinal epithelium.

The researches of Oliver and Schäfer (9, 10, 11), followed by those of Cybulski and Szymonowicz (2, 3, 4, 13, 14), have shown that the medulla of the suprarenal capsules of mammals and the suprarenal capsules of birds and amphibians (Szymonowicz, 14) (presumably the medulla only also in these), produce a remarkable and characteristic rise of blood-pressure, when an extract is injected into the circulation of a living animal. But, so far as I know, no one has previously tested the effects of extracts of the suprarenal bodies of fishes.

The following experiments were accordingly undertaken at the suggestion of Professor Schäfer, to whom I am indebted for advice and assistance on many points connected with the research. I have already published a preliminary notice (17), giving the results of initial perfusion experiments. I have now repeated and confirmed these perfusion experiments, and, in addition, have tested the effect of the materials in question upon the arterial system of mammals.

Effects of Extract of Fishes' Suprarenals upon the Arterial System.—The methods employed have been:—

1. The perfusion of normal saline solution or Ringer's circulating fluid containing the extract to be tested, through the blood-vessels of large toads after the brain and spinal cord had been destroyed by pithing.

2. The injection of the extracts into the blood-vessels of a living mammal and recording in the usual way the blood-pressure tracing with the mercurial kymograph. Dogs and cats have been used in these experiments.

The suprarenals employed in this research have been obtained mainly from *Scyllium canicula* among the Elasmobranchs and from *Anguilla anguilla* as a representative of the Teleosts, but I have also used *Scyllium catulus*, *Acanthias vulgaris*, *Galeus canis*, and others in the first-named order, and *Gadus morrhua* and several other species of Teleosts. The effects produced upon blood-pressure were practically identical in the corresponding organs of different species.

The extracts employed were obtained in various ways. Some were prepared by pounding the glands with sand and normal saline in a pestle and mortar, and subsequently filtering. Others were alcoholic, while still others were got by boiling for a short time a certain quantity of the material in a known amount of normal saline and filtering. In all cases care has been taken to obtain the solution free from particles before injection or perfusion.

For intravenous injection an extract of 1 in 25 of the fresh, moist gland has been usually employed. I have not ascertained the minimal effective dose, but 1 c.c. of such an extract (= 0.04 gram of the fresh gland) from the active glands produced a powerful effect.

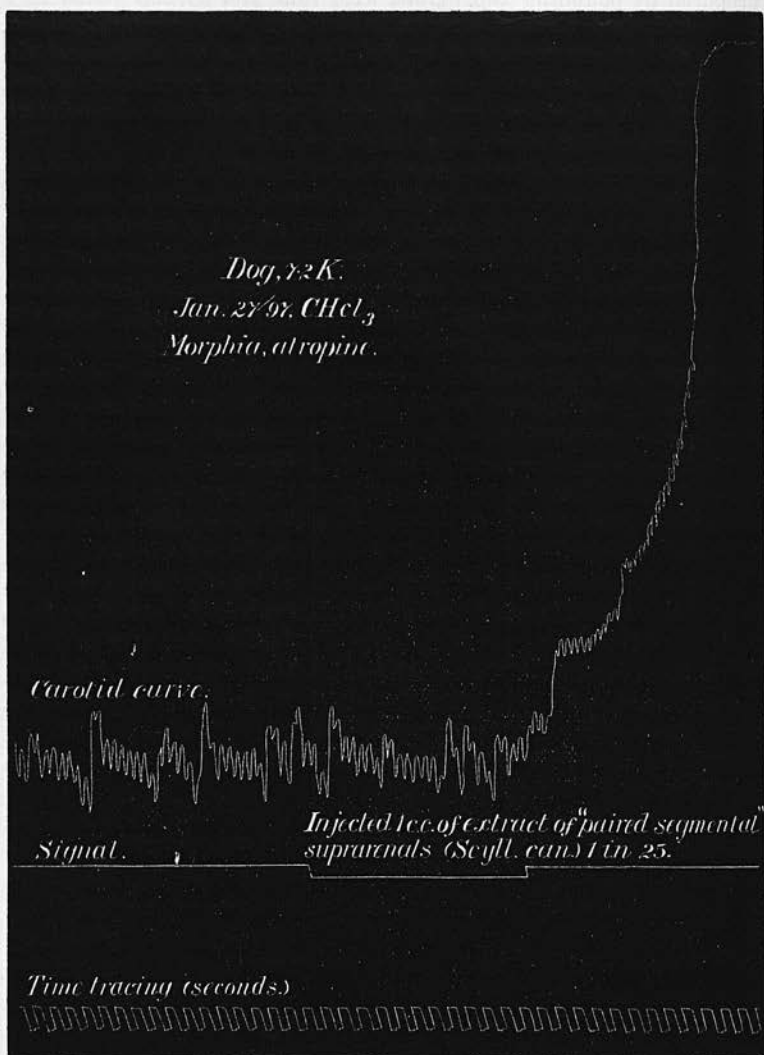
The results obtained by these two methods are quite harmonious. I had anticipated the possibility that the extract from a fish might be inactive upon a mammal, but it will be seen that this anticipation was unfounded. There is in all cases, where "medullary" substance has been injected, very striking evidence of contraction of the arterioles throughout the body. This was made manifest when using dogs or cats with the mercurial kymograph by an enormous rise of blood-pressure (see fig. 1). In the perfusion experiments upon toads the result was seen in an almost complete cessation of flow of fluid through the blood-vessels (see Experiment 1). When "cortical" substance was employed little or no effect in these directions was obtained (figs. 2 and 3, and Experiments 1 and 2). It is true there was always a slight rise of blood-pressure or a small diminution of flow of fluid when extract of interrenal was used (Experiment 1 and fig. 2), but an explanation of this is, I believe, readily to be found. The extracts from the suprarenals of Teleosts have always given negative results when tested by both methods (see Experiment 2 and fig. 3).

*The effect of the active principle upon the arterioles is due to a direct action upon the muscular tissue of the blood-vessels, and is not in any way connected with the action of the central nervous system. This is perfectly clear from the fact that the effects are well marked in the toad when brain and spinal cord have been destroyed by pithing. Oliver and Schäfer found this to be the case with mammalian suprarenal extract, though Szymonowicz and Cybulski maintain the contrary. The results of Oliver and Schäfer have since been completely confirmed by Velich.**

Fig. 1 shows the most typical effect; the lever rises gradually at first, then afterwards almost vertically. In some cases the pressure was too high to be recorded, as the mercury escaped from the end of the manometer. The effect passes off after a variable period, and the blood-pressure returns to normal. There is no need to give further details, but it will be sufficient to say that the experiments

* 'Wien. Med. Blätter,' Nr. 15, bis 21, 1896.

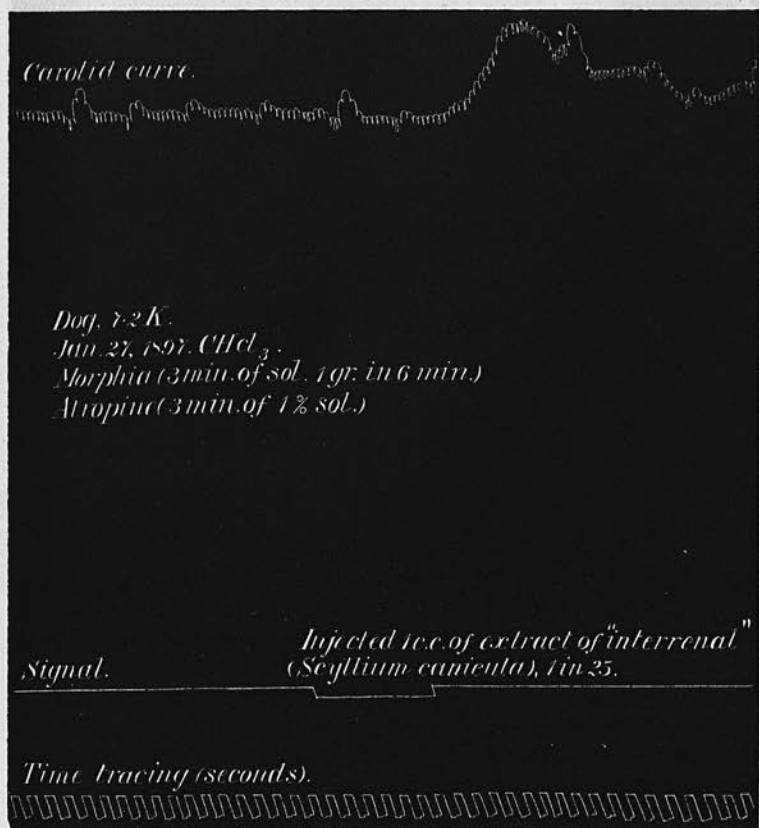
FIG. 1.



all point to the fact that the "paired segmental" suprarenal bodies of Elasmobranchs correspond precisely in physiological action to the medulla of mammalian suprarenal.

With extracts of the interrenal body of Elasmobranchs, partial effects only in the same direction are obtained. Fig. 2 shows a tracing obtained by injecting the same amount of "interrenal" as

FIG. 2.

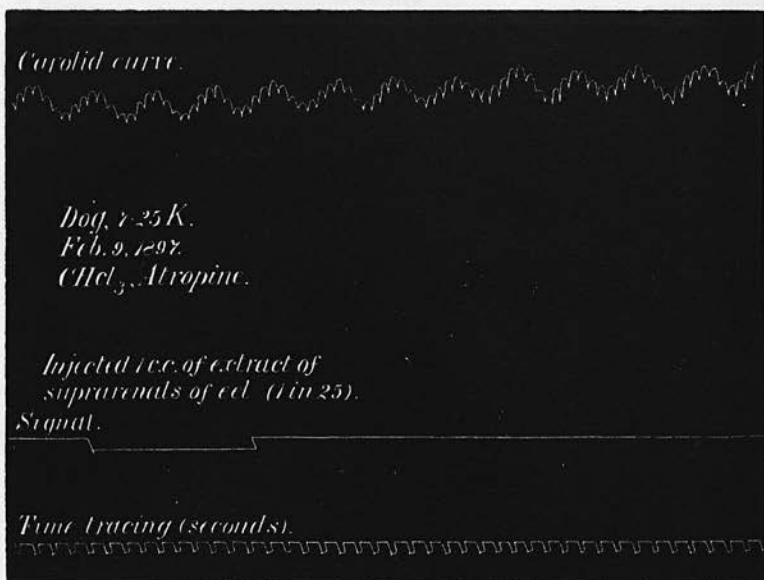


was used of "segmental suprarenal" in fig. 1. There is a striking difference between the two results.

With extracts of the suprarenals of Teleosts no effects whatever are produced. Fig. 3 shows a blood-pressure curve unaffected by the injection of extract of suprarenals of eels to the same amount as was previously employed in other experiments. Subsequent employment of mammalian suprarenal extract in the same experiment produced its proper effect.

Thus we have negative evidence of a physiological character that the interrenal body of Elasmobranchs corresponds to the "corpuscles of Stannius," the known suprarenal bodies in Teleosts, a conclusion both Diamare (5) and I myself (5, 17) had arrived at from anatomical and histological considerations.

FIG. 3.



Control experiments with extracts of "head-kidney" and muscle of fishes always gave negative results.

Perfusion Experiments.—These have been performed upon large toads. A cannula was tied into one aorta, the ligature also including the other. A snip was made in the sinus venosus, and then normal saline (0.6—0.9 per cent.) or Ringer's circulating fluid was perfused through the blood-vessels from a funnel placed about 9 to 12 inches above the animal. The toad was held in a suitable holder, and the fluid which ran through was collected in graduated cylinders and measured at the end of every five minutes. I have performed eleven of these experiments with practically uniform results. It will only be necessary to give the details of two typical ones.

In other experiments an extract made from the lymphatic "head-kidney" of different Teleosts was perfused, and also one made from muscle of various fishes. Both these always gave negative results when properly filtered.

In Experiment 1 it will be noticed that the interrenal gives a very definite result, though not so marked as that of the medullary glands. This point will be referred to again immediately. It is clear from Experiment 2 that extracts of the suprarenal bodies of Teleosts are inactive as regards the flow of fluid through the blood-vessels of a toad.

Exp. 1.—Material taken from a fair-sized Specimen of *Galeus canis*.

Large *Bufo vulgaris*. Fluid had been running about 30 minutes, pressure 25 cm.

Time.	Outflow in c.c.		Time.	Outflow in c.c.	
4·40	55	Normal saline.	5·35	32·0	} " Paired segmental" suprarenal.
4·45	50		5·40	50·0	
4·50	50	" Interrenal."	5·45	20·0	
4·55	50		5·50	2·5	
5·0	33		5·55	1·5	
5·5	11	Normal saline.	6·0	2·5	
5·10	5		6·5	1·5	
5·15	6		6·10	4·5	
5·20	6		6·15	0·5	
5·25	7		6·20	0·5	
5·30	24		6·25	0·5	
			Normal saline.		

Flow does not return to normal, although a much longer time is allowed to elapse.

Exp. 2.—Material from *Gadus aeglefinus*, *Molva vulgaris*, and *Pleuronectes platessa*.

Large *Bufo vulgaris*. Fluid had been running about 45 minutes, pressure 30 cm.

Time.	Outflow in c.c.		Time.	Outflow in c.c.	
1·45	58	Normal saline.	2·0	90	Fresh saline.
1·50	95		2·5	85	
1·55	90	Suprarenal extract from <i>Gadus aeglefinus</i> , then immediately from other two.	2·10	85	
			2·15	93	
			2·20	95	
			2·25	94	
			2·30	95	

There seems no reason to doubt that the active material in the "medullary glands" of Elasmobranch fishes is the same as that in the medulla of mammalian suprarenal, but so little of the material is procurable for chemical analysis that I have found it impossible to compare its reactions with that obtained from the higher animals. It is worth noting, however, that the extract in water or alcohol is of a pale brown tint, exactly resembling that of the medulla of mammals.* But that this brown pigment is not the active substance

* These glands become dark brown when treated with a solution of bichromate

is clear from the fact that when the material (in spirit) is kept for some time, this brown colour increases in intensity, although the extract may become quite inactive. I have found extracts in 80 per cent. alcohol become quite inactive after a lapse of two months.* The brown coloration appears to be the result of the oxidation of a chromogen previously existing in the extract.

It will have been observed that in the foregoing experiments the extract of the interrenal body produced a certain effect upon blood-pressure; this I believe can be entirely explained as the result of more or less admixture with "medullary glands." The latter are to be found close by the side of the former, so that it is practically impossible to remove it without some of them adhering. In my later experiments I tried to avoid this contamination by very careful removal of the interrenal, and, although I have not succeeded by this means in getting an extract of the interrenal quite inactive, yet I find that the more carefully it is removed, the less effect is produced by an injection of its extract. Thus I found the rise of blood-pressure due to interrenal to be much less when I had changed knife and forceps after removal of the medullary bodies, so as to avoid conveyance of the active principle in this manner.

Another explanation might be urged. The Polish physiologists find that a slight rise of blood-pressure is produced by an extract obtained from cortex only, and if this were the case it is conceivable that my results, in the case of the interrenal, are due to this slight specific action. But, when the greatest care is taken to avoid contamination, Oliver and Schäfer find the cortex quite inactive. Besides, the "cortical" glands of Teleosts give no effect and there can be little doubt that these are strictly homologous to the interrenal of Elasmobranchs.

The morphological conclusion that the two kinds of gland in Elasmobranch fishes really correspond to the cortex and medulla of mammalian suprarenal is not without its physiological significance. The cortex is always much more abundant than the medulla in mammals, resembles a secreting gland in many points of structure, and has possibly a function distinct from the medulla. The anatomical union of the two constituent portions may be in some sense accidental.

Conclusions.

1. The suprarenal capsule of the mammalia corresponds to two distinct glands in Elasmobranch fishes, the medulla corresponding *in structure and function* to the "paired segmental" suprarenal of potassium, and this constitutes a ready means of displaying them in a dissection (Semper). This test probably applies to "medulla" throughout the vertebrata.

* When there is free access of air.

bodies ("medullary glands" they may be called), while the cortex corresponds to the interrenal body.

2. In Teleosts the medulla appears to be unrepresented, the known suprarenal bodies ("corpuscles of Stannius") consisting entirely of cortical substance, and corresponding in structure, and most probably in function, to the interrenal body of Elasmobranchs.

3. The same is most probably true of Ganoids, although I am guided here solely by histological evidence; I have not been able to obtain sufficient and suitable material for physiological investigation.

Thus it appears from these researches that two primary groups of the class *Pisces* (Teleosts and Ganoids) have no "medulla" but only "cortex."* So far as I know, the only piece of work published on the physiology of the suprarenal capsules in fishes is that of Pettit (12). This observer has made out a true physiological compensatory hypertrophy of one suprarenal in the eel after the other one has been removed. This renders it probable (what indeed was suggested by histological appearances) that this "cortical gland" has a secreting function. Pettit looks upon this organ in the eel as the fundamental type of the suprarenal capsule, but it appears to me much more probable that it represents cortex alone.

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* This fact would seem to suggest that the cortex may be more important than the medulla, for, whereas in certain vertebrates the medulla can be dispensed with, the cortex is universally present.

73 *The Comparative Physiology of the Suprarenal Capsules.*

16. Vincent, Swale, 'Trans. Zool. Soc.,' vol. 14, part 3, No. 1, April, 1897 (in the Press).
17. Vincent, Swale, 'Anat. Anz.,' Bd. 13, Nos. 1 and 2, 1897.
18. Vincent, Swale, 'Birm. Med. Rev.,' Aug., 1896.
19. Weldon, 'Quart. Journ. Mic. Sci.,' vol. 24, p. 171, 1884.
20. Weldon, 'Quart. Journ. Mic. Sci.,' vol. 25, p. 127, 1885.

“Further Observations upon the Comparative Physiology of the Suprarenal Capsules.” By SWALE VINCENT, M.B. (Lond.), British Medical Association Research Scholar.* Communicated by E. A. SCHÄFER, F.R.S. Received November 2,—Read November 25, 1897.

(From the Physiological Laboratory, University College, London.)

In previous communications† I have given experimental evidence in favour of the view that the paired suprarenal bodies and the interrenal gland of Elasmobranch fishes correspond respectively to the medulla and cortex of the suprarenal capsules of the higher Vertebrata. I have further stated, as the result of numerous experiments, that the medullary portion of the suprarenal appears to be absent in Teleosts, the suprarenal bodies in this order of fishes consisting solely of cortex.

Since performing the above series of experiments my attention has been devoted to the general physiological effects of extracts

* The expenses involved in this research have been defrayed by a grant from the Government Grant Committee of the Royal Society.

† ‘Physiol. Soc. Proc.’ March 20, 1897; ‘Roy. Soc. Proc.’ vol. 61, p. 64, 1897 ‘Anat. Anz.’ vol. 13, Nos. 1 and 2, 1897.



obtained from suprarenal capsules.* The extracts were made separately from cortex and medulla, and injected subcutaneously into various mammals. It was noted that the injection of medullary material was invariably fatal if a sufficiently large dose were administered, while the cortical extracts produced no appreciable physiological effects.

In the present communication the above views have been corroborated by testing the effects of the two kinds of gland in Elasmobranchs and of the cortical suprarenals of Teleosts, when extracts of them are injected subcutaneously into small mammals. Naturally only very small quantities of material have been available for this purpose, but the effects upon mice have been quite definite.

The suprarenal bodies obtained from six specimens of *Gadus morrhua* (weighing in a moist state 0.4 gram) were extracted by boiling. The filtered extract was then injected beneath the skin of the back of a mouse. No effects whatever supervened.

Again, the paired bodies from seven specimens of *Scyllium canicula* (weighing when moist 0.3 gram) were similarly extracted, and the filtrate administered to the same mouse (which had remained in perfect health) a few days later. The animal was immediately and powerfully affected. The breathing became very rapid, the limbs became weak, the temperature lowered, and death ensued after convulsions in less than five minutes.

The interrenal gland produced no effects when similarly administered.

[A further experiment with material obtained from *Raja clavata* has been performed. The "axillary hearts" (anterior paired bodies) were removed from three fair-sized specimens, and found to weigh in a moist state 0.2 gram. The interrenal bodies were also removed, and weighed also 0.2 gram. Extracts were then prepared of each of these, and injected subcutaneously into two separate mice of as nearly as possible the same weight. The mouse which was injected with the extract from the paired suprarenals, was affected in a few minutes. The respirations were very quick at first, afterwards becoming slower and slower. Paralysis quickly came on, first in the hind limbs. All the four limbs were distinctly stiffened before death, which supervened in two hours after injection.

The other mouse, injected with extract of interrenal, died about 24 hours after injection.†—November 15.]

These experiments afford further positive evidence of the homology

* 'Physiol. Soc. Proc.,' June 12, 1897; 'Journ. of Physiol.,' vol. 22 (Nos. 1 and 2, Sept. 1), 1897.

† This result must be attributed to contamination with the paired bodies, and is analogous to the effect one sometimes obtains upon the blood-pressure when interrenal extract is injected intravenously.

of the paired bodies of Elasmobranchs with the medulla of the mammalian suprarenal. The direct evidence in favour of the homology of the interrenal with the cortex of the suprarenal is mostly morphological and histological, and I have detailed this elsewhere.*

* 'Zool. Soc. Trans.,' vol. 14, Part III, 1897; 'Birm. Nat. Hist. and Phil. Soc. Proc.,' vol. 10, Part I, 1896; 'Anat. Anz.,' vol. 12, Nos. 9 and 10, 1896.

THE EFFECTS OF EXTIRPATION OF THE SUPRA-
RENAL BODIES OF THE EEL (*ANGUILLA*
ANGUILLA).

BY

SWALE VINCENT, M.B. (LOND.).

“The Effects of Extirpation of the Suprarenal Bodies of the Eel (*Anguilla anguilla*).” By SWALE VINCENT, M.B. (Lond.), British Medical Association Research Scholar. Communicated by Professor E. A. SCHÄFER, F.R.S. Received February 3,—Read February 10, 1898.

(From the Physiological Laboratory, University College, London.)

Since an extract obtained from the suprarenal bodies of Teleostean fishes produces no rise of blood-pressure when injected into the blood-vessels of a living mammal,* and since the extract produces no physiological effects when injected subcutaneously,† and, moreover, contains no chromogen, it‡ seems clear that these bodies contain nothing corresponding to the medulla of the suprarenal capsules of the higher vertebrata.‡ These results entirely corroborated the opinion previously entertained from morphological and histological considerations, that the suprarenal gland of Teleostean fishes consists entirely of cortex.§

Now all we know about the functions of the suprarenal capsules is confined to the medulla,|| and although the cortex bears every appear-

* Swale Vincent, ‘Roy. Soc. Proc.’ vol. 61, p. 68.

† Swale Vincent, ‘Roy. Soc. Proc.’ vol. 62, p. 177.

‡ B. Moore and Swale Vincent, ‘Roy. Soc. Proc.’ vol. 62, p. 280.

§ Swale Vincent, ‘Anat. Anz.’ vol. 14, No. 5, 1897, p. 152; see also †.

|| Oliver and Schäfer, ‘Journ. of Physiol.’ vol. 18, No. 3, 1895, p. 269; Swale Vincent, ‘Journ. of Physiol.’ vol. 22 (Nos. 1 and 2), Sept. 1, 1897, p. 119.

ance of being an actively secreting gland, one can at present offer no satisfactory suggestion as to the nature of its activity. It is even a matter of surmise whether it has any functional relationship to the medulla, considering its distinct origin and location in Elasmobranch fishes.*

It is almost universally acknowledged that removal of the suprarenal gland in mammals (Brown-Séguard,† Tizzoni,‡ and Oliver and Schäfer§), and in frogs (Abelous and Langlois||), is invariably followed, sooner or later, by death, and that the symptoms during life are those of extreme muscular prostration. Of course in all these cases both cortex and medulla have been removed together, and it would be impossible to state how far the fatal effects were due to loss of the medullary substance, and how far to the loss of the cortical. But Teleostean fishes, having only cortex, seemed to offer an admirable opportunity of testing how far the cortical suprarenal glands were essential to the life of the animal.

Among Teleosts the eel is practically the only fish available for this purpose; since in most species the suprarenal bodies lie on the dorsal surface of the kidney, and would be practically inaccessible during life. Again, the length of time an eel will live out of water, and its power of resistance to the shock of operation, render it peculiarly suitable for extirpation experiments.

The eels were anæsthetised by being placed for a short time in chloroform water. The operations were performed as aseptically as possible, but without the use of chemical antiseptics. An incision an inch or so in length was made to one side of the anus, reaching the middle line in front of this aperture. The abdominal cavity being opened, the edges of the wound were held apart by means of retractors. The gut was pushed over to one side, and the ventral surface of the kidney laid bare. The suprarenal bodies were then picked out with a pair of fine curved forceps. After any bleeding had been checked, the wound was sewn up and dressed with a layer of flexible collodion.

In three cases in which the animals survived the operation, they have appeared quite lively soon after being put back in the tank. One survived twenty-eight days, another sixty-four days, and a third was killed on the 119th day. These experiments show that an eel will survive the operation of extirpation for a very much longer

* Swale Vincent, 'Zool. Soc. Lond. Trans.,' vol. 14, Part III, April, 1897, pp. 52—56; also 'Birm. Nat. Hist. and Phil. Soc. Proc.,' 1896, vol. 10, Part I, p. 1.

† 'Journ. de la Physiol.,' vol. 1, 1858.

‡ 'Ziegler's Beiträge,' vol. 6, 1889, and 'Arch. ital. de Biol.,' vol 10.

§ *Loc. cit.*

|| 'Compt. Rend. de la Soc. de Biol.,' 1891; also *ibid.*, 1892, and 'Archives de Physiol.,' 1892.

time than mammals or frogs, and the difference is so striking that one must attribute it to the absence of medulla in Teleosts, and must assume that *the cortical gland is not absolutely essential to the life of the animal*. The longest time that a frog will survive removal of its capsules is, according to Abelous and Langlois,* twelve or thirteen days, and this period is shortened in the summer to forty-eight hours. Mammals usually die in a day or two.

The validity of these experiments depends obviously upon the fact that all suprarenal material has been actually removed at the operation. This has been verified in two ways. In the first place, previous study of the anatomy of the organs in many individuals has shown that the suprarenals are never more than two in number. Secondly, all three animals have been carefully dissected *post mortem*, and no trace of suprarenal bodies has been found to be left behind.†

Pettit‡ has described a true physiological compensatory hypertrophy of one suprarenal in the eel after the other one has been removed. This indicates a secreting function for this cortical gland. Pettit looks upon this organ in the eel as the fundamental type of the suprarenal capsule; but this view is quite untenable in the face of the facts that it has none of the characters of the double suprarenal of mammals, and its removal does not cause death.

* *Loc. cit.*

† For the animal which lived 119 days this statement has been verified by Professor Schäfer.

‡ 'Recherches sur les Capsules Surrénales,' Thèse. Paris (Félix Alcan), 1896.

“The Effects of Extirpation of the Suprarenal Bodies of the Eel (*Anguilla anguilla*).” By SWALE VINCENT, M.B. (Lond.), British Medical Association Research Scholar. Communicated by Professor E. A. SCHÄFER, F.R.S. Received February 3,—Read February 10, 1898.

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‡ 'Recherches sur les Capsules Surrénales,' Thèse. Paris (Félix Alcan), 1896.

IV. *Contributions to the Comparative Anatomy and Histology of the Suprarenal Capsules.—The Suprarenal Bodies in Fishes, and their Relation to the so-called Head-Kidney.* By SWALE VINCENT, M.B.Lond., Demonstrator of Physiology and Assistant Lecturer on Histology, Mason College, Birmingham¹.

Received September 28th, 1895, read November 19th, 1895.

[PLATES IX.—XIV.]

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I. INTRODUCTORY.

I HAVE been led to investigate the suprarenal capsules in Fishes because their importance in Man and Mammals generally is no longer a matter of doubt. Their function is not yet completely known, but we shall, I imagine, not go far wrong if we state that in Mammals the suprarenal bodies are secreting-glands, and that they pour some material into the blood which is essential for the maintenance of the normal tone of the muscles throughout the body. But this function appears to be confined to the medullary portion of the gland, and, since the two portions are so strikingly different

¹ Towards the expenses of this research a grant has been made by the British Medical Association, at the recommendation of the Scientific Grants Committee of the Association.



in structure and origin, and being inclined to the opinion that these bodies are homologous throughout Vertebrates, I considered that a careful enquiry into their anatomy and histology in the lowest class of Vertebrates could not fail to be of some value as a contribution to our knowledge of their exact distribution and relationships.

Moreover, I felt that there was definite need for such an enquiry and clear statements of its results. Although some good work has been done upon the subject, it is embodied only in scattered, often antiquated and inaccessible memoirs; the text-books scarcely refer to the subject, and various writers who mention the suprarenals make serious errors as to points of fact.

Some authors have attempted to establish the view that (in Teleosts), where suprarenals are present, there is no lymphatic head-kidney, and *vice versâ*; in other words, that the suprarenals are interchangeable with the head-kidney, that where one exists the other does not. I shall be able to show that this idea is quite groundless.

Again, certain writers appear to think that suprarenals are comparatively rare objects among the Teleosts. It will be seen that, so far as my observations have gone, *they are universally present* in this order. I will not enlarge further on these points here, as they will be dealt with in detail in the body of the paper.

As for methods of work, these have been very various. I have examined fifty-five species in all, and many individuals of several species. *Most of these have been perfectly fresh*, indeed all but nine, which were preserved specimens.

In each case I have observed *in situ* the position and relations of the suprarenals and the head-kidney. After careful removal, both these have been examined microscopically. Numerous sections of various parts of different kidneys have also been made and examined.

Some preparations were made quite fresh, *i. e.* sections cut with Swift's "Ether Freezing Microtome." Others have been hardened in alcohol or Müller's fluid, stained in bulk, imbedded in paraffin, and cut with the "Rocking Microtome." The precise method I have used to the greatest extent is the following:—

The material is hardened in Müller's fluid in the usual way for about six weeks. [In some cases the process has been hastened by keeping the tissue at a temperature of about 36° C.] It is then double-stained in bulk with Ehrlich's hæmatoxylin and eosin, and imbedded in paraffin.

In working at the naked-eye anatomy in the Elasmobranchii, I have made use of both the chromic-acid method of Semper and the osmic-acid method of Chevrel.

I have made a special point of obtaining, in all cases where this was possible, perfectly fresh specimens, and no results, with one or two exceptions, have been considered worth recording, especially in a histological direction, unless the tissues were practically living at the time of dissection.

I was convinced that what was particularly needed was a series of accurate drawings of the suprarenal bodies and their relation to the kidney. Consequently I have given

an outline sketch of the kidney from the ventral surface in nearly every species examined, putting in the suprarenals in plain lines when on the ventral surface, in dotted lines when on the spinal surface. Such a series of drawings I cannot find and do not believe to exist. In the Elasmobranchii the only drawing I am acquainted with is that in Semper's paper, and this, I was sure, might easily be improved upon.

Many parts of the paper are not nearly so complete as I should have wished. Indeed, in many respects I wish the paper to be considered as merely preliminary to future work on the same subject. This applies particularly to the histological part. The head-kidney I hope to make the subject of an exhaustive research at some future time.

I have not touched upon the subject in the Cyclostomata, having so far only been able to get specimens of the small river-lamprey, but I hope to deal with their blood-vascular glands in a separate contribution¹. Further, I have not made any investigation of the development of the suprarenal bodies.

I am deeply indebted to Prof. T. W. Bridge, M.A., D.Sc., of Mason College, Birmingham, for his kindly and repeated advice on many subjects connected with this research, and for the generous manner in which he has placed specimens at my disposal; to Prof. F. J. Allen, M.A., M.D., for much important assistance; to Mr. Walter E. Collinge, F.Z.S., for help on many points; and to Prof. W. N. Parker for specimens of Protopterus and the use of some of his slides. I must also express my thanks to Prof. G. B. Howes for many suggestions, bibliographical and otherwise.

I take this opportunity of expressing my thanks to the Research Committee of the British Medical Association for a grant in aid of these investigations.

II. HISTORICAL.

The literature of this subject is so very scattered and often so inaccessible, and I have become acquainted with some papers touching upon it in such accidental ways, that I fear my account may not be complete. However, I trust that most of the important papers dealing with the general subject have fallen into my hands; at the same time it is possible that accounts of the suprarenals and discussions of their morphology in monographs may have escaped me. Then, too, some text-books may have accounts which I have overlooked; but, from the exceedingly unsatisfactory account given by Eberth in Stricker, I did not consider it would be profitable to explore these very thoroughly.

¹ Since the above was written I have, in conjunction with Mr. Walter E. Collinge, F.Z.S., investigated the subject in the Cyclostomata, with the result that nothing in the way of suprarenals can be made out. (*Anat. Anz.* Bd. xii. Nr. 9 & 10, 1896.)

[More recently Pettit (Thèse, Paris, 1896) has been unable (p. 86) to ascertain definitely whether suprarenals are present in the Cyclostomata or not.—*S. V.*, 10. 1. 97.]

The earliest account of the suprarenal bodies in fishes appears to be that of Retzius. His description, written in 1819, has reference only to cartilaginous fishes.

Retzius (18) pointed out as suprarenals certain structures in *Squalus glaucus*, *S. acanthias*, *Raja clavata*, *R. fullonica*, and *R. batis*. From his description it is evident that he refers to what is now usually termed the "interrenal body." He considered this organ to be the suprarenal on account of its resemblance in texture to the suprarenals of birds ¹.

The suprarenals in Teleostei appear to have been discovered by Stannius (20) in 1839.

In 1843 J. Müller (16) described in Myxinoids a clustered gland without a duct on each side of the cardia, which he at first considered to be a suprarenal, but afterwards thought to be thymus. In *Petromyzon* he found instead of this gland "certain white plugs with which the trunks of the posterior veins of the body are beset." These structures had been previously described by Rathke ².

Three years later, in 1846, Stannius and Ecker threw considerable light on the subject. Stannius (21) describes the suprarenals as existing both in the higher cartilaginous and in the bony fishes. His account of the suprarenals in Elasmobranchs obviously applies only to the interrenal. The segmentally-arranged bodies were not yet discovered. He gives also in this first edition a fairly good account of the general position of the suprarenals in several Teleosts and in the Sturgeon. In addition this observer questions the right of Müller's "clustered gland" to rank as a suprarenal.

Ecker (6), in addition to verifying the results of the above observer in regard to the gross anatomy of the suprarenals, gives an account of their minute anatomy, which was for many years the common store of information on this subject.

In 1851 Hyrtl (10) mentions some facts about the suprarenals in several Teleosts. He examined 222 species. He gives first a short and very imperfect account of their general position and appearances, and then mentions them very briefly under the special heading of the species. But, although he states in his introductory general description that suprarenals were found in almost all the fish he examined, yet I find, on looking through the paper, that they are only specifically noted in 28 species. In some two or three cases he states that he could not find them. In all the rest he never mentions them. He definitely found them in:—

Uranoscopus scaber.
Cottus quadricornis.
Diagramma punctatum.
Lophius piscatorius.
Chironectes punctatus.
Normyrus oxyrhynchus.

Silurus glanis.
Schilbe mystus.
Pimelodus bayard.
Salmo fario.
Saurus lacerta.
Clupea nilotica.

¹ See also Nagel, Müller's Archiv, 1836.

² See Collinge and Vincent (*loc. cit.*), also Pettit (*loc. cit.*).—S. V., 10. 1. 97.

Elops salmoneus.
Gadus barbatus.
Cobitis fossilis.
Acanthopsis tania.
Esox lucius.
Esococtus exiliens.
Belone vulgaris.
Motella mustela.

Lota vulgaris.
Phycis blennoides.
Platessa passer.
Rhombus nuchus.
Echeneis remora.
Ammodytes tobianus.
Symbranchus marmoratus.
Diodon novemmaculatum.

No doubt a large proportion of Hyrtl's specimens were not fresh but preserved, and this would often prevent the discovery of the suprarenal bodies.

In the same year Leydig (13) described the suprarenals of *Chimæra monstrosa* thus: "Each suprarenal forms a narrow streak $\frac{3}{4}$ " long, of an ochre-yellow colour. The posterior end is somewhat thicker and more rounded. They lie on the inner border of the kidney." This, of course, is the "interrenal." In Elasmobranchs we find no mention yet of the paired segmental bodies on the branches of the aorta, but only a body "in Form eines schmales ockergelben Streifens an der Rückseite der Nieren" (*Stannius*).

After this period we come to researches of much more importance, in reference at any rate to the subject in Elasmobranchs, and it will be necessary to review it in some detail.

In 1852 Leydig published his famous 'Rochen und Haie' (11). In this work he insists that the "so-called axillary hearts and their continuations on the sympathetic ganglia are to be considered as the real suprarenals of Cartilaginous Fishes, and not, as heretofore reckoned, the yellow stripes and bodies behind the kidneys." He bases this view on the fact that the paired bodies resemble the suprarenals in Mammalia in "consisting of closed bladders filled with cells," also in their abundant vascular and nervous supply. On the other hand, he says "the yellow stripes" consist simply of "masses of fat-globules and bright nuclei." He emphasizes the close connection between the suprarenals and the sympathetic nervous system. "As the pituitary body is an integral part of the brain, so the suprarenals are part of the sympathetic." In the same work Leydig expresses his opinion that the organs previously considered as suprarenals are "fat-glands" analogous to those known in the Amphibia. Referring to the Cyclostomes this author definitely states his belief that the "clustered gland" of Müller and the "white plugs" of Rathke and Müller are analogous to the suprarenals.

About this time too (1852) appeared Frey's article on the Suprarenals in Todd's 'Cyclopædia' (7). It was obviously written before the above researches of Leydig, so that the only suprarenals mentioned in Elasmobranchs are the bodies now termed "interrenal." This writer gives a very good account of the anatomy and histology, mostly after Ecker, and in the part relating to fishes, at any rate, there seems little that may be considered original.

In the next year (1853) Leydig published his 'Fische und Reptilien' (12). In this

work he gives a description of the suprarenals in the Sturgeon, and finds them to be composed of "an aggregation of fat-globules." He states that they are always placed on the walls of the blood-vessels. But he changes his view entirely on the subject of the suprarenals in cartilaginous fishes. He now considers that both the paired bodies in connection with the sympathetic ganglia and the "ochre-yellow stripes" behind the kidney belong to the same system and constitute the suprarenal capsules in this order of fishes.

Stannius, in a later edition (22), seems to have recognized both kinds of bodies. Balfour says his description is "not quite intelligible." This I consider to be quite a euphemism. I have found the description totally incomprehensible as applied to the Elasmobranchs. On the other hand he gives a very excellent account of the suprarenals in Teleosts. He states that in the Pike these bodies have been found studded in the kidney from the middle to the tail-end, and believes them to be absent in *Clupea harengus* and *Ammodytes tobianus*.

The next important step in advance was made by Semper (19) in 1875, who emphasizes the segmental arrangement of the suprarenals, and believes them to be the same kind of structure as the interrenal. In fact he appears to believe that there exists a direct anatomical continuity between them. "Hier freilich gehen sie bei manchen Formen (*Rochen, Chimæra, Scymnus, Acanthias, Mustelus, etc.*), also wahrscheinlich wohl bei den meisten Plagiostomen in einen bald weissen, bald hell- oder dunkel-gelben Körper über, welcher, zwischen den Enden der beiden Nieren liegend, dicht an der einfachen Caudalvene sitzt."

F. M. Balfour (1) in 1878 has also dealt with this subject with considerable care in his monograph on Elasmobranch Fishes. He gives an account of the history up to date, and it is to him we owe the term "interrenal" as applied to the unpaired body in *Scyllium*. He expresses his opinion that there is very probably "a third kind of body in connection with the kidney," and regrets he could not settle the point with fresh specimens. He refers to Stannius's description as possibly indicating a third structure; but, so far as I could understand this author, he seems to allude to broken-off or scattered portions of the interrenal, which, as we shall see later on, are frequently found. The "lymphoid masses" which Balfour mentions in connection with the larger vessels of the kidney do not appear to me to be of any importance in connection with this subject, as lymphoid tissue is very common in all fishes both in and surrounding the renal organs.

Balfour's researches were both anatomical and developmental. With the latter I shall not concern myself, but the former must be dealt with in some detail. He describes the general anatomical relations of both "supra-" and "inter-"renals, and then gives an account of their histology, which suffers from the fact that he had only been able to obtain specimens preserved in chromic acid. He lays great stress on the relations between the paired suprarenals and the sympathetic nervous system, but states that there is a "much smaller ganglionic development" in connection with the

posterior bodies than with the anterior. The typical suprarenal structure, he says, is best exhibited in a posterior one. "Externally there is present a fibrous capsule which sends in the septa, imperfectly dividing up the body into a series of alveoli or lobes. Penetrating and following the septa there is a rich capillary network. The parenchyma of the body itself exhibits a well-marked distinction, in the majority of instances, into a cortical and medullary substance. The cortical substance is formed of rather irregular columnar cells, for the most part one row deep, arranged round the periphery of the body. The cells measure on an average .03 mm. in their longest diameter. The medullary substance is more or less distinctly divided into alveoli, and is formed of irregularly polygonal cells &c."

Balfour mentions also that the protoplasm of both sorts of cells has a yellowish tinge, and that the suprarenals are more or less surrounded by lymphoid tissue. He gives a drawing of these appearances in pl. xviii. fig. 6. As for the connection between the sympathetic ganglia and the suprarenal bodies, he says:—"In the case of one of the posterior bodies, a small ganglion is generally found attached to both ends of the body, and invested in the same sheath; in addition to this a certain number of ganglion-cells (very conspicuous by their size and other characters) are to be found scattered through the body. In the anterior suprarenal bodies the development of ganglion-cells is very much greater. If a section is taken through the region where the large sympathetic ganglion is attached to the body, one half of the section is composed mainly of sympathetic ganglion-cells and nerve-fibres, and the other of suprarenal tissue, but the former spread in considerable numbers into the latter." At one point (*n* in pl. xviii. fig. 7) a nerve is shown entering. He states that the ganglion and nerves are so intimately united with the suprarenal body as not to be separable from it.

Balfour leaves it an open question whether there are cells of an intermediate character between the ganglion cells and the cells of the suprarenal body. Then follow the developmental researches, the general conclusion of which is that the paired "suprarenal" bodies develop as parts of the sympathetic nervous system.

Passing on to the interrenal body, this author gives a sketch of its general anatomy, and differs from Semper as to the continuity of the two kinds of structure. It will be seen that my own observations agree on this point with Balfour. With regard to the histology of the interrenal, he gives a drawing (pl. xvii. fig. 8), and describes it thus: "It is invested by a fairly thick tunica propria, which sends in septa, dividing it into rather well-marked lobules or alveoli. These are filled with polygonal cells, which form the true parenchyma of the body. These cells are in my hardened specimens not conspicuous by the number of oil-globules. . . . They are rather granular in appearance, and are mainly peculiar from the somewhat large size of the nucleus. . . ."

Balfour notes as differences between the "supra-" and "inter-"renals the distinction into cortex and medulla in the former, and the large size of the nuclei in the cells of the latter. From the developmental standpoint he concludes that the interrenal does not belong to the same system as the suprarenals, and he proceeds to enquire with which

(if with either) of these two bodies the suprarenal bodies of the higher vertebrates are homologous. He does not decide the question definitely, but inclines to the view that the *paired* bodies of *Scyllium* are homologous with the suprarenals of Mammalia¹.

The only recent account of the suprarenals in a Teleost which I have found is that of M'Kenzie (15), written in 1884, who gives a description of the suprarenals of *Amiurus catus*, with drawings of their histological appearances. They are, according to M'Kenzie, sometimes entirely concealed by the kidney-substance. This is noteworthy as being decidedly rare in this order. He describes alveoli containing large and small granular cells, the longest of them reaching from wall to wall of an alveolus. These two kinds of cells bear no constant relation to each other. This author does not believe that the bodies have anything to do with the elaboration of the blood, and is opposed to Weldon's view that the suprarenals are metamorphosed parts of the kidney just as the head-kidney is. This fish, he states, has a well-developed (lymphatic?) head-kidney in addition to the undoubted suprarenals. The interest and importance of this will be seen later on.

Chevrel (3) appears to be the last author who has written upon this subject². He, like Leydig, Semper, and Balfour, has discussed the subject in Elasmobranchs, and chiefly from the standpoint of the sympathetic nervous system. He has picked out the nerve-fibrils and suprarenal bodies with osmic acid. In this excellent memoir he gives a very good historical account, and carefully reviews Balfour's work on the subject. Chevrel states that the interrenal body is situated between the inferior surface of the dorsal aorta and the superior surface of what he calls the "interrenal vein." He describes also small detached parts of the interrenal on the superior and posterior parts of the kidneys.

In the case of the paired bodies, Chevrel denies Balfour's division into cortex and medulla, and explains the appearance obtained by the latter observer as due to the action of reagents. As will be seen below, this view is entirely corroborated by my own researches. Chevrel got no appearances anything like Balfour described. He says, "On ne voit ni cellules colonnaires à la périphérie, ni cellules polygonales au centre; il n'y a que des apparences. Et ces apparences sont dues vraisemblablement

¹ [R. Fusari ("Contribuzione allo Studio dello Sviluppo delle Capsule surrenali e del Simpatico nel Pollo e nei Mammiferi," Arch. per le Scienze med., Torino, 1892, vol. xvi. no. 14, pp. 249-301, tav. iv.-vii.), from investigations on mammals, maintains that the interrenal body is not homologous with any part of the suprarenal capsule, but with a certain adipose tissue found round the suprarenals in some mammals.

On the other hand, M. Braun ("Bau und Entwicklung der Nebennieren bei Reptilien," Arbeit. a. d. zool.-zoot. Inst. Würz., Band v. pp. 1-30, Taf. i., ii., 1882), R. Semon ("Studien über den Bauplan des Urogenitalsystems der Wirbelthiere (*Ichtiophis*), Jena. Zeitschr., 1891, Band xxvi. pp. 89-203), and F. van Wyhe ("Ueber Mesodermsegmente des Rumpfes und die Entwicklung des Excretionsystems bei Selachiern," Arch. f. mikr. Anat. Band xxxiii. 1889, pp. 461-516, Taf. xxx.-xxxii.) favour Balfour's views.

Valenti (Atti della Soc. Toscana di Scienze nat. 1889, Pisa, vol. x. tav. x) believed the suprarenal capsule to be a rudimentary organ.—S. V., 10. 1. 97.]

² See footnote to p. 49.

aux contours des mailles de la trame conjonctive des corps. Les dissociations nous ont également donné des résultats négatifs." He doubts their analogy to the suprarenal bodies of Mammalia, and describes their structure thus:—"De la fine membrane qui les enveloppe partent des filets qui vont former dans son intérieur, de concert avec ceux qui naissent de l'anneau conjonctif entourant l'artériole, une sorte de réticulum très compliqué, à mailles inégales, dans lesquelles se trouvent un nombre considérable de noyaux ovales. Chacun de ces noyaux, pourvu de plusieurs petits corps très réfringents, paraît simplement plongé dans le protoplasme granuleux; on pourrait peut-être supposer qu'il appartient à une cellule sans membrane d'enveloppe dont le protoplasme granuleux se fusionne avec celui des cellules voisines. De cette fusion résulterait une masse protoplasmique unique contenant tous les noyaux et remplissant les mailles du réticulum. Enfin des ganglions et des cellules sympathiques se trouvent assez souvent plongés dans le parenchyme du corps, et, à sa surface, circulent sans pénétrer, du moins en apparence, dans sa substance, et sans émettre de rameaux, des filets nerveux appartenant également au système sympathique."

Passing on to the interrenal, Chevrel says, "À l'état frais, les éléments propres de ce corps disparaissent sous une couche de globules clairs, légèrement teintés, qui lui donnent une couleur jaunâtre particulière." Leydig thought these globules to be fat. Balfour, on the contrary, thought they were not fat. Chevrel is of the latter opinion, since ether does not dissolve them, nor osmic acid blacken them to any extent. He proceeds to describe their microscopical structure as being much the same as that of the suprarenals. The chief differences, according to him, are—(1) Inequality in size of nuclei (10 μ in "inter," 9 μ in "supra"). (2) Absence in the suprarenal of the clear globules which the interrenal contains in abundance. (3) A distinct division sometimes, in the case of the interrenal, into "capsules ou vésicules nettement marquée." (4) A less abundant vascular supply in the interrenal.

Chevrel does not think there is any very direct connection between the interrenal and the suprarenals, and notes that the "interrenal" has no relations with the sympathetic. He does not decide whether the interrenal body is of a different order of structure from the suprarenals. As to the connection between the suprarenals and the small sympathetic ganglia, he states, "This connection in the case of the smaller bodies is not so frequent as Leydig, Semper, and Balfour imagined."

Chevrel has also more recently (4) given an account of the sympathetic system in the Sturgeon. He gives a drawing of the relations of the suprarenal bodies to the sympathetic nervous system, and also a very unsatisfactory representation of the microscopical structure of the ganoid suprarenal¹.

¹ [Since this was written, the papers of V. Diamare ("Ricerche intorno all'Organo interrenale degli Elasmobranchi col ai Corpuscoli di Stannius dei Teleostei" etc., Mem. matem.-fis. ser. 3, t. x. 3 tav., 1896) and Pettit (Thèse, 'Recherches sur les capsules surrénales,' Paris, 1896) have appeared.

These will be briefly referred to again, as occasion requires, in later footnotes.—S. V., 10. 1. 97.]

III. CLASSIFIED LIST OF SPECIES EXAMINED.

i. ELASMOBRANCHII.

A. SELACHOIDEI.

Scyllidæ: *Scyllium canicula*.,, *catulus*.Spinacidæ: *Acanthias vulgaris*.Rhinidæ: *Rhina squatina*.

B. BATOIDEI.

Rajidæ: *Raja batis*.,, *clavata*.,, *maculata*.

ii. HOLOCEPHALA.

Chimæridæ: *Chimæra monstrosa*.

iii. GANOIDEI.

A. CHONDROSTEI.

Spatularidæ: *Polyodon folium*.Acipenseridæ: *Acipenser sturio*.

iv. TELEOSTEI.

A. PLECTOGNATHI.

a. Sclerodermi.

Balistidæ: *Balistes maculatus*.

b. Gymnodontes.

Molidæ: *Orthogoriscus mola*.Tetodontidæ: *Tetrodon nigropunctatus*.

B. PHYSOSTOMI.

Murænidæ: *Anguilla anguilla*.*Conger conger*.Clupeidæ: *Clupea harengus*.Esocidæ: *Esox lucius*.Salmonidæ: *Salmo salar*.,, *trutta*.Cyprinidæ: *Leuciscus rutilus*.,, *cephalus*.,, *vulgaris*.

C. ANACANTHINI.

Gadidæ: *Gadus morrhua*.,, *øglefinus*.,, *merlangus*.,, *virens*.

Merluccius vulgaris.
Motella tricirrhata.
Motva vulgaris.
 Pleuronectidæ: *Hippoglossus vulgaris.*
 Pleuronectes flesus.
 ,, *limanda.*
 ,, *platessa.*
 Solea vulgaris.
 Hippoglossoides limandooides.
 Zeugopterus.
 Rhombus levis.

D. ACANTHOPTERI.

a. Pharyngognathi.

Coris pulcherrima.

b. Acanthopterygii.

Percidæ: *Gastrosteus spinachia.*

Perca fluviatilis.

Labrax lupus.

Mullidæ: *Mullus barbatus.*

Sparidæ: *Pagellus centrodonatus.*

Cantharus griseus.

Triglidæ: *Cottus gobio.*

Trigla pini.

„ *lyra.*

Scomberidæ: *Scomber scomber.*

Zeus faber.

Blennidæ: *Anarrhichas lupus.*

Pediculati: *Lophius piscatorius.*

c. Acanthopterygii mugiliformes.

Mugilidæ: *Mugil capito.*

d. Acanthopterygii gobiiformes.

Discoboli: *Cyclopterus lumpus.*

v. DIPNOI.

Lepidosiren paradoxa (*L. appendiculata*, Ehlers¹).

Protopterus annectens.

IV. GROSS ANATOMY.

1. ELASMOBRANCHII.

In this order there are two distinct sets of bodies which have borne the name of "suprarenals." One of these is a more or less rod-shaped structure, unpaired in some

¹ [See, however, Lankester, "On *Lepidosiren* and *Protopterus*," Trans. Zool. Soc. vol. xiv. part i., April 1896.—S. V., 10. 1. 97.]

genera, as *Scyllium*, paired in others, as *Raja*, which lies in the region of the hinder end of the kidney—in the middle line, as a rule, in the first case; on the inner and hinder border of the kidney in the second (Pl. IX. figs. 1, 2, 3, & 4, Pl. X. figs. 5, 6, & 7, *i.r.*). This structure was called by Balfour the “interrenal” body, and has since usually borne this name. The other set of structures is a segmentally arranged series of paired bodies, placed on the intercostal or parietal branches of the aorta, and extending in many cases throughout the whole length of the abdominal cavity (Pl. IX. figs. 1–4; Pl. X. figs. 5, 6, & 7, *ax.h.*, & *s.r.*).

a. SELACHOIDEI and BATOIDEI.

I have examined the following seven species, and in some cases several individuals of the same species:—

<i>Scyllium canicula.</i>		<i>Raja batis.</i>
„ <i>catulus.</i>		„ <i>clavata.</i>
<i>Acanthias vulgaris.</i>		„ <i>maculata.</i>
<i>Rhina squatina.</i>		

The Segmentally arranged Bodies.—These are disposed in much the same manner in all Plagiostomes. Their general arrangement has been already well described by Leydig, Semper, and Balfour; and Chevrel has given a description of their anatomical connections with the sympathetic. It is therefore only necessary for me to give a brief account of their usual anatomy, emphasizing such points as may seem to need it.

These bodies are placed for the most part in a very definitely segmental manner (Pl. IX. fig. 2). The anterior pair are always elongated and equal in size to several of the following bodies (Pls. IX. & X. figs. 1–7, *ax.h.*); as a matter of fact they seem to correspond usually to three or four segments. They are arranged on branches of the aorta, the intercostal arterioles (Pl. IX. figs. 1 & 4; Pl. X. figs. 5 & 6), and extend on each side of the vertebral column from the front part of the sinus of Monro to a variable distance posterior to the origin of the posterior cardinal veins. The anterior pair and some of those bodies which immediately follow these on either side are placed in the cavity of the sinus, and therefore during life are bathed in its blood (Pls. IX. & X. figs. 1–7, *ax.h.*, *s.r.*). They usually more or less completely surround the artery with their substance, and with the aid of a lens one can nearly always see the artery, vein, and a fine nerve distributed to each segmental body. The first pair are placed on or near the axillary arteries, hence their old name “Axillary Hearts.” An arteriole usually communicates between the axillary and the succeeding branch of the aorta, and runs through the whole length of the body (Pl. IX. figs. 2 *a* & 4).

In the anterior part of the abdominal cavity these bodies have no relation to the kidney-substance, but in the region of this organ they become more or less imbedded in it. Where the renal substance is distinctly segmented they are often placed deep down in the grooves which separate the segmental portions, and are often in this way almost completely hidden. They usually overlap the region of the interrenal, and often

extend nearly to the hinder end of the kidney in company with the interrenal (Pl. IX. figs. 2 & 4; Pl. X. figs. 5 & 7, *s.r.*). In other cases (Pl. IX. figs. 1 & 3; Pl. X. fig. 6, *s.r.*) they cannot be traced very far behind the anterior extremity of the interrenal. When the segmentally arranged bodies extend very far back they have a great tendency to get less and less distinct and more fragmentary in appearance.

Their relation to the sympathetic is made evident in a general way by ordinary care in dissection, but the precise details of this relationship are not at all easy to make out. Chevrel has, however, described this part of the subject with such care that little need be said; but as very little besides his work has ever been done upon this subject, it may be as well to call attention to some points. It is a great mistake to suppose that the sympathetic ganglia are all, or indeed mostly, wrapped up in the same sheath as the segmental suprarenal bodies. This is undoubtedly true in many cases, perhaps in all, of the first pair, but it is not nearly so common with the posterior ones. Indeed, without in any way questioning the value of Balfour's developmental researches, I am inclined to think that the connection between the sympathetic nervous system and these bodies has been overstated. They are intimately involved in the sympathetic plexuses, and often have tiny ganglia very close to them; but in the adult, at any rate, whatever their developmental relations may be, *it can, in my opinion, not be truly said that they are an integral part of the sympathetic nervous system.*

The Interrenal Body.—This body, as we have seen, was the structure to which the name "suprarenal" was first applied. After the discovery of the "paired suprarenals" of Leydig, a new name was required for the old body. This was supplied by Balfour, who called it "interrenal."

The interrenal body is an "ochre-yellow" rod-shaped structure, paired in the Rays, unpaired in the Sharks, lying usually in the region of the posterior part of the kidney, but sometimes extending as far forward as its anterior extremity (Pls. IX. & X. figs. 1-7, *i.r.*). It bears a striking resemblance in its colour, general appearance, and relations to the kidney, to the suprarenals of Amphibia and Reptilia.

The unpaired interrenal of the Dog-fishes (Pl. IX. figs. 2, 3, & 4; Pl. X. fig. 5, *i.r.*) lies between the inferior surface of the dorsal aorta and the superior surface of the unpaired caudal vein, or, as Chevrel prefers to call it, the "interrenal" vein.

The paired interrenal of the Skates (Pl. X. figs. 6 & 7, *i.r.*) lies on the median side of the ureter and on a superior level, so that it often lies on the dorso-internal edge of each kidney adjoining the middle line.

In addition to this one often finds slight streaks or dots of the same characteristic yellow colour in other parts of the kidney¹.

¹ This may be compared on the one hand with the multiple suprarenals of the Sturgeon, and on the other with the frequency of "accessory" suprarenals in Teleosts and in Mammals. The accessory bodies in Mammals are said to consist of cortex only, and it may be as well to note here that my investigations lead me to conclude that interrenal, suprarenals in Teleosts and Ganoids, and cortex in Mammals are all strictly homologous with one another.

The interrenal is generally much thicker behind than in front (Pl. IX. figs. 1, 3, & 4); in fact, while it is posteriorly often markedly bulbous, it usually tapers off anteriorly into a broken line of extreme tenuity. It diminishes in diameter, however, not regularly, but is often more or less moniliform; the constrictions may be complete here and there, and at the anterior extremity one often finds several small pieces of interrenal separated by a considerable interval from the rest of the body (Pl. IX. figs. 1, 3, & 4; Pl. X. figs. 5 & 7, *a.i.r.*).

In the Batoidei the interrenal is never quite symmetrical; nearly always the body of one side extends further forward than that of the other, and in one case, in *Raja batis* (Pl. X. fig. 6, *i.r.*), I found a complete and comparatively thick bridge connecting the interrenal of one side with that of the other. This might perhaps be looked upon as a single body behind, which became divided in front; in this instance the organ extended further forward on the right side, and further backward on the left.

In some cases (e. g., *Acanthias*) the unpaired interrenal body appears to be placed not quite mesially, but is laid on the median surface of one or other kidney (Pl. X. fig. 5, *i.r.*).

Occasionally (*Raja maculata*) the anterior piece of the interrenal of each side, which is cut off by more or less of an interval from the rest of the body, shows curious claw-like processes on its outer side running in the kidney-substance towards the ureter (Pl. X. fig. 7, *a.i.r.*).

Balfour quotes Semper as describing an anatomical connection between the interrenal and the paired bodies. Balfour questions this, and I am convinced from the examination of several fresh specimens, both of *Scyllium* and *Raja*, that there is never any such connection or continuity. *The two kinds of structure are always totally independent and unconnected.* I have mentioned in the historical section Balfour's surmises with regard to the existence of a third kind of body in relation to the kidney in *Scyllium*, and I have intimated that masses of adenoid tissue were to be expected, and were frequently found in various situations in and about the kidney. I have, nevertheless, carefully searched for anything which might rank as a "third kind of body." I have been able to examine a number of fair-sized perfectly fresh specimens, and I have failed entirely to find anything of the kind. So that we may consider that we have to limit the morphological and physiological problem, difficult as it is, to the relationships and significance of the paired segmental bodies and the "ochre-yellow strips" or interrenal bodies. The problem which naturally presents itself is:—Which of these two structures (if not both) corresponds to the suprarenal capsules of Teleosts and higher Vertebrates? For an account of the discussion see the historical section above. My own view will be stated after I have given a description of the histology.

In the above account I have treated the Sharks and Rays together, because there is not sufficient difference between the general arrangement in the two cases to make a separate description necessary.

b. HOLOCEPHALA.

In *Chimæra monstrosa* (Pl. IX. fig. 1) from the examination of four well-preserved specimens, I find the suprarenals arranged almost exactly after the type of the Plagiostomes. There is the same interrenal, unpaired as in the Dog-fishes¹, enlarged and rounded posteriorly and broken up at its anterior end. There is also the same arrangement of the segmental bodies, the only noticeable difference being that the anterior pair, instead of being elongated and irregular, are smooth and regular oval in shape (Pl. IX. fig. 1, *ax.h.*)². They are, nevertheless, many times larger than any of the other bodies of the same series.

2. GANOIDEI.

Among Ganoids I have only been able to obtain representatives of two families of the Chondrostei, viz., *Acipenser sturio* and *Polyodon folium*. The *Polyodon* was a spirit-specimen in a bad state of preservation, and I could find nothing in the way of suprarenals, so that I am limited to the Sturgeon for information about this order. The Sturgeon is practically the only Ganoid it is possible to examine in anything like a fresh state in this country. I have been able to obtain and have carefully examined two specimens whose tissues were, to all intents and purposes, in a living condition. The first specimen was 1.65 metre in length, with a kidney 63 centim. long; the second was 2.14 metres, with a kidney of 1 metre.

The suprarenals in the Sturgeon are "ochre-yellow" bodies of precisely the same tint as the interrenal in Elasmobranchs. They vary extremely in size and shape, and are scattered in a more or less irregular manner throughout the substance of the kidney (Pl. X. fig. 8, *s.r.*). They are for the most part finely lobulated, almost coarsely granular to the naked eye, and many of the larger ones have processes or claws extending out in various directions into the kidney-substance. A certain number of the larger bodies are visible on the surface of the kidney, or revealed with very little dissection. A still larger number come into view on slitting up the posterior cardinal sinus, since they lie in abundance in its walls and in the immediate neighbourhood. A large residue, including the majority of the smaller bodies, are only revealed by digging away the kidney-substance in various parts.

I find the larger bodies placed anteriorly (Pl. X. fig. 8); and in this respect my observations differ from those of Leydig, who says that the larger ones are posterior. It is quite possible that the arrangement differs in different specimens. I found none whatever in the hinder fifth of the kidney, and by far the larger number, at least of bodies of any size, were in both my specimens in the anterior seventh, *i. e.*, just behind the lymphatic head-kidney (Pl. X. fig. 8, *h.k.*). Thus the most striking feature about their arrangement is their extreme anterior position as compared with Teleosts.

¹ Leydig describes a paired "suprarenal," but although my specimens were old, yet I am convinced that there was a single median interrenal in each case.

² [This appearance may possibly be due in part to the effect of long preservation.]

Many of the suprarenals are of exceeding minuteness, even less than 1 mm. in diameter, and these are seen in large numbers from the interior of the posterior cardinal sinus, whence they appear like "tubercles" in the wall of this vessel; indeed the appearance of these tiny bodies as seen through the lining epithelium of the vein is almost identical with the caseous nodules of pathology. In the two specimens I have examined the large suprarenals were arranged in two very irregularly symmetrical groups just behind each "head-kidney."¹ Each group consisted of about a dozen, and all of them were in close proximity to the venous sinus (Pl. X. fig. 8).

Some of the suprarenals lying on the posterior surface of the kidney were flattened, almost wafer-like.

The bodies I have seen varied in size from about 1 mm. in diameter to something under 1 cm., but measurements are difficult as their shape is often so irregular. They have a decidedly fatty appearance to the naked eye, and on being placed for a few hours in a 5 per cent. solution of osmic acid they become quite black, so that the presumption is that they contain some material of a fatty nature.

I have not been able to make out any very intimate relations between the suprarenals and the sympathetic nervous system in the Sturgeon, but I find that in many cases the bodies are placed on blood-vessels which are running in the kidney-substance.

3. TELEOSTEI.

a. PLECTOGNATHI.

In the tribe Sclerodermi I have only been able to obtain a small spirit-specimen of *Balistes maculatus*. It was not in a good state of preservation, and the results were negative.

In the Gymnodontes I have examined the Sun-fish (*Orthogoriscus mola*) as a representative of the Molidae and *Tetrogon nigropunctatus* among the Tetrodontidae. The last was an ill-preserved specimen and nothing was found. The following is the arrangement in the Sun-fish:—

MOLIDÆ.—In a specimen of *Orthogoriscus mola* (Pl. X. fig. 9, s.r.), 70 cm. in length, with kidneys of 20 cm. in length, I found one suprarenal only, which appeared to belong to the right side (Pl. X. fig. 9, s.r.). It was kidney-shaped, whitish, and fatty-looking, but of firm texture, and was about 1 cm. long by about 5 mm. broad.

b. PHYSOSTOMI.

MURÆNIDÆ.—In this family I have investigated both the Conger and the Silver Eel. There are two suprarenals in both species; these are in *Conger conger* (Pl. X. fig. 10, s.r.) triangular with rounded corners, in *Anguilla anguilla* round or oval in shape. Their position is peculiar in that they lie very anteriorly, being not far behind the point where the two crura of the kidney unite (Pl. X. fig. 10, s.r.). They are situated

¹ [In some cases they extend into the lymphatic tissue.—S. V., 10. 1. 97.]

on the ventral surface of the kidney, and are usually closely approximated to the middle line. They are only slightly imbedded in the substance of the kidney. The following may be taken as the typical arrangement in the *Muraenidæ*:—

The suprarenals are about 1·5 mm. in diameter (of course they may be much larger in *Conger*). They are triangular with rounded corners; there is one on each side of the middle line and they are nearly in contact. They are on the ventral surface of the kidney, just behind the junction of the crura, and both are on the same level. The bodies are smooth, pale pink, and only slightly imbedded in the kidney.

CLUPEIDÆ.—In *Clupea harengus* (Pl. X. fig. 11) I have found two unequal suprarenals placed on the spinal surface of the kidney at about the mid-point of its length.

ESOCIDÆ.—I have examined two examples of *Esox lucius* (Pl. XI. fig. 12). The first specimen was 50 cm. in length, the second 57, both being young specimens.

In the first (Pl. XI. fig. 12) the suprarenals were two in number, one on each side. They were imbedded in the substance of the kidney, nearer the spinal than the ventral surface, and placed distinctly in advance of the mid-point of the kidney length, so as to be about in the middle point of the length of the body. The bodies are thus even more anterior than in the eels. They were each about 3·25 mm. long by 2 mm. broad. Their surface was distinctly lobulated (Pl. XI. fig. 12, *s.r.*).

In the second their arrangement appeared at first sight to be identical with that of the first, but, on closer examination, the left was seen to be represented by two bodies, and these were placed slightly in advance of the right one. They were, like those above described, imbedded in the kidney-substance. But in this specimen there were tiny "accessory" bodies, some two or three in number, in different parts of the kidney. I have not found, however, anything approaching the condition described by Stannius, in which the posterior half of the kidney is studded with suprarenal bodies. Very possibly this appearance was pathological.

SALMONIDÆ.—In a specimen of *Salmo salar*, 83 cm. long, I found five suprarenals (Pl. XI. fig. 13, *s.r.*). There were three on the left side and two on the right. None of them were visible on the ventral surface of the kidney, as they were placed on the lateral or spinal surfaces. The bodies belonging to the right side were situated respectively 20·5 and 20 cm. from the hinder end of the kidney, being placed almost in the middle point of its length. Those of the left side were placed at unequal intervals opposite them. The right suprarenals are respectively 5 mm. and 3 mm. in diameter. The larger is anterior and slightly kidney-shaped. The largest on the left side is directly opposite the larger on the right; it is 7 mm. by 3·5 mm. and distinctly kidney-shaped. At a short distance in front of this is a body about half its size and likewise kidney-shaped. At a further interval behind it lies an elongated oval one. The suprarenals are very pale pink in colour, almost white, and have a fatty appearance. They do not project appreciably from the surface of the kidney. They are distinctly lobulated and marbled with blood-vessels.

In another Salmon, a young fish only 47 cm. in length, I found three suprarenals, placed, as in the former specimen, at about the middle point of the length of the kidney and on the spinal surface. There were two chief ones, right and left respectively, situated each about 1 mm. from the middle line, the left one being about 3 mm. by 1.5, the right about 5 by 1.5, but irregular in shape. About 1 cm. anterior to these two is another about 1 mm. by .5 mm. on the left side.

In a specimen of *Salmo trutta*, 58 cm. long, with a kidney of 26 cm., I found the suprarenals seven in number. There were six on the spinal and one on the ventral surface, all small. They were pale pink, roundish or oval bodies, and were partly imbedded in the substance of the kidney. This fact, coupled with the presence of one on the ventral surface, suggested to me that some might be completely buried in the substance of the kidney. This, however, I found not to be the case. The most anterior one was very small, and was situated 10 cm. from the anterior end of the kidney; the rest were scattered throughout the succeeding 4.25 cm. The one on the ventral surface was 12.5 cm. from the anterior extremity of the kidney. None of the bodies were more than 3 mm. in diameter.

In *Osmerus eperlanus* (Pl. XI. fig. 14) the suprarenals were represented by two miliary bodies about the size of a pin's head, projecting from the hinder end of the kidney, placed one behind the other (*s.r.*).

Among the Cyprinidæ I have examined:—

<i>Leuciscus rutilus.</i> (Pl. XI. fig. 15.)		<i>Leuciscus vulgaris.</i> (Pl. XI. fig. 17.)
„ <i>cephalus.</i> (Pl. XI. fig. 16.)		

The suprarenals are usually two; but in a specimen of *L. vulgaris* there were four (Pl. XI. fig. 17, *s.r.*). They are usually rounded in this family.

As to position, they are usually in the posterior fourth of the kidney, but they may reach as far forward as the junction of the posterior with the middle third. They are usually placed one on each side of the middle line, but are often very close to it. They are on the spinal surface or the edge of the kidney.

In the fishes of this family I have examined the bodies have never been more than about 2 mm. in diameter, and they are often buried to some extent in the kidney-substance.

c. ANACANTHINI.

GADIDÆ.—In this family I have investigated:—

<i>Gadus morrhua.</i> (Pl. XI. fig. 18.)		<i>Merluccius vulgaris.</i> (Pl. XI. fig. 20.)
„ <i>æglefinus.</i> (Pl. XI. fig. 19.)		<i>Molva vulgaris.</i> (Pl. XI. fig. 21.)
„ <i>merlangus.</i>		<i>Motella tricirrhata.</i>
„ <i>virens.</i>		

In the Gadidæ there is considerable variation in number and size of the suprarenals, although their shape is nearly always rounded.

As for number, two must be regarded as the rule, but there is even more variation

in this respect than in the Pleuronectidæ (*q. v.*). Thus, in a specimen of *Gadus morrhua* I have found as many as five; in *G. merlangus* I found only one. I have occasionally found one also in *Molva vulgaris*. In *Merluccius vulgaris* I have found in one case as many as five; in this case the suprarenal of the left side was represented by four small bodies instead of one larger one (Pl. XI. fig. 20, *s.r.*).

Their position is usually one on each side, but, as in other families, the right and left are rarely quite on the same level, one being usually anterior or posterior to the other. They also vary as to their relation to the middle line, some being more lateral, others more central.

The suprarenals in this family are almost always visible on the ventral surface of the kidney, though they may (either one or both) be lateralized, or even exceptionally may be partially on the spinal surface. They are usually more or less imbedded in the kidney-substance.

The bodies appear to be situated always in the region of the posterior third of the length of the kidney, though they sometimes approach very near the anterior limit of this distance.

The size varies from 1 mm. to 1 cm. in longest diameter in the fishes I have examined.

In one specimen of *Gadus morrhua* the arrangement was peculiar. The suprarenals were five in number. The tail of the kidney projected 3 cm. under the hæmal arch. Four of the bodies were under the arch on the ventral surface of the kidney; they were compressed into angular form owing to their position. There were two large ones, the anterior being 1 cm. by .5 cm. (irregular oblong), the posterior being rhomboidal and having about the same greatest dimensions. There were in addition two quite small bodies placed between the two larger ones. The fifth one was on the spinal surface of the kidney, just anterior to the hæmal arch. It is about 1 cm. by .5 cm., oval, and appears divided into two parts on the surface by a median longitudinal depression.

The typical arrangement of the suprarenals in the Gadidæ may be stated thus:—

The organs are rounded and about 5 mm. in diameter. There is one on each side of the middle line on the ventral surface of the kidney, but one is more lateral than the other. They are placed at about one quarter the length of the kidney from its hinder end, and one is slightly anterior to the other. They are smooth and partly imbedded in the kidney-substance, and are pale pink in colour.

PLEURONECTIDÆ.—I have been able to obtain and examine:—

<i>Pleuronectes flesus.</i> (Pl. XI. fig. 22.)	<i>Hippoglossoides limandoides.</i> (Pl. XII. fig. 26.)
„ <i>limanda.</i> (Pl. XI. fig. 23.)	<i>Solea vulgaris.</i> (Pl. XII. fig. 27.)
„ <i>platessa.</i> (Pl. XI. fig. 24.)	<i>Rhombus lævis.</i> (Pl. XII. fig. 28.)
<i>Hippoglossus vulgaris.</i> (Pl. XII. fig. 25.)	<i>Zeugopterus.</i>

In Pleuronectidæ there is considerable variation in the number, form, size, and

position of the suprarenal bodies; the variation in each of these respects affects not only the different species, but even different individuals of the same species.

With regard to their number this may be stated as usually two. Thus there are most often two in *Hippoglossus vulyaris*, *Pleuronectes fesus*, *P. limanda*, and *Solea vulgaris*. But I have found one only in some specimens of *P. limanda* and *Hippoglossoides limandoides*, while I have found three in one specimen of *P. fesus*. [In this case, however, the two of one side were close together, and were, taken together, not larger than the one of the opposite side.]

Their shape is nearly always rounded, but in *P. fesus* one was oval.

As to their position, the bodies appear to be affected to some extent by the characteristic asymmetry of the family, though sometimes they may be arranged symmetrically. There is usually one belonging to each side, but sometimes one is placed behind the other in the middle line (Pl. XII. fig. 26, *s.r.*). This was found, *e. g.*, in *P. fesus* and *Solea vulgaris*. Occasionally they are placed abreast, but both on one side of the median line; this occurred in *P. limanda*. Often the body of one side is decidedly more anterior or posterior than that of the other. Again, sometimes they are close together in the middle line (Pl. XI. fig. 24); at other times separated by the whole breadth of the kidney.

The suprarenals are always enclosed in the capsule of the kidney; but appear never to be imbedded in the kidney-substance in this family. They are always near the posterior end of the kidney, and never further forward than the junction of the posterior with the middle third of the kidney.

The size of the capsules in the Pleuronectidæ varies in specimens I have seen from .5 mm. to 1.75 cm. in diameter. They do not appear to vary very directly in proportion to the size of the individual fish, but they are larger in the larger species.

The typical arrangement of the suprarenals in the Pleuronectidæ may be described as follows:—

The organs are about .75 cm. in diameter and rounded. There is one on each side of the median line on the spinal surface of the kidney, but one is nearer to the middle line than the other. They are situated about one-quarter the length of the kidney from its posterior extremity, and one is placed rather in front of the other. They are smooth and free on the kidney-surface, and are pale pink or glistening white in aspect.

d. ACANTHOPTERI.

In the Pharyngognathi I have only been able to obtain a spirit-specimen of *Coris pulcherrima*. It was not in a good state of preservation and no suprarenals were found.

In the Acanthopterygii I have been enabled to investigate representatives of several families.

PERCIDÆ.—In two specimens of Perch (*Perca fluviatilis*, Pl. XII. fig. 29) I have found only one suprarenal body to be present in each case. In both it was about

8 mm. from the hinder end of the kidney on its spinal surface, and was about 1 mm. in diameter.

Gastrosteus spinachia was too small for anything to be seen with certainty.

In a specimen of *Labrax lupus* 70 cm. in length, with a kidney of 30 cm., I found two suprarenals placed one immediately behind the other on the spinal surface. The anterior one is 5 mm. by $2\frac{1}{2}$ mm.; the posterior one is about half the size of the anterior.

MULLIDÆ.—Two specimens of *Mullus barbatus* (Pl. XII. figs. 30 & 30 A) have been examined. In one, 24 cm. long, there were three suprarenals present; in the other, 42 cm. long, there were five.

In the first specimen these were crowded together in the middle line on the spinal surface about 3.25 cm. from the hinder end of the kidney (Pl. XII. fig. 30, *s.r.*).

In the second one (Pl. XII. fig. 30 A) there were two "chief" bodies, right and left, situated a few mm. behind the hinder end of the kidney, attached to the kidney and to the intestine and body-wall by fibrous strands. The left one has an "accessory" body just behind it, and there are two small ones on the ventral surface of the left tail of the kidney (Pl. XII. fig. 30 A, *s.r.*). The right chief body is 4 mm. by 3 in diameter, the left 3 by 2.

It is interesting to note, in relation with the abundance of suprarenal tissue, that this fish is of a red colour, and has an intensely pigmented, almost black, peritoneum.

SPARIDÆ.—In the common Sea-Bream (*Pagellus centrodonatus*) I have found two suprarenals, 2 mm. in diameter, and very pale pink in colour, situated 1 cm. from the hinder end of the kidney on its spinal surface (Pl. XII. fig. 31). In *Cantharus griseus* almost exactly the same arrangement was found.

TRIGLIDÆ.—In this family I have examined *Cottus gobio* (Pl. XII. fig. 32), *Trigla pini* (Pl. XII. fig. 33), and *T. lyra* (Pl. XII. fig. 34). The rule as to number is the same as in Teleosts generally, *i. e.*, that there are two; but in one specimen of *Trigla pini* I have found one only, in the middle line, on the spinal surface, about 8 mm. from the hinder end of the kidney.

Their shape is rounded, and their position as a rule bi-lateral; but in *Trigla lyra* I have found two, placed one behind the other, both to the left of the left edge of the kidney near its hinder extremity (Pl. XII. fig. 34, *s.r.*).

Except in this one example of *T. lyra* I have always found them on the spinal surface of the kidney in this family.

They are of a very pale pink colour, and are free on the surface of the kidney, sometimes attached to the body-wall by bands of fibrous tissue. In size they vary between 1 and 2 mm.

SCOMBRIDÆ.—In this family I have been able to examine *Scomber scomber* and *Zeus faber* (Pl. XII. figs. 35 & 36).

In the Mackerel (Pl. XII. fig. 35) I have found the suprarenal bodies on the ventral aspect of the kidney, about 4.5 cm. from its posterior extremity, almost

completely concealed, however, by kidney-substance. The body of the right side was rounded and about 2 mm. in diameter, the left was about 3 mm. by 1.5 mm. In another specimen, however, I found them placed on the *dorsal* aspect of the kidney at about the middle of its length, the right being slightly smaller than, and somewhat anterior to, the left one.

Frey says that in this fish the suprarenals are placed one behind the other. This is certainly not the rule, but it may be so in some cases.

I have examined several specimens of John Dory (Pl. XII. fig. 36). There were usually two suprarenals, one on each side of the middle line, but occasionally the body of one or other side has been represented by two smaller bodies. Sometimes they are placed side by side, sometimes one behind the other. They are always near the junction of the posterior crura of the kidney. They are mostly white or slightly iridescent and smooth, being enclosed in a firm fibrous capsule. They are rounded and situated on the spinal surface of the kidney. This is noteworthy, as I have always found them on the ventral surface in *Scomber*. Another point of distinction between the two genera is that in the John Dory they are not imbedded in the kidney-substance; they always lie within the posterior quarter of the kidney.

BLENNIDÆ.—In a specimen of *Annarhichas lupus* (Pl. XII. fig. 37), 115.5 cm. in length, I found two suprarenals, situate 5 cm. from the hinder end of the kidney. The left was on the ventral surface of the kidney, nearly round, and 5 mm. in diameter. The right was on the dorsal or spinal surface, and, being the larger, its central point was posterior to that of the left, as their anterior ends were on the same level. This right body was oval in shape and 1 cm. by .5 cm. The organs were partly imbedded in the kidney-substance.

PEDICULATI.—In the Angler (*Lophius piscatorius*, Pl. XII. fig. 38), in a fish of 54 cm. in length, I found five suprarenals. The chief pair were situated on the ventral surface of the kidney, about 1 cm. from its hinder end. The right was 3 mm. in diameter, the left 3.5 mm. They were of a pale flesh-colour and marbled with very fine blood-vessels.

In addition to these two, there was on the right side a body about 1.25 mm. in diameter, just at the hinder extremity of the kidney, where the ureter springs from its substance; again, just anterior to it is another, about one-third its size. On the left side there is also a second body, about 1.5 mm. by .75 mm., situated midway between the "chief" body and the end of the kidney.

The larger suprarenals were more or less imbedded in the substance of the kidney.

MUGILIDÆ.—In *Mugil capito* (Pl. XIII. fig. 39), 55 cm. long, I found one suprarenal capsule of large size (6 mm. by 3). It was placed about 4 mm. from the posterior extremity of the kidney, and, being imbedded in the kidney-substance, its large size enabled it to be seen either from the spinal or the ventral surface (Pl. XIII. fig. 39).

In another example, 35 cm. long, there were two suprarenal bodies, on the spinal

surface, at the extreme hinder end of the kidney. They were packed close together in the middle line, the right one being about 2.5 mm. by 2, and the left being about 2 by 1.

Here, as well as in *Mullus barbatus*, we have a proportionately large amount of suprarenal tissue associated with a deeply pigmented peritoneum.

DISCOBOLI.—I have only so far been able to examine one specimen of *Cyclopterus lumpus* (Pl. XIII. fig. 40). This fish was 46.25 cm. in length. The suprarenals were situated on the spinal surface of the kidney. The central point of the left was 3 cm. from the hinder end of the kidney, that of the right was 3.75 cm. distant. The right body was rounded and about 4.5 mm. in diameter, the left was oval (5 mm. by 2.5 mm.).

It will have been seen from the above account that in the Teleosts I find suprarenal bodies in all fresh specimens examined. There are usually paired, round or oval, pale pink bodies, placed on the spinal or ventral surface of the kidney. They are near the posterior extremity of the renal mass and are either free on its surface or more or less imbedded in its substance.

4. DIPNOI.

Nothing is known of the suprarenal capsules in this order of fishes. At any rate they are not described in *Lepidosiren* (9)¹; in *Ceratodus* (8) and in *Protopterus* their presence is exceedingly doubtful². However, what has to be said on this head will be stated below in the histological section (V.).

Having thus reviewed the gross anatomy of the suprarenal bodies in the orders I have examined, a few general remarks must be here interpolated. Being unable to obtain fresh specimens of any of the Dipnoi, I will leave this order quite out of the question². In Elasmobranchs, Ganoids, and Teleosts, suprarenals have long been described, but never very systematically or connectedly. This I have endeavoured to do as far as possible in the above account. That there was need of this is clear from the fact that some zoologists of standing still seem largely to ignore their existence. Thus Beard (2), in his very interesting paper, says:—"Not one of the least brilliant of Miháلكovics' discoveries is that of the relationship between the reproductive gland and the suprarenal bodies³. Miháلكovics showed that the non-nervous part of these organs is the most anterior portion of the reproductive gland, and that in those animals in which suprarenals occur the germinal cells which give rise to them have undergone degeneration and have got separated off from the rest of the germinal epithelium as a mass of cells remaining in a so-called embryonic state."⁴ This may be true enough,

¹ See also Ehlers, E., "Zur Kenntnis der Eingeweide von *Lepidosiren*," Vorläufige Mittheilung, Nachrichten der k. Gesellschaft der Wissenschaften zu Göttingen, Math.-physik. Klasse, 1895, Nr. 1.

² See footnote 2, page 73.

³ It is noteworthy in this relation that in the Reptilia the suprarenal body is most often in very close relationship with the reproductive gland. The same applies to birds.

⁴ [It may be observed, by the way, that the medulla is probably *not* "nervous," and that the cortex is certainly *not* "embryonic."—S. V., 10. 1. 97.]

but Beard goes on: "It is a significant fact, hitherto, I believe, unnoticed, that *suprarenals are found only in those forms in which a reduction in number of ripe sexual elements required has taken place*"¹. In regard to this I can only state that suprarenals (one or both parts) are probably universally present throughout Elasmobranchs, Ganoids, and Teleosts. Further, this writer observes: "In the present state of our knowledge of these bodies, I do not wish to lay too much stress on the point of existence or non-existence of suprarenals in any order of Vertebrates." But he adds: "If Rabl's 'tree' be correct in respect of the ancestry of Ganoids from Sharks I can conceive that *the non-existence of suprarenals in the former group*"¹ would be a fact which our author might find difficulty in accounting for—unless he ignored it entirely!"

Suprarenals non-existent in Ganoids! Either Beard has quite overlooked their presence in the Sturgeon, or he has some view of his own as to the significance of those yellow bodies which are scattered throughout the kidney. If the latter were the case one would have surely expected him, in dealing with the subject, to note the fact.

Further on in the same paper our author gives a "tree," in which it is stated that *suprarenals are totally absent not only in Ganoids and Marsipobranchs, but also in Teleosts*². It would be interesting to know what he calls those little bodies I have represented in my plates. Later on he says: "It would doubtless be interesting to find some traces of suprarenal bodies in the Dipnoi." It will be seen from what I say on this subject under the head of histology, that I am decidedly of the opinion that in all probability there are suprarenals of some sort in the Dipnoi³.

With regard to the occurrence of suprarenals in Teleosts, in addition to the species in which I have described them above, there are mentioned many other species in which other writers have found them. Thus Stannius and Ecker, also Hyrtl, state that they are present in several species I have not been able to obtain. M'Kenzie, too (15), describes them in *Amiurus catus*. So that, although of course I cannot affirm from my own observations that these bodies are universally present in this order, I should, from a joint consideration of my own and previous researches, consider this to be more than probable. *If suprarenals are not present in all Teleosts, in which species are they absent?*

V. HISTOLOGY.

1. ELASMOBRANCHII.

My results in this department appear to differ in many respects from those of Leydig, Semper, and Balfour. They agree fairly well in some respects with those of Chevrel, but there are important points of difference, and, besides, Chevrel's histological drawings are so imperfect that little can be learnt from them.

¹ The *italics* are mine.—S. V.

² This is not stated in so many words, but the "tree" has inscribed upon it, "Suprarenals totally absent on this side"; and "this side" includes the orders named above.

³ [These have since been discovered by Petitt (*loc. cit.*).—S. V., 10. 1. 97.]

PAIRED "SUPRARENAL" BODIES.—With regard to the segmentally-arranged bodies, there is not a great deal new to be said. But it is certain that in all cases the structure is very different from that which Balfour described and depicted. Chevrel explains Balfour's appearances as due to the action of reagents, and I am satisfied, from the examination of many individuals and many species with various modes of preparation, that there is never any such arrangement of a cortex of columnar and a medulla of polyhedral cells (Pl. XIII. figs. 41 & 42).

The structure of these bodies is far from easy to describe, and this I find, notwithstanding that my material was perfectly fresh and my preparations mostly very satisfactory. The organs are surrounded with a tolerably firm fibrous capsule of a thickness about 4–7 μ (Pl. XIII. fig. 41, *c.*), which sends in septa (*s.*), which in some parts are distributed almost as regularly as in a Mammalian lymphatic gland. These septa rapidly break up into an irregular fibrous meshwork which is distributed throughout the body (Pl. XIII. fig. 41, *str.*).

The parenchyma of these bodies is not arranged in any definite acini or alveoli, thus marking them off distinctly from the suprarenals in Teleosts, Ganoids, and the interrenal body in Elasmobranchs (*q. v.*) and indeed from suprarenal capsules in other Vertebrata.

There are, as a rule, no definite cell-outlines to be made out, and the main part of the parenchyma appears to consist of an irregular or wavy fibrous stroma (Pl. XIII. fig. 41, *str.*), with protoplasm (*pr.*) and scattered nuclei of round or oval shape (*n.*). The protoplasm is often granular, sometimes finely, sometimes coarsely. The nuclei are of different characters, sometimes showing nuclear figures, at other times devoid of them, sometimes large and faintly stained, sometimes small and darkly stained. They vary in diameter from 5 to 9 μ . However unsatisfactory this may seem, it is all that can be ascertained, and it is difficult to imagine how former observers such as Leydig and Balfour could have described them as having definite lobules and cell-outlines.

But there are definite cells in some parts (Pl. XIII. fig. 42, *p.c.*) quite apart from the easily recognizable nerve-ganglion cells. They have, so far as I know, not been previously described. They are mostly triangular or multipolar in shape (Pl. XIII. fig. 42, *p.c.*) and of a uniform sepia-brown tint, and they contain large, very darkly stained, round nuclei. It is difficult to state their size, as their shape is so irregular; they vary, however, in their greatest lengths from 10–30 μ ; the nucleus is usually about 6–8 μ in diameter. These cells are found particularly in the more central parts of the anterior paired bodies, but their distribution is irregular. The brown coloration of these cells is possibly due to the Müller's fluid in which the material was hardened. But, even if this be the case, the appearances indicate a difference in chemical reaction, and therefore in physiological import. These cells appear in some places to communicate together by their processes, but whether this communication is real or apparent I cannot be absolutely certain. Is it possible that these cells have anything to do with nerve-cells?

There is no essential difference in structure between the more anterior and the more posterior paired bodies. But, as Balfour has pointed out, the ganglionic development is more abundant in the case of the anterior ones. The presence of nerve-cells in the substance of the body itself is also more frequent in the case of the anterior suprarenals; in fact, nerve-cells are almost absent from the interior of the most posterior bodies, which consist entirely of suprarenal tissue proper.

The anterior pair or "axillary hearts," however, from their size and extensive nervous connections, require a separate description.

A longitudinal section of the "axillary heart" of *Scyllium canicula*, taken somewhere near its median part, shows that the body consists of an external and an internal portion. The internal part is characterized by the above-described brown pigmented cells¹. The external part on one side is composed to a great extent of large nerve-cells with nerve-fibres running longitudinally. The nerve-cells are on an average $55\ \mu$ in diameter, but some of the oval ones may have a length of more than twice this number. This formation extends for about two-thirds of the length of the gland. On the opposite side and at the ends their external part is composed of the tissue which makes up the bulk of the segmental bodies, viz. a very fine but irregular fibrous matrix enclosing protoplasm with oval nuclei without definite cell-outlines².

At about a third of the length of the gland from the anterior end, a large group of nerve-cells occupies the central part of the structure, and scattered nerve-cells are distributed in other parts of the organ.

In some instances (*e. g.* axillary hearts of *Acanthias vulgaris*) there are to be seen some very large nuclei, twice or thrice the usual dimensions, and in addition one sees nuclei of varying sizes down to the very smallest.

This is not intended to be an exhaustive account of the histology of these bodies, and with one more remark I will conclude for the present what I have to say about them. I believe that many of the fibrils in the paired suprarenals (with the exception, perhaps, of the axillary hearts), which Balfour took for nerve-fibres, are in reality nothing more than connective tissue, which, as we have seen, runs in an irregular manner throughout the parenchyma.

INTERRENAL BODY.—I may as well state at the outset that I agree with the view that this body corresponds with the cortical part of the suprarenal in Amphibians, Reptiles, Birds, and Mammals. I am further of opinion that it is essentially a secreting-gland. These conclusions have been forced upon me by its very close resemblance in structure to the cortex of the suprarenal capsules of higher Vertebrates, and by its strikingly

¹ The appearance of these pigment-cells is quite different from those which are found in various organs and tissues in fishes. There are in most cases no irregular masses or granules, but the whole cell, which has clear and definite outlines, is of a uniform brown tint. In some few cases, however, the cells appear to be of the ordinary coarsely granular type.

² Since the above was written, by careful examination of a good preparation with oblique light, I have succeeded in making out the cell-outlines in the "axillary hearts" of *Scyllium canicula*.

glandular arrangement into alveoli and its markedly granular protoplasm. The cell-outlines, too, are clearly seen in the majority of instances (Pl. XIII. fig. 43, *al.w., e.c.*). The alveoli appear to be arranged, in some parts at any rate, in a more or less radiating manner round large veins or venous sinuses (Pl. XIII. fig. 43, *v.s.*).

A very striking feature in most of my sections is the presence of structures which remind one of the "demilunes" in mammalian mucous glands (Pl. XIII. fig. 43, *d.c.*). Their presence is quite clear and unmistakable, but I cannot guess at their significance¹.

The general appearance under the microscope reminds one very forcibly of cortical suprarenal tissue in the Mammalia. The interior of the organ is made up of lobules or alveoli, each enclosed in a delicate but distinct fibrous capsule about $2\ \mu$ in thickness. These alveoli are of various sizes, more or less oblong in form, about $50\ \mu$ thick and reaching $140\text{--}150\ \mu$ in length, so far as I can judge by my sections; in many cases fibrous tissue appears to divide the individual cells one from another. The cells vary much in shape and size, the majority being elongated; some of the longest of these are $30\text{--}50\ \mu$ in length and reach quite across the thickness of an alveolus. The nuclei of the cells have an average diameter of $10\ \mu$. The above description of the interrenal is taken from a specimen of *Raja clavata*. The interrenal of *Scyllium* has much the same structure, but the alveoli are not perhaps quite so clearly marked out. This applies to the Sharks generally.

In *Chimæra* the anterior pair of the suprarenal bodies ("axillary hearts"), although long preserved in spirit, presented appearances which are worth recording. It is somewhat easier to imagine definite cells in the case of *Chimæra* than in the Elasmobranchs, for although there are no distinct cell-walls to be seen, yet the protoplasm appears to be gathered in separate portions of varying shape round the nuclei. These are of very different sizes and shapes. It is noticeable that there seems to be no ganglion of any great size in immediate connection with the body, and undoubted nerve-cells in its substance are almost totally absent.

The interrenal of *Chimæra* shows on microscopic examination a distinct alveolar arrangement as contrasted with the absence of such an arrangement in the paired suprarenals. This corresponds with what is found in the Sharks and Rays.

With regard to the true nature of these two kinds of body in Elasmobranchs, and the question as to their relations to the suprarenal bodies in the higher Vertebrates, there are one or two points to be noticed.

1. The interrenal of the Cartilaginous Fishes bears a very striking external resemblance to the structure which, in Amphibians and Reptiles, is always admitted to be a suprarenal. Its colour, its position, and its proneness to become broken up at its anterior end are all points of resemblance.

¹ The drawing (Pl. XIII. fig. 43) represents the appearances after hardening, double-staining in bulk, and saturating with paraffin. When examined fresh, the structure is largely concealed by the abundance of fatty-looking globules.

2. The interrenal, in its histological features, very closely resembles the suprarenals of Teleosts, and in some cases its structure is almost identical with that of the cortex of certain Mammalian capsules.

3. The paired bodies, as we have seen, have not such a definitely glandular appearance. They consist simply of a fibrous stroma, protoplasm, nuclei of various characters¹, and nervous elements.

Although the question is still very doubtful, and though I have not attempted any investigation of the development, I am decidedly inclined to the view that if one and not both of these bodies corresponds to the suprarenals of the higher Vertebrata, this one is the interrenal and not the paired suprarenal. And I am led to this view from consideration of its general appearance and position as well as its minute structure².

I think there can no longer be any doubt, at all events, that the paired suprarenals and the interrenals are totally distinct structures and almost certainly have quite different functions.

On the other hand, one is much more tempted to believe that the interrenal corresponds to the cortex and the paired suprarenals to the medulla of the Mammalian capsules, and this hypothesis would, so far as I can see, accord fairly well with known facts. But I should hesitate to give myself over entirely to this view until the development of the suprarenals in Mammals has been put upon a more satisfactory basis. Besides, even if this hypothesis were correct, it would not be by any means a final solution of the difficulty. For the questions naturally arise, What is the significance of this dual origin in Elasmobranchs? What is the essential nature of the interrenal and the segmental bodies? Balfour and others have proved conclusively a very intimate structural and developmental connection between the sympathetic chain and the segmental bodies. But, in effect, what does this mean? The segmental bodies are not in their essence nervous structures, and we know of nothing elsewhere which illustrates or throws any light on this curious development of glandular material in connection with the nervous system.

Again, I am not sure that the paired segmental bodies are not more intimately related to the blood-vascular than to the nervous system. We have seen that each one is placed around an arteriole, and many of them are immersed in the blood of the cardinal sinus. Further, it occurs to me that, after all, their connection with the sympathetic system may be in a certain sense accidental: *i. e.* they are abundantly supplied by the sympathetic as are other abdominal organs; but that, owing to their position, close to

¹ See footnote 2, page 66.

² Since the above was written, and as the result of further investigations throughout Vertebrates, I have elsewhere emphasized the view that the suprarenals of Mammals are to be regarded as compound glands derived from these two organs in Elasmobranch Fishes, and have suggested that each portion probably has a distinct function. The function of the medulla is becoming tolerably well understood. The function of the cortex is still unknown (Oliver and Schäfer, Proc. Physiological Society, 1895; Swale Vincent, Proc. Birm. Nat. Hist. & Phil. Soc. 1896, vol. x. pt. i.; Birm. Med. Review, Aug. 1896; also Anat. Anz. xiii. Bd. Nr. 1 & 2, 1897).

the main chain of the sympathetic, they have become connected with it in a remarkably intimate manner¹.

2. GANOIDEI.

STRUCTURE OF THE SUPRARENAL BODIES OF THE STURGEON.—I have examined some of these bodies after putting them quite fresh into 1% osmic acid for twenty-four hours, and then cutting in gum. They were stained quite black to the naked eye, and on cutting and examining microscopically their alveolar structure was obvious.

If examined immediately in Farrant's fluid, the alveoli appeared to be filled with mulberry-masses of material most probably of a fatty nature, as they had taken a deep brown stain with osmic acid, so that the cell-outlines were not to be made out.

If, however, the sections were passed through turpentine or Canada balsam, the structure was beautifully shown (Pl. XIV. fig. 44). The rounded or elongated oval alveoli (50–60 μ in diameter, or even 100 μ long by about 60 μ broad) are bounded by bold thick walls, averaging 3 μ in thickness (*al.w.*), and the cell-outlines were admirably preserved (*x*). The preponderating shape of the cells was round or oval, and in some parts they are seen to overlap, as the section was thick enough to contain several layers (*x*). In other parts the cells are more polyhedral or irregular. Like the alveoli, they vary somewhat in size; their average diameter is about 20 μ . The nuclei (*n.*) are deeply stained and somewhat irregular in shape, having a diameter of 3–6 μ . The protoplasm is very finely granular as a rule, occasionally more coarsely granular². There are small nerve-ganglia in connection with some of the bodies.

¹ As for the meaning of the two kinds of body present in the Elasmobranchs and of one only in Teleostei and Ganoids there are two alternative theories.

One is that the two kinds of structure are both represented in the higher Vertebrates, but that the paired bodies have disappeared in Teleosts.

The other view is that the paired bodies in Elasmobranchs are the remains of former more important bodies, while in higher forms they disappear altogether. In favour of this it may be urged that their nerve-supply is quite disproportionate to their size and apparent importance, and possibly represents the persistence of a nerve-supply suited to a former larger structure.

As to which of these is the correct view I cannot at present be certain, but on the whole perhaps the usual view is the most probable, viz., that in Elasmobranchs the paired suprarenals and the interrenal correspond respectively to the medulla and the cortex of Amphibians, Reptiles, Birds, and Mammals.

There is not much difficulty in recognizing that the interrenal of the Cartilaginous Fishes corresponds to the cortex of higher Vertebrates, but it is far from easy to imagine that the masses of protoplasm with scattered nuclei which constitute the paired bodies in Elasmobranchs are really homologous with the branched granular cells of the medulla of higher Vertebrates.

² When the suprarenals of the Sturgeon are hardened, double-stained in bulk, and cut in paraffin, they do not show nearly such a distinct alveolar arrangement as do those treated fresh with osmic acid. The larger oval nuclei show a very distinct nuclear network and a large darkly-stained nucleolus centrally placed. In other cases only dark nuclear granules of various sizes are to be made out. The cells appear for the most part made up of a variable number (5–6) of vesicles, from which evidently the fat has been dissolved by this mode of preparation. The cells of the body have shrunk to some extent, so as to leave spaces of variable extent between them.

I have no doubt, from the above structure, that these bodies are representatives of the suprarenals in Ganoids, and in my opinion they correspond to the cortical portion in higher Vertebrates.

3. TELEOSTEI.

The minute structure of the suprarenal bodies does not exhibit any wide variation throughout the different families of Teleosts. Between the individual members of the families the differences are of course still less. There are, however, such differences, and these appear to consist chiefly of variation in amount of fibrous tissue, variation in blood-vascular supply, and in the shape of the alveolar compartments into which they are all divided.

The organs are surrounded by a capsule of very varying thickness (in the species I examined from 4 to 70 μ), in close connection with which are sometimes found sympathetic nerve-fibres and small ganglia, and blood-vessels. Outside the capsule there is usually more or less adenoid tissue. In the majority of instances this is nothing more than a local increase, in the neighbourhood of the suprarenals, of the ordinary renal inter-tubular adenoid tissue.

The capsule is always thicker throughout the area which is in contact with the kidney. This is probably to be explained by the fact that we have a double layer, consisting of the capsule of the suprarenal and the capsule of the kidney, fused together at this part. There is never any direct anatomical connection between the parenchyma of the suprarenals and kidneys, and, so far as I have been able to discern, nothing to suggest that the suprarenals are parts of the kidney.

The fibrous capsule sends in trabeculæ, which divide and subdivide at first in a rather irregular manner; but ultimately they form in all cases very regular alveoli, having about the same average dimensions as those of the interrenal of the Elasmobranchs (*q. v.*), *strikingly suggestive of those of secreting-glands*, and these alveoli are, as a rule, completely filled with the suprarenal cells, which are much smaller than those of the interrenal of Elasmobranchs. But in some species (*Conger conger*, *Anguilla anguilla*, and *Salmo trutta*) there is a more or less empty space in the centre of each alveolus (Pl. XIV. figs. 45 & 46, *c.sp.*). These spaces are, however, never complete; one finds scattered cells, nuclei, and shreds of protoplasm, which suggest that this space does not exist in life. Most probably the central cells of each alveolus are more loosely connected together than the rest, or possibly they suffer a very rapid *post-mortem* change¹. In by far the majority of Teleosts a very regular row of nuclei can be traced round the circumference of each alveolus, and in many cases their cell-

¹ [Pettit (*loc. cit.*) has laid great stress on this peculiar structure of the alveoli in the Eel, looking upon it as the fundamental type of a suprarenal gland. He finds a true physiological compensatory hypertrophy of one gland after removal of the other, and urges that the body is a true secreting-gland. But he seems to be totally unaware that the known suprarenals of the Eel and other Teleosts correspond to the cortex only of the Mammalian gland, and that all we know about the function of the suprarenals so far is confined to the medulla.—S. V., 10. 1. 97.]

outlines can also be perceived. In some cases, as in the Trout, the alveoli are very distinctly marked, and have every appearance of being not closed vesicles, but in communication one with another.

The essential suprarenal cells I find to be of two kinds. The first are irregular branched cells, most often tending towards a spindle-shape, about 7μ – 8μ in length, with very large prominent nuclei (Pl. XIV. figs. 48 & 49). These nuclei are often as large in diameter as the widest part of the cell (*i. e.*, about 3.5μ) (Pl. XIV. fig. 48), and appear to bulge it out at that point. In the nucleus can be seen a number of small dark nucleoli, and often a distinct nuclear network. The protoplasm of these cells is distinctly granular.

The second kind of cell is usually irregularly triangular, having generally a greatest length of about 6.5 or 7μ , with a small dark nucleus not more than 2.5μ in diameter (Pl. XIV. fig. 49).

These two kinds of cells are readily distinguished, and both are usually present in any given specimen, but in very varying proportions.

I have doubted whether these appearances might be simply due to treatment or to accidental modes of staining, but I believe they depend in some way on the functional activity (for the suprarenals are *not* mere embryonic remains), stage of development, or the age of the fish, as their relative occurrence is found to differ very widely even among closely allied species. Thus in *Gadus aeglefinus* I found nearly all the cells had large round clear nuclei and nuclear figures, while in *Merluccius vulgaris* the cells appeared almost all to have small dark nuclei¹. This point I hope to have the opportunity of investigating by taking series of specimens of different ages, and after different modes of feeding, starvation, poisoning, &c. At present I must leave their true nature quite an open question.

*There is no distinction to be made out between cortex and medulla in this order of fishes, or, rather (as appears probable by comparison with other groups of Vertebrates), the suprarenal consists entirely of cortex*².

I have made careful preparations of the suprarenals of all the species whose gross anatomy is given above, but, as I have said, these do not offer any great variety among themselves. It may, however, be useful to indicate briefly the kind of variation one finds in the different families by a few illustrative extracts from my laboratory notebook. Perhaps one of the most characteristic appearances is found in the Murænidæ. In this family (Pl. XIV. figs. 45 & 46) the alveoli are rounded, and contain cells polyhedral or angular in shape. These are arranged for the most part in a single tier around the circumference of each alveolus, leaving an irregularly-shaped cavity in the

¹ I have even found that in one specimen of *Mullus barbatus* there was a vast majority of one kind of cell, and in another specimen of the same fish a corresponding preponderance of the other kind.

² [Diamare (*loc. cit.*) has arrived at the same conclusions as myself as regards the homology of the interrenal body in Elasmobranchs with the suprarenal bodies of Teleostei. It follows that *the representative of the suprarenal medulla is absent in Teleostean fishes.*—S. V., 10. 1. 97.]

centre (Pl. XIV. fig. 46, *c.sp.*). This appearance is described above, and some explanation of it has been offered. The alveolar walls are permeated by capillary blood-vessels (Pl. XIV. fig. 46, *cap.*).

In the Pleuronectidæ the appearance under a low power is very like that of a lymphatic gland, but under a high power an alveolar arrangement can always be seen, and the nuclei are seen to belong to more or less closely-packed cells of the two varieties described above. In *Pleuronectes limanda* distinct acini are often seen almost like those of the mammalian pancreas, filled with cells of spindle-shape, with large round nuclei and very distinct nuclear figures. There is a tendency towards a clear space in the central part of each. In *Rhombus lavis* the acini are quite filled with cells, which are more rounded than in other members of this family, and there is generally more cell-protoplasm.

In the Gadidæ the individual members do not differ very widely from each other. In *Gadus morrhua* the cells are pear-shaped, oval, rounded or irregular, and in the specimens I have examined nearly all have large round figured nuclei. In *Gadus æglefinus* the appearance is peculiar: the acini appear to be occupied by scarcely anything more than free nuclei with nuclear figures, the cell-protoplasm being scanty and irregularly branched. *Molva vulgaris* shows the acinar arrangement very well, with a very regular ring of nuclei round the outside of each alveolus.

Pl. XIV. fig. 47 represents the appearances in the suprarenal of the Wolf-fish (*Anarrhichas lupus*). The alveoli are elongated, and there is an incomplete central space (Pl. XIV. fig. 47, *c.sp.*). Thus it is possible to consider that there are two chief types in the alveolar arrangements of teleostean suprarenals: one, as in the Murænidæ, is not unremindful of the testis in some animals (*cf.* Miháلكovics, 14), while the other is more suggestive of the mammalian pancreas.

The suprarenals of the Sunfish (*Orthogoriscus mola*) have a very peculiar structure, in that the acini are very long and tubular.

4. DIPNOI.

In *Protopterus annectens*, Parker (17) describes "around the kidney, but more particularly along its dorsal and outer sides, masses of brown cells, which in appearance remind one of the adrenal bodies of Amphibia," and he suggests the enquiry "whether they or the lymphoid cells which give rise to them have anything to do with the adrenals."

I have examined this point with some care, and I have been able to verify in every detail Parker's account of this lymphoid tissue, both round the kidneys and along the alimentary canal, and forming the substance of the spleen. This I was enabled to do by means of two specimens of *Protopterus* which Prof. Parker was kind enough to send me.

By the kindness of Prof. Bridge, I have also been able to examine the kidneys and

surrounding tissue of *Lepidosiren*. The specimen was a long-preserved one, and I could make out nothing with the naked eye. On cutting sections, however, the same pigment-patches were obvious in the perirenal tissue as in *Protopterus*; if anything, these were more abundant in *Lepidosiren*. Here, too, the resemblance to suprarenals was greater than in *Protopterus*, for I found not only small patches or individual pigment-cells, but large rounded accumulations, which represent not continuous columns, but spherical masses, thus approximating anatomically to adrenals.

This tissue is of such great interest from many standpoints that I hope before long to be able to give a fuller description of it in another place. I am persuaded that it is really a "large-celled adenoid tissue," and some of the chief varieties of leucocytes can be recognized in some of my sections. But the appearance in places is so very glandular that Prof. Schäfer, who has been kind enough to look at some of my slides, said he should be very much inclined to think it might be suprarenal tissue, if a material so very like it were not found in other places. In fact, the intestinal walls show abundance of the same structure, and the spleen is very little different¹.

I have carefully compared both these with the pigment-patches in other parts, and find that they are quite comparable to these, so that, on the whole, I am inclined to the view that they have nothing to do with the adrenals.

Nevertheless, from *à priori* considerations, I believe that adrenals of some sort are almost certainly present in the Dipnoi. These fishes closely approach the Amphibians in many respects, and I am persuaded that could one obtain perfectly fresh specimens of large size, suprarenals of a type resembling that of the Amphibians would be found².

My investigations upon the structure of the suprarenal capsules in Fishes all point to their being *blood-vascular secreting-glands* of two distinct kinds, and this coincides entirely with the most recent views as to the function of the Mammalian organs.

VI. THE RELATION OF THE SUPRARENAL BODIES TO THE HEAD-KIDNEY.

1. *Historical.*

Balfour (23 and 24) first clearly made out that in *Acipenser* and *Lepidosteus* the anterior dilatations of each kidney consist not of kidney-substance, but of lymphatic tissue. He says, "*Thus the whole of that part of the apparent kidney in front of the*

¹ But, after all, it may be that there is no "great gulf" fixed between the leucocytes of adenoid tissue and the cells of a secreting-gland. I have recently seen a preparation from a case of Paget's disease of the nipple in the human subject which appeared to show a transition between the epithelial cells of the ducts and ordinary leucocytes. See also Beard (*Anat. Anz.* ix. Band, Nr. 15, p. 481, and his references to Kölliker and A. Prenant).

² [Since the above has been in type, Pettitt (*loc. cit.* pp. 67-68) has claimed to have found the suprarenals in *Protopterus*. He says that in general form and relations they resemble those of the Teleostei, while in minute anatomy they are rather like those of Batrachians. But he gives no histological details, and says nothing about cortex and medulla.—S. V., 10. 1. 97.]

wreter, including the whole of the so-called head-kidney, is simply a great mass of lymphatic tissue, and does not contain a single uriniferous tubule or Malpighian body." He next proceeded to examine *Esox lucius*, *Osmerus eperlanus*, *Anguilla anguilla*, and *Lophius piscatorius* among Teleosts, and found pretty much the same condition as in Ganoids. He does not speak very positively about the Angler, but believes that tubules were present in all parts of the kidney. He sums up "that the pronephros, though found in the larvæ or embryos of almost all the Ichthyopsida, except the *Elasmobranchii*, is always a purely larval organ, which never constitutes an active part of the excretory system in the adult state." Balfour describes the lymphatic tissue of the so-called head-kidney as formed of trabecular work and cells resembling a lymphatic gland. This tissue is very vascular, with a regular plexus of very large capillaries, which appear to have distinct walls, and which pour their blood into the posterior cardinal vein as it passes through the organ. With regard to the function of this tissue Balfour suggests that this is either the formation of lymph-corpuses or of blood-corpuses, and he was inclined provisionally to regard it as a lymphatic gland.

Parker (Brit. Assoc. Reports, 1882) stated that in many instances the mesonephros has grown forward in front of the air-bladder, and taken the place of the pronephros.

In studying *Dactylopterus volitans*, Calderwood (25) found the pronephros entirely separated from the body-kidney, and situated anterior to the abdominal cavity in the same transverse plane as the heart. On section this head-kidney appeared to be a functional kidney, only it did not contain so many tubules as the body-kidney. In *Cyclopterus lumpus* he finds that not till the fish has become sexually mature does its head-kidney commence to degenerate. Calderwood concludes that in adult Teleosts the renal function is performed in some instances by the body-kidney only, in others by the head-kidney only, and in others, probably a very limited number, by both the body- and head-kidneys. Besides *Dactylopterus* he is aware of only one instance where the head-kidney is described as possessing tubules and Malpighian bodies, viz. *Fierasfer* (Emery 26 and 27)¹.

Weldon (35 and 36), in a paper on the head-kidney of *Bdellostoma*, describes a lobulated glandular body lying in front of the secreting part of the kidney, which he suggests is "a part of the embryonic kidney, modified in connection with the needs of the animal to perform some unknown function in the elaboration or purification of the blood." Then he instances Balfour's description of the lymphatic head-kidney in Teleosts and Ganoids as being a further illustration of a modification of a part of the embryonic kidney into an organ like a lymphatic gland. Next he suggests that in higher Vertebrates the suprarenal capsules are similarly modified portions of the primitive kidney. He continues, "*In Teleostei suprarenals are, at all events, frequently absent*²; or, as I would suggest, they are represented by the greatly-metamorphosed

¹ In a later paper (Scientif. Trans. Roy. Dublin Society, vol. v. (ser. ii.) ix. 1895, Survey of Fishing-grounds, &c.) Holt and Calderwood add to this list *Mora mediterranea* and all the species of *Macruridæ*.

² The italics are mine.—S. V.

head-kidney described by Balfour. In other cases *where suprarenals have been detected*¹, they have always been attached to the surface of the kidney." Later on he talks about "*the very general absence of suprarenals as separate structures in Teleosteans*"¹, as if their lying upon the surface of the kidney abolished them as "separate structures"! More recently, Miss Kirkaldy (33) has expressed much the same views as Weldon. She remarks, "It may therefore be concluded that the pronephros in *Myxine* represents the mesoblastic part of the suprarenal bodies, which have been shown by Prof. Weldon to be derived from the anterior part of the mesonephros in the higher Vertebrata."

I have already shown conclusively that suprarenals are not frequently absent, but are probably always present. It only remains to deal with their supposed relation to the head-kidney. Weldon's teaching seems to have found pretty general acceptance. Thus Auld² says, referring to the lymphatic tissue of the head-kidney, "Now *in Teleosteans and Teleosteid Ganoids which possess this tissue no suprarenal organs are found*¹, and hence it is to be concluded with Balfour (!) that they are represented by this tissue." Balfour, at any rate in the paper quoted, says nothing of the kind; but the comparative portion of Auld's paper is of no importance, except as illustrating the injurious influence of Weldon's inaccuracy.

It will have been noticed that although many writers have declared suprarenals to be often absent in Teleosts, none of them have stated definitely in what species we may look for them in vain. The above quotations imply a very general belief something to this effect: that suprarenal bodies are rare phenomena in Teleosts and Ganoids, and that when present there is no lymphatic head-kidney, while when they are absent their place is taken by this structure.

The following quotation from Wiedersheim (*Lehrbuch der vergl. Anat. der Wirbelthiere*, 2^{te} Aufl., Jena, 1886) shows the need for clearing up this point:—

"Bei Teleostiern sind die Nebennieren nicht überall in klarer und überzeugender Weise nachgewiesen, wo dies aber der Fall ist, handelt es sich, wie früher schon angedeutet wurde, um Beziehungen zu der in lymphoides (adenoides) Gewebe umgewandelten Kopfniere. (Dies gilt nach W. Weldon auch für die *Cyclostomen* [*Bdellostoma Forsteri*].) In andern Fällen, aber, sind sie enge mit der Niere verbunden."

The plain facts of the case are quite the contrary, and are these:—

*Suprarenal capsules are present in certainly the majority of Teleosts and Ganoids, and I believe in all. Further, as far as I know at present, the purely lymphatic head-kidney is present in all Ganoids and in all Teleosts except Lophius, Dactylopterus, Fierasfer, and, as will be stated below, Orthagoriscus mola*³.

¹ The *italics* are mine.—S. V.

² Brit. Med. Journ., Oct. 6th, 1894.

³ And, according to Holt and Calderwood, in *Mora mediterranea* and the *Macruridæ*.

2. *The Nature of the Intertubular Material in the Kidneys.*

The lymphatic head-kidney is not in any true sense a very specialized portion of the kidney. By "lymphoid" tissue we mean a variety of retiform connective tissue, in which the meshes of the network are filled up to a large extent with lymph-corpuscles. These differ from the white corpuscles of the blood in that their nuclei show a network. Some are as large as white blood-corpuscles, others (the majority) have a minimum of protoplasm, and appear as almost free nuclei. This structure is found typically in a mammalian lymphatic gland.

Now, on examining the kidney of any fish, the tubules appear to be separated by a variable, often a large, amount of intertubular material, which presents all the features given above characteristic of lymphatic or adenoid tissue. This appearance presents a marked contrast to the compact mass of tubules and Malpighian bodies one sees in a mammalian kidney. The kidney of the frog appears to be intermediate between the mammalian and fish's kidney, in respect of the amount of this intertubular adenoid tissue.

This tissue varies in amount in different regions of the kidney, but on the whole forms a fairly even bed for the tubules. In Teleosts, as one approaches nearer and nearer to the anterior end of the organ, the amount of adenoid tissue becomes greater and greater until in most cases the extreme anterior extremity of the apparent kidney consists entirely of adenoid tissue.

3. *Histology of the Head-Kidney.*

STRUCTURE OF THE HEAD-KIDNEY OF THE LING (*Molva vulgaris*).—The tissue was hardened in spirit, stained in bulk with hæmatoxylin and eosin, and imbedded in paraffin; sections were then cut with the rocking microtome.

On examination with a low power, the organ is seen to be obviously a lymphoid structure. Not a trace of kidney-tubules or Malpighian bodies is to be found in any part of the section. The organ is enclosed in a very definite fibrous capsule. There are large blood-vessels¹ in abundance full of red blood-corpuscles.

With a high power the substance of the head-kidney is seen to be made up of a delicate reticulum enclosing in its meshes closely-packed leucocytes *with many red cells apparently free in the reticular spaces*, as well as in the large capillaries. In addition, there are many hexagonal crystals of a red colour, most probably oxy-hæmoglobin², and masses of dark pigment-crystals of acicular form, evidently some derivative of hæmoglobin.

I have found practically the same structure in the head-kidneys of the Pleuronectidæ, Gadidæ, and in fact in all Teleosts I have examined. I have only found this lymphatic

¹ And, in some cases, blood-sinuses (*vide infra*).

² The crystals of oxy-hæmoglobin obtained from the blood of the Squirrel and Hamster (Halliburton) are described as of this shape, also those from the Mouse (Bojanowski) and Horse (Hüfner and Bücheler). It is tolerably certain that these crystals are of the same character.

head-kidney absent in *Lophius piscatorius* and *Orthogoriscus mola*. Other authors have added some few more species, see above, also summary below. A few detailed illustrations will suffice.

Cyclopterus lumpus.—I have particularly examined the kidney of this species. It will be seen (Pl. XIII. fig. 40) that it has a peculiar shape.

At its anterior extremity are two dark red spherical masses of tissue, only attached to the rest of the kidney by connective tissue. On microscopical examination these are found to consist of an extremely vascular lymphoid tissue, with no trace of urinary tubules or Malpighian bodies¹.

The divided portion of the kidney on each side is represented by two very thick masses nearly half the total length of the kidney (fig. 40).

I find that almost the anterior third of this part, as well as the dark red bodies in front, is composed entirely of lymphoid tissue. As one approaches the junction of the anterior and middle thirds of this part of the kidney, one or two tubules make their appearance in the central portion of the section. In the middle third tubules are more frequent, while in the posterior third the appearance is almost that of "body-kidney" generally.

So that we have in *Cyclopterus* a well-developed lymphoid head-kidney, with an anterior part completely constricted off. This constriction may possibly throw some light upon other masses of lymphoid tissue which one finds in the neighbourhood of the kidney in Elasmobranchs as well as in Teleosts.

With regard to *Lophius piscatorius*, which was supposed by Hyrtl to have only a head-kidney, I find with Balfour tubules and Malpighian bodies in all parts of the kidney-mass except the extreme anterior end, where Malpighian bodies are absent. Here, too, there is more adenoid tissue than elsewhere, and it appears more probable that the whole kidney is contracted longitudinally, and that the lymphoid remains of the pronephros have been encroached upon by the mesonephros than that the whole of the ordinary excretory organ has been lost, and the pronephros has remained as the functional kidney.

In *Anguilla anguilla* I found in a specimen 68 cm. long, with a total length of kidney of 25 cm., that exactly the anterior three-quarters of the ununited portion of kidney on each side was entirely lymphoid, *i. e.*, half the total length of the kidney. At the mid-point of the kidney-length tubules begin to appear and rapidly increase in number till the normal secreting structure is reached.

In the *Sturgeon* the whole of the part *h.k.* (Pl. X. fig. 8) as far as the dotted line is purely lymphoid. There is also a small area of lymphatic tissue at the extreme hinder end of the kidney.

In the *Sunfish* all parts of the kidney contain urinary tubules, even the extreme

¹ [This structure corresponds to that of a "hæmo-lymph gland" (see Vincent and Harrison, Journ. of Anat. and Phys., Jan. 1897).—S. V., 10. 1. 97.]

anterior end which reaches far into the head. So that this species must be added to the list of those which have no purely lymphatic head-kidney.

4. *Function of the Lymphatic Head-Kidney.*

I am convinced that the appearances above described (blood-corpuscles free in the tissue spaces, crystals of oxy-hæmoglobin and other derivatives of hæmoglobin) point to a blood-destroying function of the lymphoid anterior end of the kidney, and very possibly also of the rest of the intertubular material, and this appears not unreasonable since lymphatic glands in Man can probably carry on this function. They appear to do so, at all events after removal of the spleen, and it is not conceivable that an organ should be able to take on in an emergency duties which it had never performed to the slightest extent previously¹.

5. *Relation of the Suprarenals to the Head-Kidney.*

I have already sufficiently disproved the idea that where one of these is present the other is absent. I have further, by careful measurements, attempted to make out if there were any inverse ratio between them as to respective bulk, but in this I have failed entirely. So that I am forced to conclude that there is no anatomical relationship whatever between them.

Physiologically one cannot be so certain, but it seems very likely that the head-kidney functionates as a lymphatic gland, while the suprarenals, in all probability, are secreting-glands, which minister to the needs of the blood, just as in the higher Vertebrates. Functional relationship is, then, equally improbable.

Groslik (29) considers that the head-kidney of adult Teleosts consists of two parts, the degenerated pronephros and the cortical part of the suprarenals, and that the known suprarenals of Teleosts correspond to the medullary substance in the Amniota².

It is certainly curious that we find the lymphatic head-kidney just in those cases where only one portion of the suprarenal appears to be represented. But, in my opinion, the part which is not represented in Teleosts and Ganoids is the *medulla* and not the cortex, so that, if the head-kidney has anything to do with the suprarenals at all, I should expect that it would represent the medulla. But, satisfactory as such a conclusion would be, I cannot find any grounds for it whatever. *There is nothing in the structure of the degenerated pronephros which suggests any connection with supra renal structure of either kind.*

The question as to the physiological correspondence of the suprarenal in Fishes to the organs in higher Vertebrates, I hope to have the opportunity of settling at an early date by means of direct experiment².

¹ [It has been mentioned above that Balfour considered the function to be that of formation of red corpuscles. This view has also been held by Emery (26), and Bizzozero and Torre, Mem. Accad. Lincei Roma, vol. xviii. 1883-84.—S. V., 10. 1. 97.]

² An t. Anz. xiii. Bd. Nr. 1 & 2 (1897).

VII. SUMMARY AND CONCLUSIONS.

A. *Gross Anatomy.*

My investigations in this department have led me to conclude that:—

1. *Suprarenals are almost certainly present in all Elasmobranchii, Holocephala, Ganoidei, and Teleostei, and very probably in Dipnoi also*¹.
2. In Elasmobranchs *the interrenal body is totally distinct and separate from the segmental bodies, and there is no kind of connection between them.*
3. *There is no "third kind of body" in relation to the kidneys, as Balfour surmised there might be.*
4. *The yellow bodies scattered in the Sturgeon's kidney are the true suprarenals in Ganoids, and correspond to the interrenal of Elasmobranchs and the suprarenals of Teleosts.*

B. *Histology.*

The following points in histology are either new or have not been sufficiently emphasized by previous observers:—

1. In Elasmobranchs *the interrenal body consists of definite alveoli, containing cells with large nuclei, and curious structures resembling "demilune" cells of mucus-glands.* This structure indicates its "*secretory*" nature and its analogy to the suprarenals of Teleosts and the cortical part of the suprarenals of the higher Vertebrates.
2. *The segmentally arranged bodies in Elasmobranchs have no cortex and medulla, no definite alveoli, and cell-outlines seen only with difficulty.* There are, however, in some places *branched pigment-cells* which appear to communicate together by their processes. The nuclei are of very varying size.
3. *These segmental bodies, having such a different structure from the interrenal, are probably different also both morphologically and physiologically*².
4. *That the fibrils which Balfour observed in the substance of the paired bodies were probably many of them only connective tissue, that the significance of the relations of the paired suprarenals to the sympathetic has been much overstated, and that their relation to the vascular system is probably much more important.*
5. *The suprarenals in the Sturgeon have a structure which is definitely alveolar and cellular—analogueous to the interrenal of Elasmobranchs and the suprarenals of Teleosts.*
6. *The interrenal of Elasmobranchs and the suprarenals of Ganoids and Teleosts are in their essence "secreting-glands," as the Mammalian organ is now believed to be.*
7. *The segmental suprarenals of Elasmobranchs are also secreting-glands, though probably of a different nature*².

C. *Head-Kidney.*

1. That *all Teleosts and Ganoids, as far as is known at present (except Lophius, Dactylopterus, and Fierasfer, Orthogoriscus mola, Mora mediterranea, and all the species of Macruridæ), have a "lymphatic head-kidney."*

¹ See footnote 2, page 73.

² See Anat. Anz. xiii. Bd. Nr. 1 & 2 (1897).

2. That *this head-kidney is a lymphoid organ with a probable blood-destroying function.*

3. That *the kidney of fishes consists of two totally distinct parts—(1) The secreting-tubules and Malpighian bodies, and (2) an adenoid intertubular material.*

4. That *the head-kidney in adult Teleosts is not a "specialised" portion of the primitive kidney, but simply an increase, at the anterior end, of the lymphatic tissue which exists between the tubules throughout the kidney.*

5. That *there is no anatomical or physiological relationship of any kind between the suprarenals and the head-kidney.*

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EXPLANATION OF THE PLATES.

Reference-letters to figs. 1-40 (Plates IX.-XIII.).

a.a., axillary artery; *a.i.r.*, anterior broken-off portions of the interrenal body; *ao.*, aorta; *ax.h.*, anterior pair of suprarenal bodies; *f.t.*, bands of fibrous tissue; *h.a.*, anterior limit of hæmal arch; *h.k.*, head-kidney; *i.a.*, intercostal arteries; *i.r.*, interrenal body; *k.*, kidney; *l.k.*, lobe of kidney-substance; *n.*, nerves running through deep fissures in head-kidney; *æ.*, œsophagus cut across; *s.r.*, suprarenal bodies; *sy.*, main chain of the sympathetic; *sy.g.*, sympathetic ganglion; *sy.pl.*, sympathetic plexus; *ur.*, ureter.

Figs. 1-40 represent the outlines of the kidneys in the several species examined, with the suprarenals and interrenals shaded in. In the Teleosts (figs. 9-40) the suprarenals when on the ventral surface are drawn in plain lines, when on the spinal surface in dotted lines.

PLATE IX.

- Fig. 1. Ventral view of the kidney, suprarenals, and interrenal of *Chimæra monstrosa*, showing the smooth, oval, anterior pair of suprarenal bodies. $\times 1$.
- Fig. 2. Dissection of *Scyllium canicula* (young female specimen) giving a ventral view of suprarenals and interrenal. The parovarium has been dissected away. This drawing may be taken as a typical representation of these bodies in Elasmobranchs. The connections with the sympathetic are indicated to some extent in the anterior part of the figure. The suprarenals were displayed by Semper's chromic acid method. $\times \frac{1}{2}$.
- Fig. 2 A. From the same preparation as the last. First three suprarenals of each side. $\times 2$.
- Fig. 3. Suprarenals of *Scyllium canicula* brought out by Chevrel's osmic acid method. Their irregular outline is well shown, and many of the sympathetic fibrils are stained black. $\times 1$.
- Fig. 4. Ventral view of kidneys, suprarenals, and interrenal of *Scyllium catulus*. This drawing shows fairly well the relations to the sympathetic. There is a large plexus anterior to and outside the axillary hearts, with occasional ganglia. $\times \frac{1}{2}$.

PLATE X.

- Fig. 5. Suprarenals, &c., of *Acanthias vulgaris*, shows sympathetic relations in anterior part. The interrenal is not quite in the middle line, but is laid on the surface of the left kidney. $\times 1$.
- Fig. 6. Ventral view of kidneys, &c., of *Raja batis*. This drawing represents a not unusual condition in the Rays, in which there is a bridge-like communication between the interrenals of the two sides. The sympathetic is shown to some extent about the middle of the left kidney. $\times 1$.
- Fig. 7. Same view in *Raja maculata*. The anterior separated portions of the interrenals show processes or claws on their outer sides. $\times 1$.
- Fig. 8. Ventral view of kidney and suprarenals of *Acipenser sturio*. Part of the kidney-substance has been dissected away so as to display the suprarenal bodies distributed throughout the organ. $\times \frac{1}{10}$.
- Fig. 9. Ventral view of kidneys and suprarenal of *Orthogoriscus mola*. The kidneys are a very peculiar shape. There is one suprarenal attached by fibrous bands behind the right kidney. $\times \frac{1}{4}$.
- Fig. 10. Kidney and suprarenals of *Conger conger*, suprarenals on ventral surface of kidney. $\times \frac{1}{2}$.
- Fig. 11. *Clupea harengus*, suprarenals on spinal surface of kidney. $\times 1$.

PLATE XI.

- Fig. 12. *Esox lucius*. Suprarenals in kidney-substance. $\times \frac{1}{2}$.
 Fig. 13. *Salmo salar*. Five suprarenals on spinal surface of kidney. $\times \frac{1}{4}$.
 Fig. 14. *Osmerus eperlanus*. Suprarenals projecting behind hinder end of kidney. $\times 1$.
 Fig. 15. *Leuciscus rutilus*. Suprarenals on ventral surface. $\times 1$.
 Fig. 16. *Leuciscus cephalus*. Suprarenals on ventral surface. $\times 1$.
 Fig. 17. *Leuciscus vulgaris*. Suprarenals on spinal surface. $\times 1$.
 Fig. 18. *Gadus morrhua*. Suprarenals on ventral surface. $\times \frac{1}{3}$.
 Fig. 19. *Gadus aeglefinus*. Suprarenals on ventral surface. $\times 1$.
 Fig. 20. *Merluccius vulgaris*. Suprarenals on ventral surface. $\times \frac{1}{2}$.
 Fig. 21. *Molva vulgaris*. Suprarenals on ventral surface. $\times \frac{1}{2}$.
 Fig. 22. *Pleuronectes flesus*. Suprarenals on ventral surface. $\times 1$.
 Fig. 23. *Pleuronectes limanda*. Suprarenals on spinal surface. $\times 1$.
 Fig. 24. *Pleuronectes platessa*. Suprarenals on spinal surface. $\times 1$.

PLATE XII.

- Fig. 25. *Hippoglossus vulgaris*. Suprarenals on spinal surface. $\times \frac{1}{3}$.
 Fig. 26. *Hippoglossoides limandoides*. Suprarenals projecting from hinder end of kidney. $\times 1$.
 Fig. 27. *Solea vulgaris*. Suprarenals on spinal surface. $\times 1$.
 Fig. 28. *Rhombus laevis*. Suprarenals on spinal surface. $\times 1$.
 Fig. 29. *Perca fluviatilis*. One suprarenal on spinal surface. $\times 1$.
 Fig. 30. *Mullus barbatus*. Suprarenals on spinal surface. $\times 1$.
 Fig. 30 A. Another specimen, showing hinder end of kidney and five suprarenals. $\times 1$.
 Fig. 31. *Pagellus centrodontus*. Suprarenals on spinal surface. $\times 1$.
 Fig. 32. *Cottus gobio*. Suprarenals on spinal surface. $\times 1$.
 Fig. 33. *Trigla pini*. One suprarenal on spinal surface. $\times 1$.
 Fig. 34. *Trigla lyra*. Two suprarenals off left side of tail of kidney, attached by bands of fibrous tissue. $\times 1$.
 Fig. 35. *Scomber scomber*. Suprarenals on the ventral surface of the kidney. $\times \frac{1}{2}$.
 Fig. 36. *Zeus faber*. Suprarenals on spinal surface of the kidney. $\times 1$.
 Fig. 37. *Anarrhichas lupus*. Left suprarenal on ventral surface of kidney, right one on spinal surface. $\times \frac{1}{4}$.
 Fig. 38. *Lophius piscatorius*. Five suprarenals on ventral surface of the kidneys. Notice peculiar shape of the kidney-masses. $\times 1$.

PLATE XIII.

- Fig. 39. *Mugil capito*. One large suprarenal in substance of tail of kidney; could be seen from either surface. $\times \frac{1}{2}$.
 Fig. 40. *Cyclopterus lumpus*. Suprarenals on spinal surface of kidney. $\times \frac{1}{2}$

Reference-letters to figs. 41-49 (Plates XIII., XIV.).

ad., adenoid tissue of kidney between the tubules; *al.w.*, walls of alveoli; *bl.d.c.*, blood-corpuscles; *c.*, capsule; *cap.*, capillary blood-vessels; *c.sp.*, central space in alveoli; *d.c.*, cells resembling "demilune" cells; *e.c.*, elongated cells; *n.*, nuclei; *n.c.*, nerve-cell; *n.net.*, nuclear network; *nl.*, nucleoli; *p.c.*, branched pigment-cells; *pr.*, granular protoplasm; *s.*, septa; *str.*, fibrous stroma; *t.*, tubules of kidney; *v.s.*, venous sinuses; *x*, cells seen to be overlapping.

- Fig. 41. Section of a suprarenal body of *Acanthias vulgaris*, showing the capsule, trabeculæ, stroma, protoplasm, and various-sized nuclei. Zeiss H. immers. E. P. 2. Drawn with Zeiss's camera lucida.
- Fig. 42. Section of a suprarenal body of *Scyllium canicula*, from about the middle region of the abdominal cavity. In this section are seen a large nerve-cell and several branched pigment-cells. Zeiss H. immers. E. P. 2. Camera lucida.
- Fig. 43. Section of the interrenal body of *Raja clavata*, showing alveoli of various shapes and sizes, filled with cells, many of them elongated. Zeiss apochrom. $\frac{1}{12}$ " water immers. Camera lucida.

PLATE XIV.

- Fig. 44. Section of a suprarenal body of *Acipenser sturio*. The body was put into osmic acid about 12 hours after death, and sections were cut with the freezing microtome on the following day. The alveolar arrangement is well seen and the cell-outlines are admirably preserved. Zeiss H. immers. E. P. 2. Camera lucida.
- Fig. 45. Section through a portion of the kidney and the two suprarenals of *Conger conger*, showing the renal intertubular material, the low power appearance of the suprarenals, and their connexions with the kidney. $\times 70$.
- Fig. 46. Portion of suprarenal of *Conger* from same slide as preceding, showing the alveoli containing a regular tier of irregular cubical cells, and central spaces containing nuclei and shreds of cells. Zeiss apochrom. $\frac{1}{12}$ " water immers. Camera lucida.
- Fig. 47. Section of suprarenal of *Anarrhichas lupus*, showing a curious serpentine arrangement of the alveoli. Zeiss $\frac{1}{12}$ " apochrom. water immers. Camera lucida.
- Fig. 48. Separate cells of suprarenal of *Pleuronectes limanda*. Zeiss apochrom. $\frac{1}{12}$ " water immers. Compens. 0.18.
- Fig. 49. Separate cells of suprarenal of *Mullus barbatus*. Shows the two kinds of cells. Same power as fig. 48.

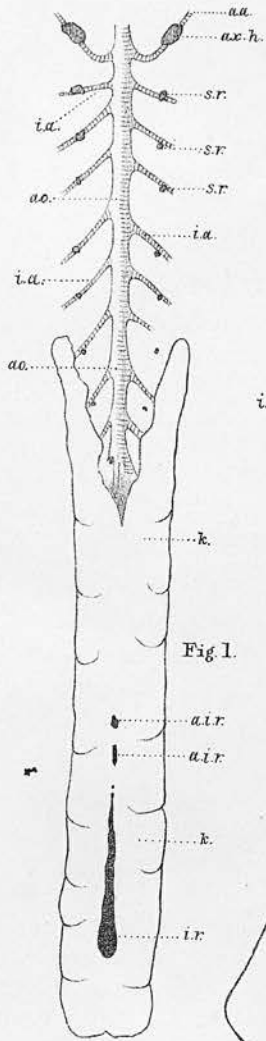


Fig. 1.

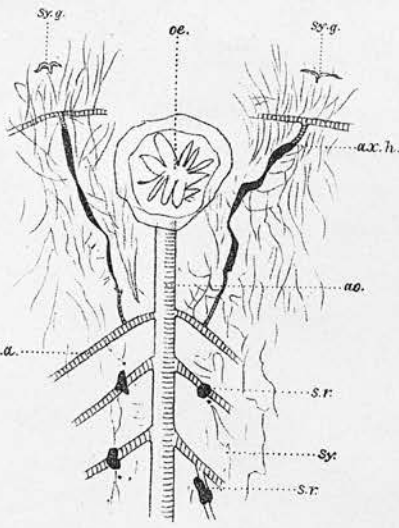


Fig. 2a.

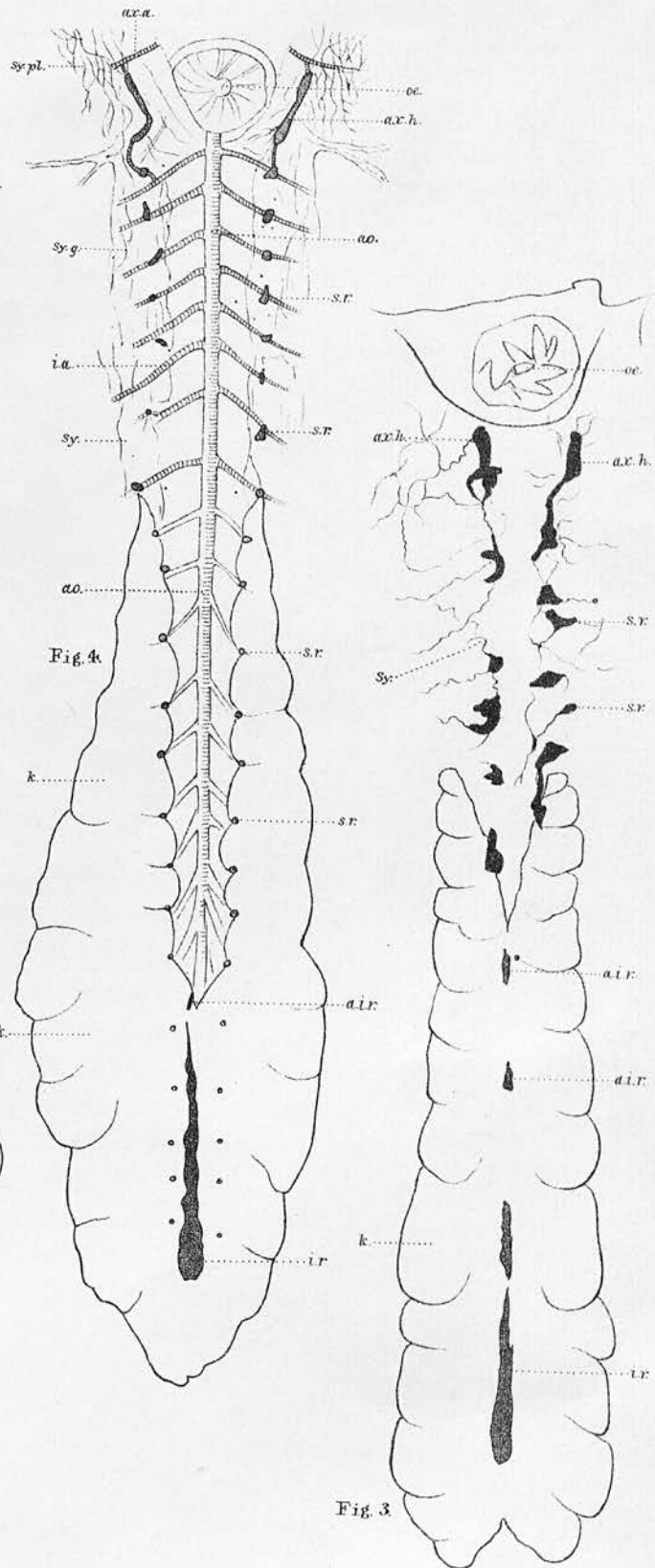


Fig. 3.

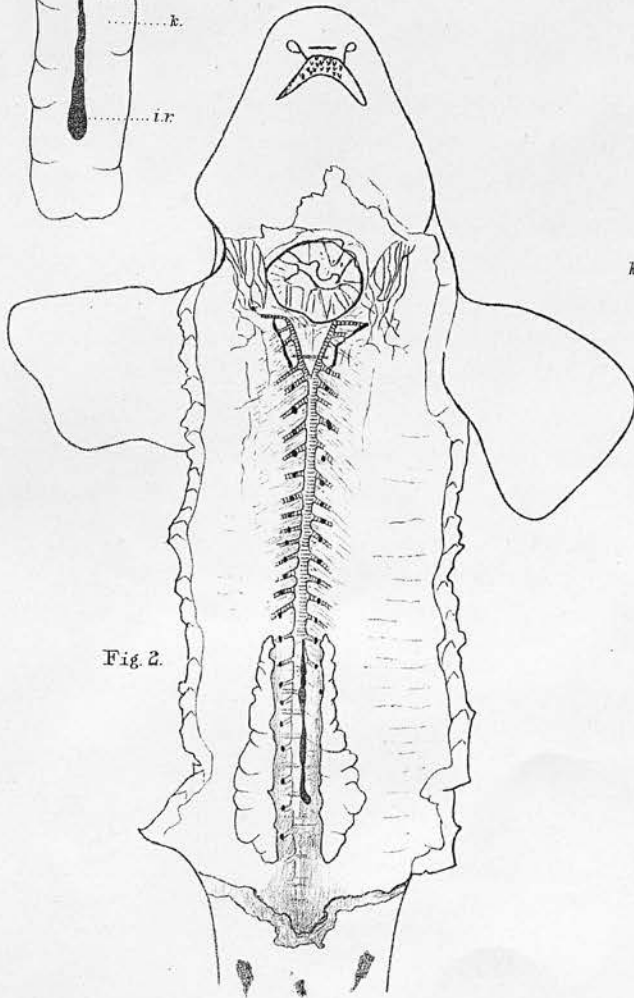
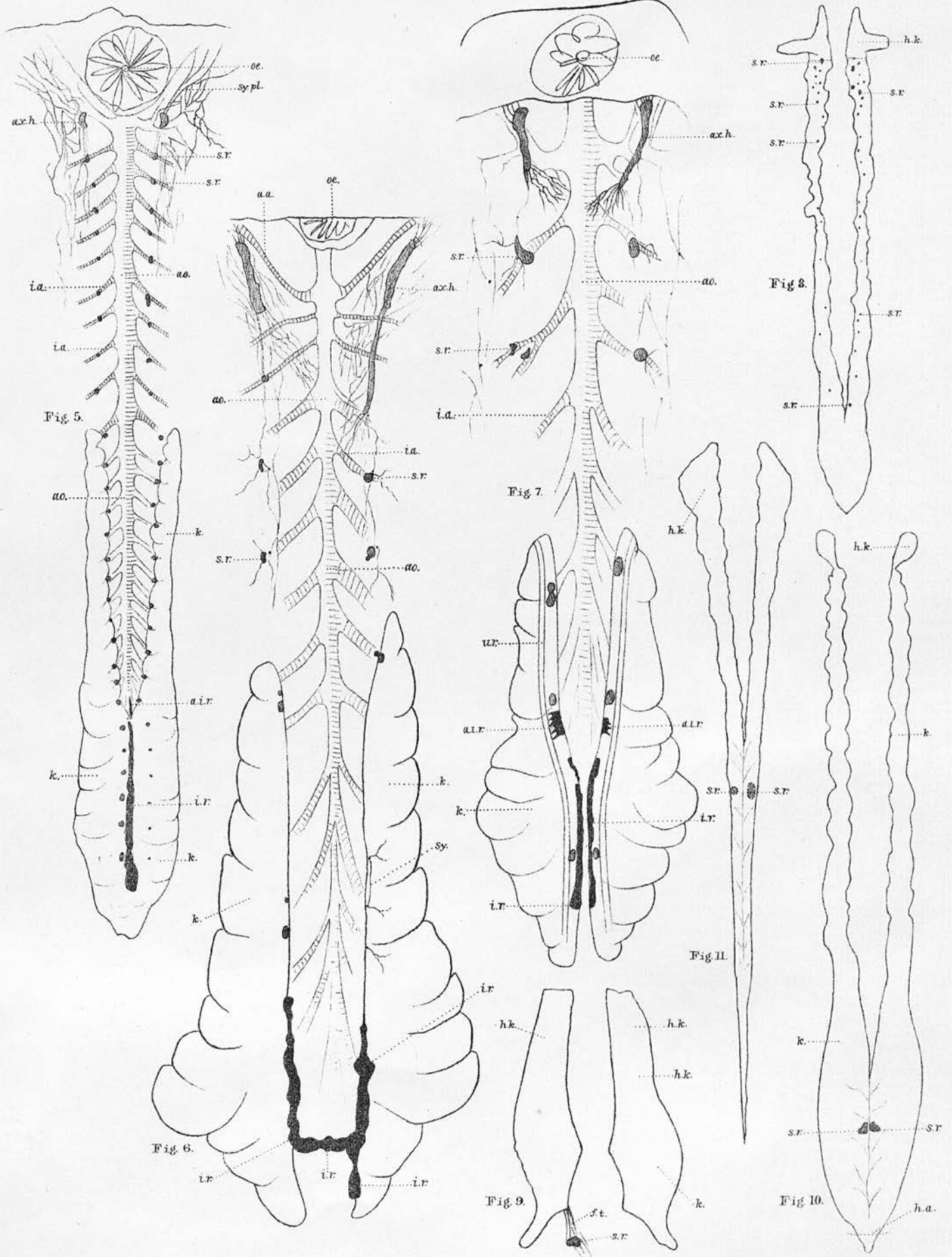


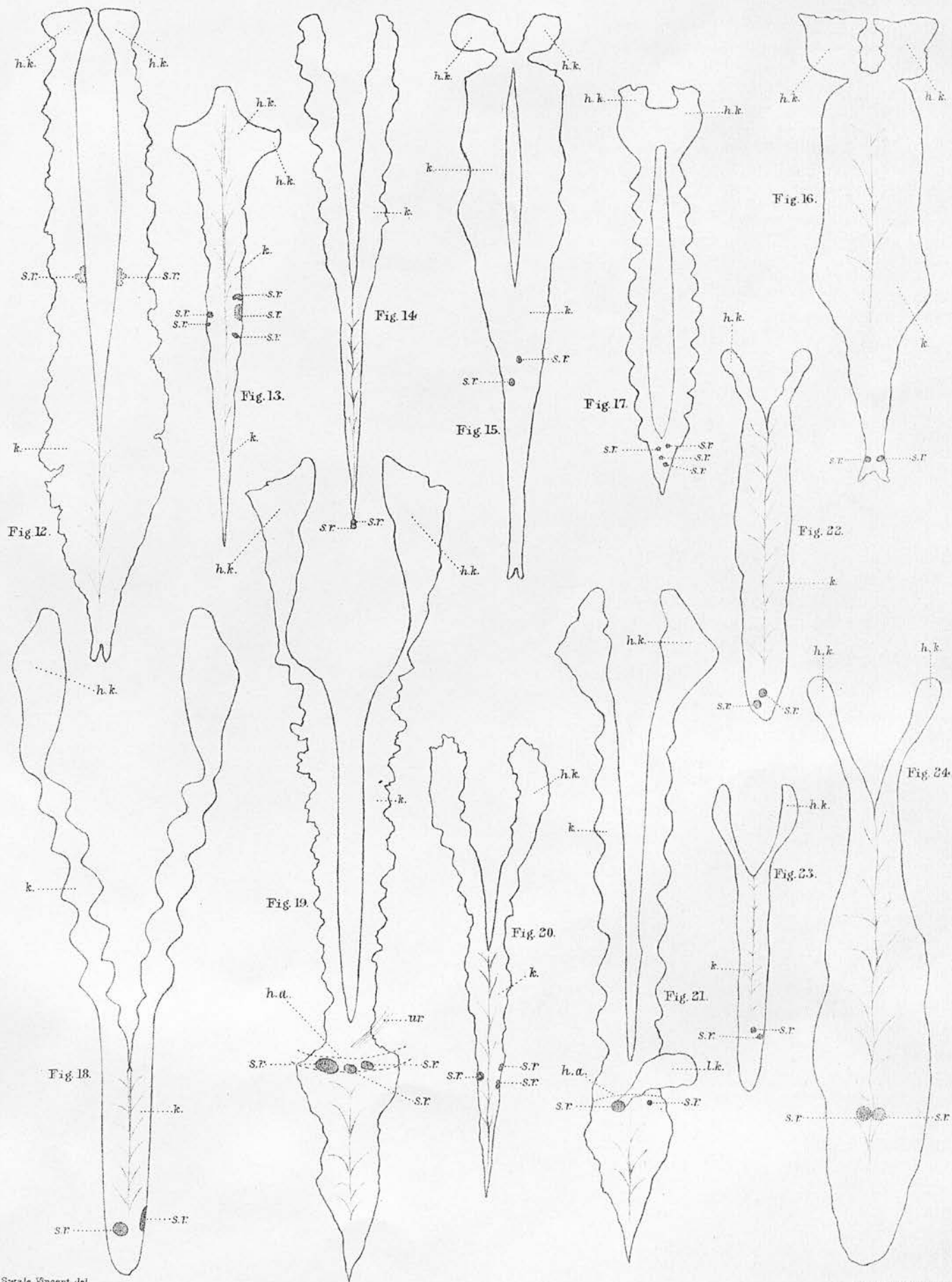
Fig. 2.



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M.P.Parker lith.

Geo. West & Sons imp.

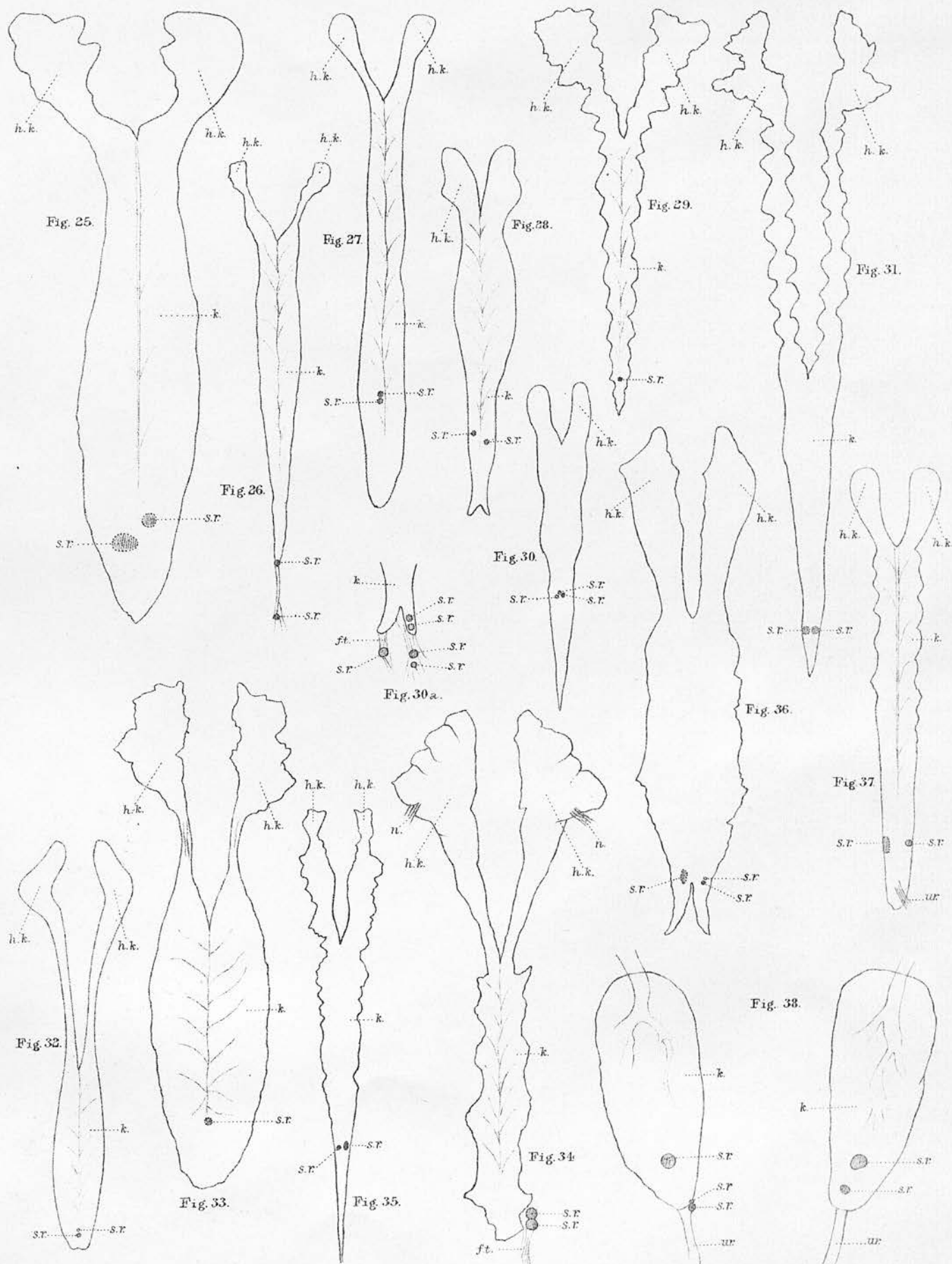
SUPRA-RENAL BODIES IN FISHES.



Swale Vincent del.
M.P. Parker lith.

Geo. West & Sons imp.

SUPRA-RENAL BODIES IN FISHES.



Swale Vincent del.
M.P. Parker lith.

Geo. West & Sons imp.

SUPRA-RENAL BODIES IN FISHES.

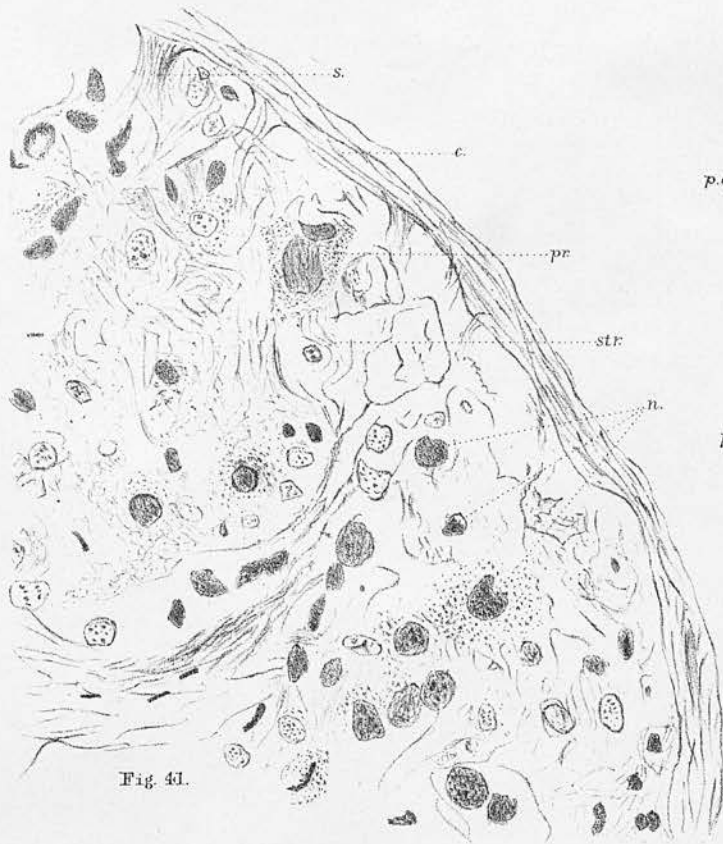


Fig. 41.

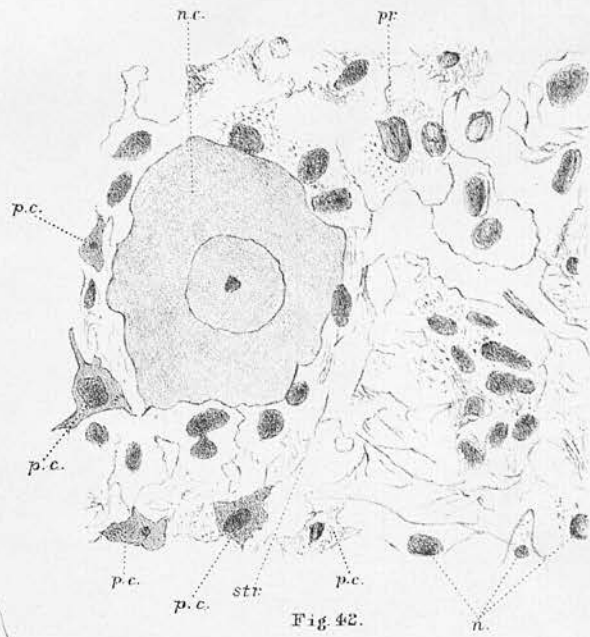


Fig. 42.

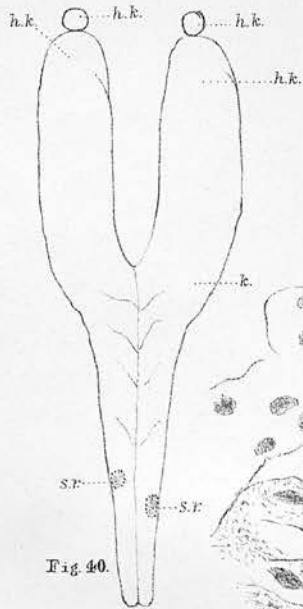


Fig. 40.

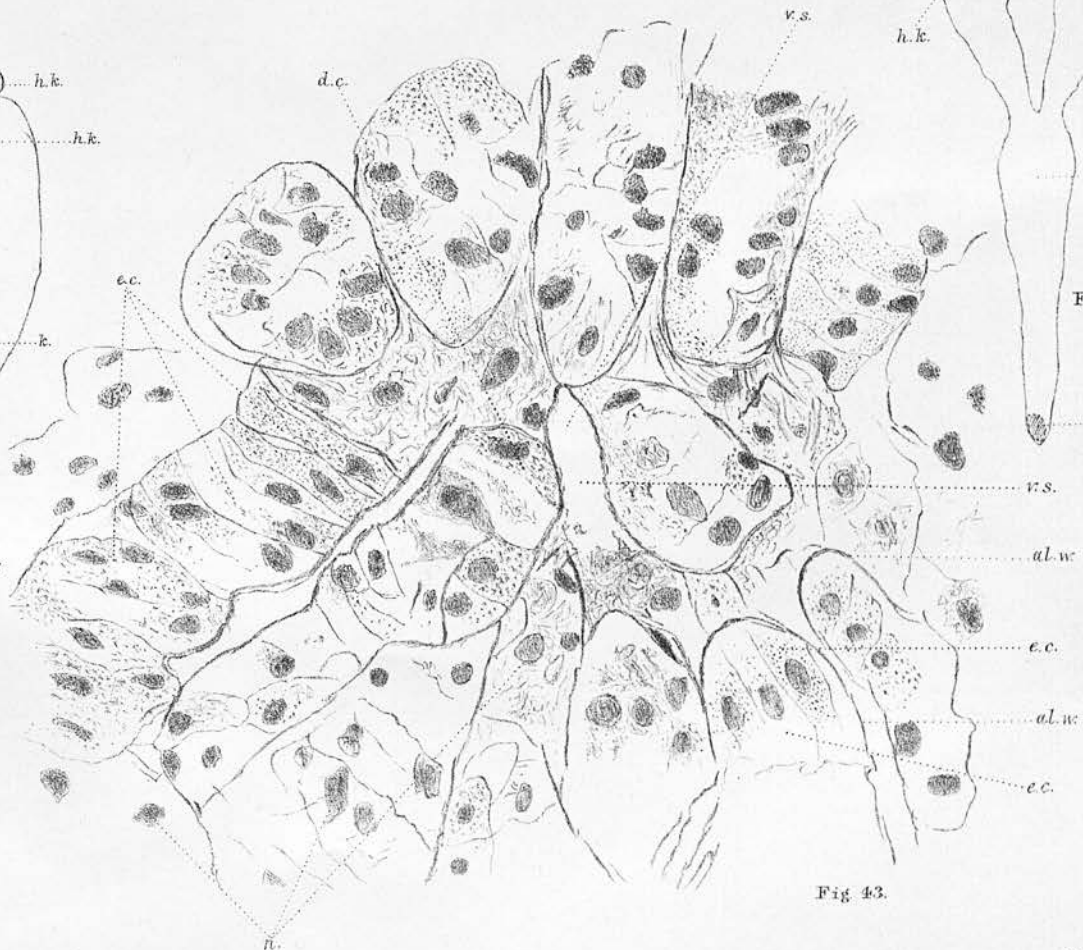


Fig. 43.

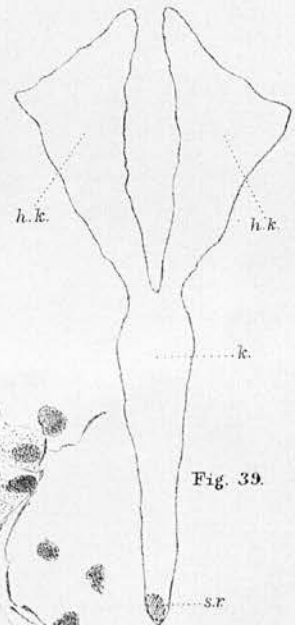


Fig. 39.

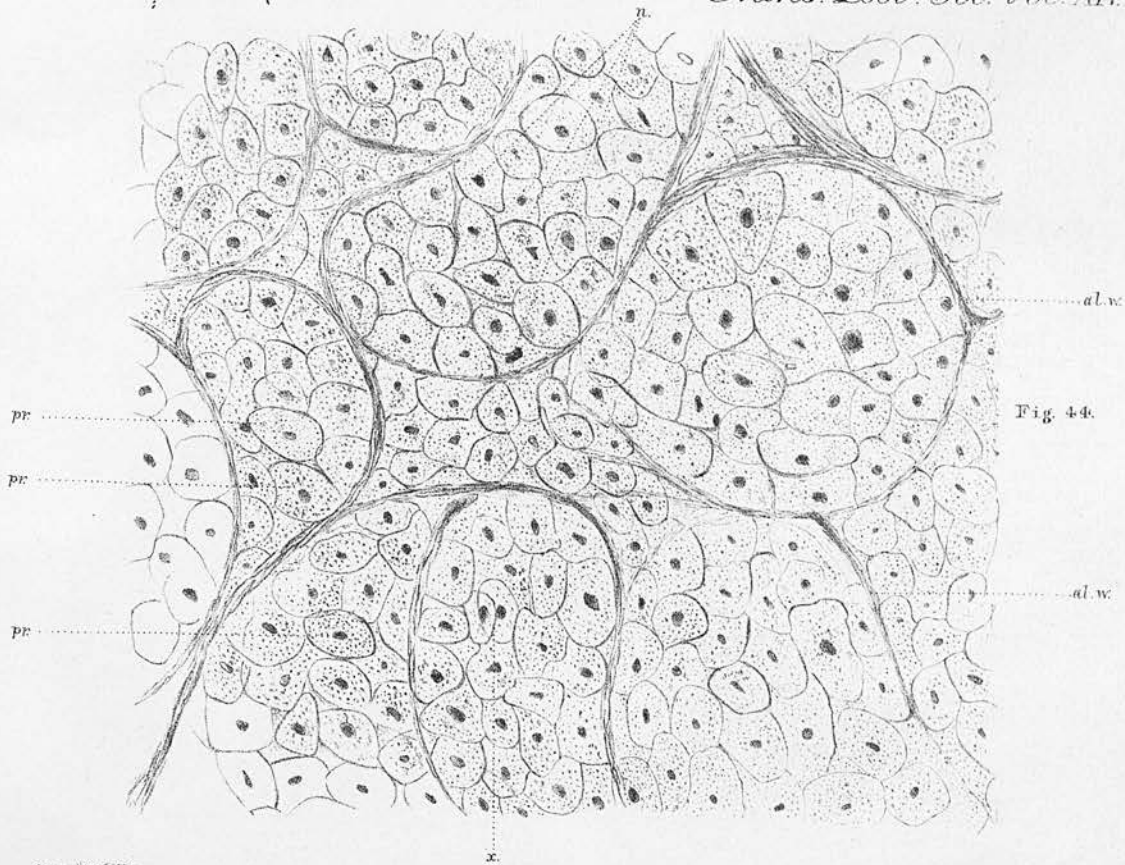


Fig. 44.

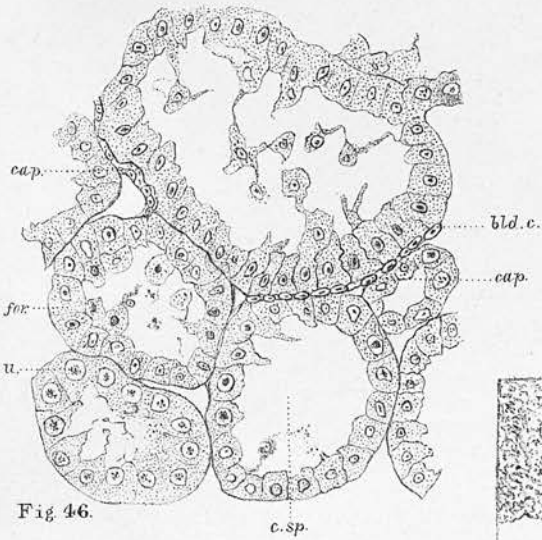


Fig. 46.

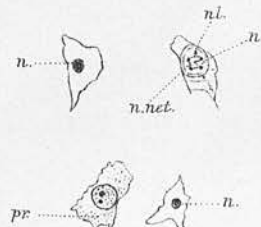


Fig. 49.

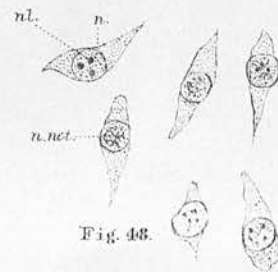


Fig. 48.

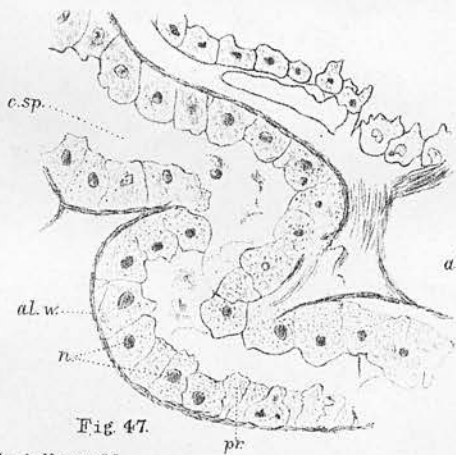


Fig. 47.

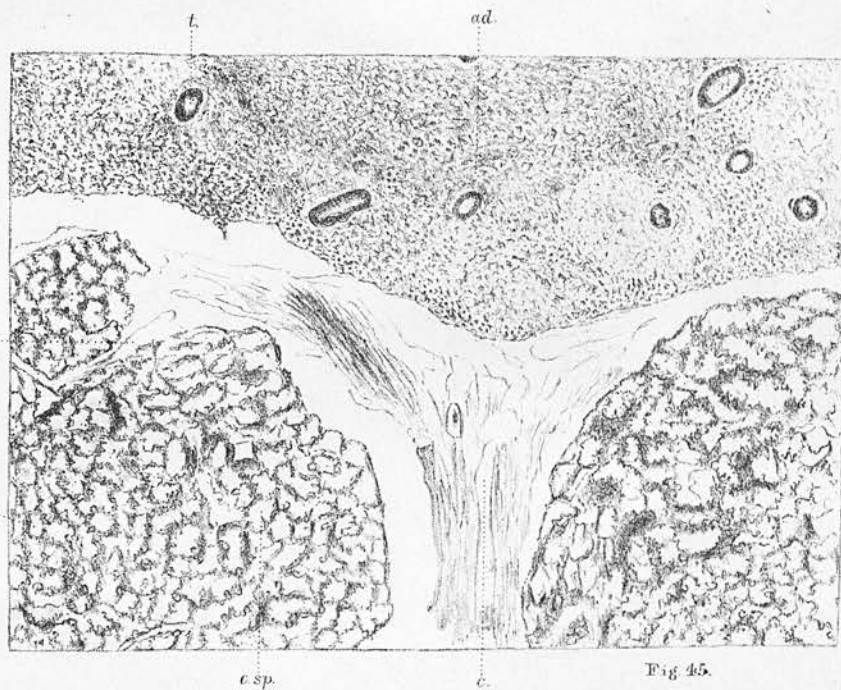


Fig. 45.

Swale Vincent del.
M. F. Parker lith.

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