THE PITUITARY BODY IN GIANT ANIMALS FOSSIL AND LIVING: A SURVEY AND A SUGGESTION

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WHEN G. Elliott Smith, comparative anatomist of the brain, in his description of an endocast of the cranial cavity of a giant Moa briefly remarked "The hypophysis is very large" (1902), little was yet known of the relation of the pituitary gland to body size. Nor could F. Nopcsa, the palaeozoologist, realize the full implications when he demonstrated that the fossa hypophyseos is larger, in relation to the brain cavity proper, in giant dinosaurs than in their smaller relatives (1917). For the definite proof of the influence of the pituitary gland on body growth, the separation, from the many other substances produced by the gland, of the anterior lobe growth hormone, was not achieved until 1921 (H. M. Evans).

I. PITUITARY GLAND AND BODY SIZE: SOME ESTABLISHED FACTS

Pathology

The normal growth-regulating function of the pituitary body (PB) was first inferred from its disturbances in man. Human growth disturbances were found to be accompanied by abnormal PBs: dwarfs suffer from hypopituitarism, abnormally tall men from hyperpituitarism. The latter disease occurs in two forms. In acromegaly, the sella turcica of the sphenoid bone is enlarged (in 93 per cent of cases) by a tumor in which the acidophilic secretory cells of the anterior pituitary lobe are increased. In human giantism, in contrast to acromegaly, intensive growth starting before or during adolescence produces a well-proportioned abnormally tall skeleton; hyperplastic changes in the anterior pituitary lobe widen, lengthen, and deepen the sella.

While we know that size variations occurring normally in nature tend to "mendel back" to medium size (unless selected by breeders), clinicians have found family predisposition to pituitary diseases; for example, three sisters and a brother described by J. Bauer were normally built giants of 190, 185 and 183 cm. in height and an achondroplastic dwarf of 121 cm. Geneticists also have ascertained a linkage between defective development of the animal PB and the inheritance of structural distortions (Stockard, in *The Pituitary Gland*, cf. Bibliography).

Experiments

Animal experiments have shown that, when the pituitary body is removed, growth stops altogether and cannot be revived by any kind of medication, whereas the slowing down of growth in thyroidectomized animals is entirely cured by treatment with anterior lobe extracts (Evans, in *The Pituitary Gland*). Natural dwarfs occurring in Evans' rat colony were always restored to complete normality by administration of the growth hormone (Evans et al., '33).

In the normal rat, the response of the bones to injections of anterior lobe extract is an over-stimulation of normal periosteal growth (cf. for example, Evans, Handelsman). Injected rats become twice as heavy as the controls; some of them surpass the normal maximum size of the species. The absence of acromegalic stigmata in these giant rats has been attributed to the fact that in rats the bone epiphyses never unite (Putnam, in *The Pituitary Gland*). This assumption is based on the disputed doctrine that giantism is the acromegaly of youth. Experiments with various breeds of dogs tend to show (if conclusions

may be drawn from the reaction of so few individuals) that racial constitution decides the result of experimental hyperpituitarism. An English bulldog grew to almost twice the weight of littermate controls through anterior lobe injections; growth, however, was not evenly distributed but typically acromegalic (Putnam *et al.*). In dachshunds, symmetrical overgrowth = giantism occurred consequent on injections, the only outstanding acromegalic feature being folded skin (Evans *et al.*). In sheep-dogs likewise, no difference of the skeletons was observed, apart from size, between an experimental giant of 30 kg. and its litter control of 20 kg. weight (Evans *et al.*).

Hypophysectomized chick embryos never reached the size of controls of the same age (Fugo). As far as the writer is aware, none of the records of pituitary injection experiments on birds, nor any report on reptile experiments mention the animals' size. In the case of the sauropsids, therefore, palaeontological data (see below) fill an actual gap in the chain of proofs of the rôle played by the PB in conditioning body-size—already decisive enough, however. A diet of cattle anterior lobe not only increased the rate of growth in *Amblystoma*, but these newts never ceased to grow after reaching the normal maximum size of the two species used in Uhlenhuth's experiments.

Relative size of the pituitary body

In endogenous giants, the size of the PB was stated above to vary in direct proportion to the amount of secretion. This applies not only to human pathological cases but may become apparent in normal size variation. In the larger breeds of cattle, and in the larger individuals within a breed, the PB is larger in relation to body size than in smaller ones (Petersilie). A moderate positive correlation exists between the weight of the PB, but particularly of the anterior lobe, and body size in the normal adult human (Rasmussen, in *The Pituitary Gland*). Large human skulls have in general larger sellae turcicae than small skulls (Kadanoff). In the exogenously developed experimental giants the PB is, of course, not, or hardly, enlarged, supply from outside replacing hypersecretion. The foxhound bitch injected by Benedict *et al.* grew to 150 percent the weight of its sister, yet the increase in PB weight was only 7 percent; uterus and ovaries were 300 percent, thyroid and spleen, 100 percent heavier; the difference in brain weight amounted to no more than 3 percent.

We are here facing a phenomenon which has an extremely important bearing on our present investigation: the fact that brain growth follows other laws than body growth and PB growth.

Experimental proofs thereof are abundant. Mortimer, investigating only the skulls of young rats after hypophysectomy, observed that snout growth is more impeded than the development of the brain case, and that post-operative treatment with growth hormone produces satisfactory growth only in the snout. In the giant rats produced by the experiments of Rubinstein (in *The Pituitary Gland*), the brain was always smaller in relation to body size than in normal rats. Rubinstein's extensive experimental and mathematical investigation definitely showed that the growth hormone, while markedly stimulating body growth, fails to affect the growth or structure of the central nervous system.

The palaeontological aspect

This only confirms the palaeozoologists' experience of phylogenetic increase in body size. The comparative anatomist too is, of course, well aware that the brain and neurocranium of a larger animal are smaller in relation to body size than those of its smaller congener. The palaeontologist sees the neurocranium actually lagging behind during phylogenetic increase of body size, as a rule, and always in the evolution of definite giants.

The recent achievements of medicine and experimental zoology now reveal the seat of the force which must have promoted phylogenetic body growth as it does ontogenetic growth. They enable the palaeontologist to investigate, as directly as is possible within his realm, the growth organ itself, and to check the development of its size—that is, its power—with that of the brain even where only skulls are preserved.

Due to its complex origin, the pituitary, master among endocrine glands, is, so to speak, directly accessible to palaeo-anatomical investigation. The PB is lodged in the brain case because its "posterior lobe" (posterior in man) is its pars nervosa, the neurophysis, ontogenetically a downward diverticulum from the floor of the diencephalon. Yet it lies below the brain case proper and may be provided with its own capsule by the sphenoid bone (the sella turcica in man), because its epithelial portion, the hypophysis s. str. ("anterior lobe" = pars glandularis, etc.) is a pars buccalis, ontogenetically the terminal part of an upward

diverticulum from the dorsal side of the roof of the mouth.

Until now, however, apart from dinosaur giantism only one phylogenetic trend has been interpreted in terms of hyperpituitarism: Keith found that the differences between *Homo sapiens* and *Homo primigenius* are mainly the latter's acromegalic symptoms! This view had also been taken by Larger, but he emphatically denies the connection between PB and *l'acromégalie-gigantisme*. In vain the palaeozoologist searches neozoological literature for data of animal PBs with reference to the formation of their specific body size (except for the papers of Robb and Rost discussed below); nor have any investigators of animal and human PBs taken into account the palaeozoological facts referred to in our introductory sentences. Yet normal animals, living and extinct, testify plainly to the phylogenetic significance of the pathological, statistical, and experimental observations which may be summarized as follows:

(1) Body-growth, but apparently not brain growth, is dependent upon the amount of growth hormone produced by the anterior lobe of the PB. (2) More hormone is produced by large glands than by small ones. (3) Hyperpituitarism enlarges the sella turcica. (4) Tendency to hypo- and hyper-pituitarism is hereditary. (5) Hyperpituitarism can produce animals above maximum normal size.

II. REPTILES

[No Anamnia have been studied with regard to our subject. Enlightening differences might be revealed by comparisons of the PB of giant fish with that of smaller congeners such as a 450 kg. *Thunnus* and an 8 kg. *Neothunnus*. Likewise, there doubtless exist differences between the PB of small frogs and that of the 30 cm.-long *Rana goliath*; in Herrick's figures of the middle sections of brains of adult *Amblystoma tigrinum* (maximum body size 27 cm.) and *Cryptobranchus alleghaniensis* (55 cm.), I find the glandular lobe of the PB less than half as long as the tectum mesencephali in the smaller but exactly as long as the tectum in the larger newt.]

There are giants among the living reptiles such as 5 m.-long snakes, 2 m.-long turtles, and 3 m.-long lizards; their PBs remain to be studied, and to be compared with those of the small representatives of these orders. The size of lizard PBs should, furthermore, be compared with the volume of the

pituitary fossa of 8-10 m.-long mosasaurs: this pouch in the skull base was the bony capsule of the PB and thus reproduces approximately the size of the long-vanished gland. Some reptiles, however, are excluded from palaeoendocrinological investigation by the fact that only the distal extremity of their PB lies in no more than a trough-like depression on the sphenoid bone. In others, the fossa may retain its embryonic condition, that is, remain open across the entire sphenoid bone. Thus, the ichthyosaurs should prove particularly favorable objects for comparative investigation. It appears that this could be undertaken on intact skulls. A widely open cranio-pharyngeal canal penetrates the basisphenoid of some ichthyosaurs. Endocasts of this canal might exhibit illuminating differences between specimens of different size; the outside opening has been found in the largest known (2 m.-long) *Ichthyosaurus* skull as well as in smaller specimens. The pituitary space proper is a well-marked expansion within the cranio-pharyngeal canal of the giant dinosaur family Atlantosauridae of which it is believed that this persistent communication between the brain and mouth cavities was a family character. (O. C. Marsh: for literature on fossil brain cavities see lists in Edinger, 1929 and 1937.)

It is, of course, no mere coincidence that the only animals so far described as having, so to speak, disproportionately large pituitary fossae are the giants par excellence—the dinosaurs. In Jurassic sauropod skulls, the 25 m.-long but slimly built *Diplodocus* shows a slender sac below the brain case as deep as this is high; in the stouter 17 m.-long *Camarasaurus*, the lower part of the sac has a much greater diameter than the upper (Fig. 1): the "anterior lobe" of the PB being ventral to the other parts in reptiles. Apart from the fossae of giant sauropods which he briefly characterized as *ungeheuer* (monstrously large), Nopcsa investigated the fossae of seven small and seven large dinosaur genera. This enabled him to restrict direct comparison to genera of established ancestry. His interpretation of *dinosaur giantism as being the result of an increase in pituitary function* is therefore based on the, so to speak, actual observation of a process, namely that "bei diesen Tieren im grossen und ganzen mit der Zunahme der Körpergrösse eine Zunahme der Hypophyse ihrem Hirn gegenüber Hand in Hand geht ... die Grösse des Hirnschädels bleibt dabei stationär." This means that, in dinosaurs, phylogenetic increase in body-size was accompanied by

an increase in size of the PB, while brain size remained the same. The many endocranial casts of dinosaurs now known prove the basic truth of Nopcsa's ('17) doctrine.

Brown and Schlaikjer note among the differences between the endocranial cast of the primitive small ceratopsian *Protoceratops* from the Mongolian Upper Cretaceous and that of the large advanced *Anchiceratops* from the American Upper Cretaceous ('40, p. 192) that the PB in the former is "relatively small and narrow," in the latter, "relatively large and broad." Dr. Brown very kindly allowed the present writer to examine the
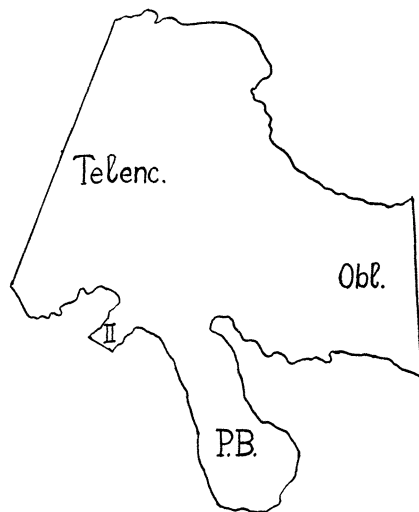

FIG. 1. OUTLINE OF ENDOCAST OF BRAIN CAVITY OF CAMARASAURUS SUPREMUS

From left side, after Osborn. Two-fifths natural size. Telenc.: cast of caudal portion of forebrain chamber. Obl.: cast of medulla oblongata chamber. II: cast of optic nerve canal. PB: cast of fossa pituitaria.

two endocasts. The length of the brain case, from the notch between the olfactory and optic nerve foramina to the foramen magnum, was found to be 65 mm. in *Protoceratops* and 72 mm. in *Anchiceratops*. Brain length, however, measured from that notch to the posterior end of the cerebellum, was exactly the same in the small and the large forms, viz., 49 mm.: only the medulla oblongata was more voluminous in the giant. The *Protoceratops* skull from which the cast was taken is 611 mm. long. The only complete *Anchiceratops* skull is 1660 mm. long but is from a smaller individual than that which furnished the cast (Sternberg). On the other hand, the difference

between the casts of the pituitary fossae is indeed very striking. Both are well set off from the brain cast proper by a stalk. Their greatest lengths, breadths and heights are: *Protoceratops*, 13, 11, 21 mm.; *Anchiceratops*, 14, 21, 37 mm. While in *Protoceratops* the pituitary fossa tapers in breadth and length and its cast is a pointed wedge, that of *Anchiceratops* retains the same breadth and length almost to the lower extremity.

Exact data on the relative sizes of brain case and pituitary fossa in dinosaurs have been given by Janensch ('35)—data which are not known of any living animal. Janensch was able to study several brain casts of three Jurassic sauropod genera, the entire skeletons of each of which were known to him and, in one instance, even that of the very individual which furnished a cast. This was a representative of those greatest giants which ever trod the earth, viz. the genus *Brachiosaurus* which could raise its head 12 m. above the ground; the body reached 25 m. in length, and some 50 tons in weight.

Janensch estimates the body of his specimen in life at 25 cubic meters. It has a brain cavity proper of 309.5 cubic cm. and a fossa hypophyseos 13.8 ccm. = 4.5 percent of the brain cavity. In a smaller *Brachiosaurus* skull, the proportion is 198.2:15.2 = 7.4 percent. In the smaller genus *Barosaurus*, in an individual the body of which was estimated at 15 cubic meters, a brain cast of 198.8 ccm. had a much larger hypophyseal appendage—18.5 ccm. = 9.4 percent. Within the species, however, the smaller the skull, the smaller the relative size of the PB was found to be—for instance, 9.2 ccm. = 7.6 percent of the 120.8 ccm. brain cavity. In the still smaller *Dicraeosaurus* (skeleton-length 13.20 m.), the numbers, including a parietal sinus of the brain cavity, are 194:14 = 7.2 percent; excluding the sinus, 140.8: 14 = 9.9 percent.

These figures prove that there existed a tribe of animals in which the PB was so large that the volume of its capsule was as much as $\frac{1}{10}$ of the brain case volume. This was the group which contained the largest terrestrial animals ever known.

Pointing to the prevalent sterility in human giants and acromegals, Nopcsa suggested that hyperpituitary decrease of sex functions, along with the general decrease of natural resistance in any giant body, was the cause of *extinction* of the sauropods. In our opinion, Nopcsa goes too far in stressing the parallel between

the normal dinosaur giantism and the human hyper-pituitary diseases. Particular objections spring from two standpoints:

1. The sauropods flourished for many millions of years after reaching giant size. Abundant up to the end of the Cretaceous period, they then disappeared together with practically all characteristically Mesozoic phyla, small and big.

2. The anterior pituitary lobe itself also produces a sex hormone, and this normally prevails over the growth hormone in the adult. Sexual dysfunction in hyper-pituitary women has been observed by Henderson to occur only when the sella turcica is considerably enlarged by an adenoma of the PB. This pathological growth compresses the cells which elaborate the hormones controlling sex function, but it does not destroy them. After operations with radical extirpation of the adenoma, Henderson found that the normal menstrual cycle was resumed and pregnancy occurred. The enlargement of the dinosaur fossa hypophyseos, however, was normal. Animal experiments too have shown that certainly not every kind of hyperpituitarism causes sterility. Experimental administration of cattle anterior lobe, even though disturbing the sexual rhythm in young rats, has increased sex activity in senile rats, caused hens to lay more and larger eggs, produced hypertrophy of the gonads in young alligators, and stimulated the ovaries of frogs.

III. BIRDS

The general remark in the *Handbuch der Zoologie* on the avian PB, *"wenig entwickelt"* (Stresemann, p. 107), calls for correction. Küenzi's comparisons of the brain-part surfaces throughout the bird system showed that the PB is relatively small, for instance, in sparrows, rather large in fowl, and very large in the ratites.

The greatest body-size also is attained by the earth-bound ratites. The largest ostriches reach 260 cm. body-height; the largest flying bird, the albatross, 116 cm.

Flightless types in various euornithid orders also developed giant forms. The largest living penguin, the emperor, stands 1 m. high. Its PB should be investigated together with that of a small penguin. A Miocene penguin was twice as large as the emperor penguin. Its skull, however, is still unknown, and so is the skull of an Eocene ground-bird of fourfold ostrich-height.

The largest ratite genera are also extinct. Complete skeletons have been mounted from medium-sized bones only, not from the largest. That of a *Dinornis maximus*, the New-Zealand Moa, is 255 cm. high; one of the Madagascar *Aepyornis maximus*, 300 cm.

Now the very strata which contain the remains of these subfossil heavy giants have also furnished remains of smaller, lighter-built representatives of the respective families to which the giants belong, down to the size of a turkey. It is obvious that the smaller forms, although they lived together with the giants, are less advanced types. They are therefore considered the ancestral forms (Lambrecht), and we here possess evidence of *development of giantism within families*. Since the avian brain is so tightly fitted into the skull that endocasts furnish exact replicas of the brain form, and since the avian PB, set well off the brain by its long stalk, is encased in a separate bony chamber, the two ratite families furnish excellent tests of the problem we are concerned with.

Dinornithids

We have said that Elliot Smith was struck by the size of the PB in the Moa. Owen, too, who first described the brain of *Dinornis maximus*, had remarked in 1872: "The hypophysis, as represented by the cast of the sella, is of considerable size." The significance of this becomes apparent when the *Dinornis* endocast (Royal College of Surgeons, London, catalogue number D. 148) is compared with an endocast of the smaller dinornithid *Anomalapteryx* (Senckenberg Museum, Frankfurt a.M., Av. 29 a).

Not having sawed skulls at hand in which to measure the interior spaces, and not being able to take volumetric measurements on the plaster casts or to apply a formula to those differently shaped parts of the casts, the writer took recourse to a simple method feasible for comparison, though inaccurate as to absolute size. The three diameters of the PB casts were multiplied with each other, and so were those of the forebrain casts (the form of which, unlike that of other brain parts, is similar in both families investigated). The imaginary cubes, of course, suggest volumes larger than are actually present either in the wedge-shaped or globular PBs or the heart-shaped forebrains. As, however, they are only computed for the sake of comparison with each other, the relative figures at which we are finally aiming, the proportion of the cubes, cannot be far from the true proportions of PB and forebrain. Indeed, Rost calculated the volume of the PB in two races of pigeon by addition of section superficies as well as by multiplication of the diameters of the PB and, in spite of the difference in the resulting absolute numbers,

found practically the same inter-racial ratio by both methods, namely, 1:1.414 and 1:1.49, respectively.

In *Anomalapteryx didiformis*, the diameters of the PB are 8.5, 7, 8 mm., the cube, 476 cmm.; the telencephalic cube is 29.500 cmm. The proportion of PB size to forebrain size, therefore, is 1:62 (1:67 in the ostrich endocast RCS, D 155). In *Dinornis maximus*, the figures are 12 x 12 x 14 mm. = 2016 cmm. and 68.880 cmm.: the proportion is 1:34. In relation to forebrain size, the pituitary body of *Dinornis* thus is found to have had almost twice the size of an *Anomalapteryx* PB. The ratio *Anomalapteryx:Dinornis* is: body height, 1:2.1; forebrain volume, 1:2.2; but PB volume, 1:4.2.
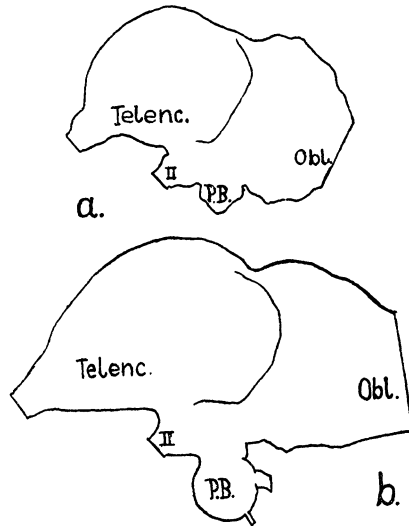

FIG. 2. OUTLINES OF ENDOCRANIAL CASTS OF (a) MULLERORNIS AGILIS (b) AEPYORNIS MAXIMUS

Left side views, two-thirds natural size. In (b) the cranio-pharyngeal canal is seen to open into the pituitary fossa from below, the carotid artery canal from behind.

Aepyornithids

It is true that we do not know the size of the individuals which furnished endocasts of brain cases either in the dinornithids or the aepyornithids. However, the author's investigation of 6 aepyornithid brains belonging to 4 species (Edinger '42) showed that two brains of one species are almost exactly alike, in spite of the size variability within aepyornithid species. Only one brain of each species was complete with PB.

Seen from above, these casts are rather similar to each other and to ostrich brains. The lower

side reveals striking differences: the PB of the ancestral genus *Mullerornis* is the size of a blueberry (384 cmm.), that of the largest *Aepyornis* species, *A. maximus*, is the size of a cherry (3038 cmm.). The PB volume compares to the forebrain volume, with rising body size, as follows: *Mullerornis*, 1:102; *Aepyornis hildebrandti*, 1:82; *Aepyornis medius*, 1:36; *Aepyornis maximus*, 1:24!

When reading the table of interspecific ratios given in Table 1 (computed from numbers to be published in Edinger '42), the following points should be born in mind:

1. Below the stalk, which is not included in the measurements taken, the PB of *Aepyornis maximus* bulges out to form a globe, while those of *Mullerornis* and the smaller *Aepyornis* species are somewhat flattened antero-posteriorly; that is, the computation of the "cube" exaggerates the size of the PB more in

TABLE 1

Interspecific ratios

	BODY-HEIGHT	FORE-BRAIN-VOLUME	P.B.-VOLUME
Mull.:Aep. hild.	1:1.1	1:1.6	1:2.0
Mull.:Aep. med.	1:1.4	1:2.0	1:5.6
Mull.:Aep. max.	1:1.7	1:1.8	*1:8.0*
Aep. hild.:med.	1:1.3	1:1.2	1:2.8
Aep. hild.:max.	1:1.6	1:1.1	1:4.0
Aep. med.:max.	1:1.2	1:0.9	1:1.4

the case of the smaller species than in the giant, the relative PB volume of which would therefore appear even larger had the actual volumes been measured.

2. The body-heights are two-dimensional measurements and their comparison does not express the increase in body-volume in the evolution of the aepyornithids; this, naturally, was greater. However, height-comparison throws more light on the respective body-volume of these animals of identical build, with so small a trunk between such enormous legs and neck, than it would in almost any other animal. The numbers in the first column of the table rely on no more than the following mounted skeletons:

Mullerornis agilis: Tananarive (Madagascar), 148 cm.

Aepyornis hildebrandti: Tananarive, 165 cm.; London (England), 158 cm. = ∼ 160 cm.

Aepyornis medius: no skeleton mounted; 211 cm. was computed from medium height of *Aep. max.* by the proportion of the medium tibiotarsus lengths of the two species.

Aepyornis maximus: Tananarive, 221 cm.; Paris (France), 300 cm. = ∼ 260 cm.

These figures are so striking that we may draw the following conclusions although they are based on but one brain case of each species:

With increasing body-height in aepyornithid birds, the forebrain volume increases at a slightly higher rate than does body-length (but presumably at a lesser rate than does body-volume) only when the primitive genus is compared with the advanced genus. Within the genus which developed giantism, forebrain increase stays behind increase in body-height. Meantime *the PB increases at a much greater rate than does the body, manifesting almost 4½-fold the increase of forebrain volume in a comparison between the small genus and the largest giant species.*

Manifold though the activities of the PB are, the evolutionary trend in aepyornithids shows that this hyper-development of the PB was connected with their natural giantism. Even without the possibility of histological examination we are entitled to assume that the striking enlargement of these fossil pituitary fossae was due to an enlargement of the glandular lobe of the long-vanished PB.

Characters of subfossil ratites other than size likely to be due to hyper-activity of the PB

It has long been known that the volume of *eggs* of all *Aepyornis* species, above and below ostrich size, is much larger than that of ostrich eggs. The diameters of *Aepyornis* eggs are 280–340 and 213–245 mm., those of ostrich eggs 150–155 and 110–130 mm. This now proves to be a natural parallel, on a grand scale, to the effect on eggs of experimental hyperpituitarism: the eggs of pituitary-fed hens were over ⅓ heavier and ⅕ larger than the eggs of controls (Gutowska).

Together with their usually large size, there is one other characteristic distinguishing ratites from flying birds which is influenced by pituitary hormones—their *plumage.* Plumage development is controlled by the thyroid, the action of which, however, is regulated by the PB. Hypophysectomy in adult pigeons was followed by heavy moulting (Hill); the feathers of chickens hypophysectomized as embryos were shorter and less well developed, their sheaths were thicker and tougher and did not release the barbs as easily as in controls (Fugo). Implantation of anterior lobe stimulated feather regeneration (Voitkevic). Likewise, in human pathology, reduction of pituitary function causes loss of hair, while increase in hair-thickness and of the areas of hair-distribution

(hypertrichosis) is observed in more than half the cases of giantism and acromegaly. Thus the fact that *Dinornis,* according to the numerous pits for feather insertion found in the metatarsal integument, must have been feathered down to the toes (Owen, 1883), and the peculiar "hair-likeness" and luxuriance of the plumage of the large ratites, now appear as a natural parallel to human hyperpituitary hypertrichosis. The looseness of the ratite feather barbs obviously is a natural counterpart to Fugo's experiment. The plumage of the aepyornithids is not known, but feathers of *Dinornis* have been found; they are soft, their barbs do not cling together to form a vane but are loose, filamentary: just the opposite to the feathers of Fugo's hypophysectomized chicken.

From the ecological viewpoint, this kind of feather is just one of the characteristics of birds unable to fly, and so is their size. How very far we are from being able to discriminate cause and effect, from knowing what is primary and what is secondary, is obvious from the existence of Lowe's doctrine according to which the ratite type is primitive, and branched off the main bird stem before flight was developed. If this were so, then, from the standpoint of the present investigation, we certainly could not consider the ratite feathers as signs of a kind of pituitary "disturbance" for they would be primitive, no "Zuruecksinken auf den Typus der Halbdune" (Stresemann). While agreeing with Romer's ecological interpretation of the origin of flightless birds, namely, that birds were liable to return to ground life in areas free from enemies (that is, areas in which extravagant hyperpituitarism and hypopituitarism (island dwarfs!) could also develop without immediately endangering the species), we note that no less an ornithologist than Stresemann forms just the reverse conception. In his opinion, the loss of the power of flight was the inevitable consequence of increase in body-size. From our point of view, this would mean nothing less than that the development of the ratite bird type was due to the activity of the pituitary gland!

Wiman (see Edinger and Wiman) has discovered a canal running from the nethermost pit of some *Aepyornis* (but no *Mullerornis*) pituitary fossae downwards and slightly backwards to the palate. The "venous foramen" on the lower side of the basisphenoid and the "mid-vertical canal" described and figured by Owen (1879, p. 263, 272, 280) in three *Dinornis* species show that such

persistence of the cranio-pharyngeal canal occurred in the other subfossil giant ratite family too. There is no record of this feature in other birds. Jaekel's search for the cranio-pharyngeal canal in present-day reptiles succeeded in discovering it only in three individuals; it may be significant that these were one alligator, one turtle of the large species *Chelone midas* whose shell reaches 130 cm. in length, and one lizard of the largest tejid species *Tupinambis teguixin* which is almost 1 m. long. We mentioned above that this embryonic character was retained in the largest-known, thus doubtless hyperpituitary, *Ichthyosaurus* (according to Fraas: *Gefässkanal*, p. 15), but also in "smaller" Ichthyosauri which, however, would have been considered giant reptiles had they lived to-day. It is certainly striking that the same is the case in Plesiosauria. The basisphenoid foramen described by White ('35) in the largest known plesiosaurian, the 372 cm.-skull of *Kronosaurus*, exactly corresponds to the pharyngeal opening of the canal descending from the ichthyosaurian fossa hypophyseos, and so does this foramen in the 68 cm.-long skull of *Macroplata* (White '40). As "extraordinary, ... unique for *Trinacromerum* and *Polycotylus* among Plesiosaurs" this same foramen had been mentioned by Williston; it thus existed in a third plesiosaurian family, in animals of 3 m. body length. A median foramen in the palate of the type skull of the largest pterosaurian, *Pteranodon ingens*, is regarded as *Hypophysenloch* by Versluys (p. 758); in my opinion, however, the position of this vacuity (in front of the orbits in an animal whose brain lies behind the orbits) forbids this interpretation. On the other hand, a persistent cranio-pharyngeal canal is observed in all skulls of one giant dinosaur family, the Atlantosauridae.

It thus appears that persistence of the embryonic cranio-pharyngeal canal is much more common in giant birds and reptiles than in small ones. Should more material prove this to be true, the canal might be considered another sign of sauropsid hyperpituitarism.

There is also one record of the canal in an adult giant whale (*The Pituitary Gland*, Fig. 93a). On the other hand, it follows from Cave's statistics of the occurrence of the canal in higher primates that within a non-hyperpituitary group of mammals the frequency of persistence of the canal is by no means proportionate to body-size; the canal was present in 0.2 percent of the 5000 human skulls investigated by Cave, while the percentage in his ape material was: Orang, 14 percent; Gorilla, 35 percent; Chimpanzee, 64 percent.

IV. MAMMALS

The very name "sella turcica," derived from human osteology, indicates that the mammalian PB does not possess an actual bony capsule (and the term should not, in the writer's opinion, be applied to such fossae as are found, e.g., in birds). Not even the clinoid processes transversely bordering the laterally open "saddle" are present in every mammal. De Beer's description of the complete absence of a dorsum sellae in *Sorex* (1929: "the floor of the pituitary fossa—if it is permissible to speak of such a structure in *Sorex*—passes insensibly back into the basal plate") is rendered particularly instructive for the palaeo-endocrinologist by the addition of a list of mammalian genera exhibiting a similar state as well as a list of genera with a well-marked dorsum sellae. The former belong to the most primitive orders, Monotremata, Marsupialia and Insectivora, and to Sirenia and Edentata. The latter are Rodentia, Carnivora, Ungulata and Primates. But in the latter orders too, the palaeo-neurologist may find on the base of an endocranial cast only a low, ill-delimited protuberance representing the shallow depression in the sphenoid, upon which, rather than in which, the gland lay in the living animal. Furthermore, there are also mammals lacking any trace of a sella.

Thus, as far as Mammalia are concerned, the proposed investigation rests mainly with the neozoologist. Fortunately, some information on the PB of living mammals has already been published which yields results when viewed from our present standpoint. On the other hand, a great proportion of the existing endocasts of fossil mammals was described at the time when anatomists were mainly interested in forebrain convolutions, hence they published only top-view illustrations, and scarcely mentioned a single feature of the brain base.

This is, for instance, true of the description of the endocast of the Pleistocene marsupial *Thylacoleo* (of lion's size). The specimen in the endocast-collection of the Royal College of Surgeons of England shows, however, that this giant's PB must remain unknown—only the dorsum sellae has left a mark. The case of the cranial cavity of the living *Phascolomys* is entirely flat in the

pituitary region, while that of the giant kangaroo, *Macropus giganteus*, bears a well-delimited prominence.

From the endocast of *Tillotherium*, the Eocene insectivore of bear-size, nothing but an extremely ill-defined sella can be inferred. In accordance with Wislocki's finding of extremely shallow sellae in living sloths ('38), the pituitary area is flat in endocasts of fossil Edentata; yet the Gravigrada include such contrasts as the lightly built Miocene types and the stout Pleistocene *Megatherium* of 6 m. body-length.

Some Carnivora endocasts show no distinct pituitary protuberance (*Canis, Ursus, Meles*), some an ill-delimited one (*Lutra, Ailuropus*), and some obviously reproduce the distinct form of the PB: *Ailurus*, and most strikingly, *Felis tigris*. This tiger's PB was 13 mm. long and 10 mm. broad. The cat's PB measures 4 x 4 x 2-3 mm. (Trautmann) and thus is no smaller relatively than the tiger's. Similarly, Robb's comparison of the PB:body-weight ratio within one living rodent species demonstrated that the same decrease in relative PB-weight as takes place during growth in the small Polish rabbit and the giant Flemish rabbit is observed in the comparison of the adult forms; the relative PB-weight is even larger in the full-grown "dwarf" than in the "giant." If, however, comparison is made between the endocasts of various rodent genera, the pituitary region is seen to be flat but for one striking exception. This concerns the most bulky living rodent, *Hydrochoerus* (1 m. long, ½ m. high), which has, below a forebrain 65 mm. long, a pituitary protuberance 12 mm. in length.

The coin-shaped PB of the halicorid Sirenia makes hardly any impression in the flat sphenoid bone—but here too we encounter one significant exception. On endocasts of the giant seacow, the 7-10 m.-long subfossil *Rhytina*, there are slight hypophyseal elevations measuring no less than 21 x 33, 28 x 35 and 29 x 29 mm., while forebrain-lengths are 120-123 mm.

One of the few differences between the endocranial casts of the Eocene oldest sirenian and oldest proboscidean genera is that the latter has a prominent PB 14 x 9 x 4 mm. In the endocast of an *Elephas*, however, the pituitary region is indistinctly modelled. From a figure of an elephant brain (Smith '02), PB length and breadth have been measured at 40.3 and 24.5 mm. respectively. Likewise, Wislocki ('39) found the

diameters of the PB of an adult Indian elephant 42 x 26 x 12, and he states that the proportion of its 7.53 g. weight to body-weight is no larger than in the hog (0.0002 percent = 1:50,000). But in the present context it appears significant that the neural lobe is very much smaller than the glandular lobe, their weight-ratio being 1:8.4. The only other record on the elephant PB is macroscopical only and refers to a 25-day-old calf (Dexler '07); the diameters are 24 x 16 x 6.

In a survey of the Roy. Coll. Surg. ungulate endocasts, the size of the pituitary protuberance in *Hippopotamus* at once strikes the eye. Its diameters are 27 x 25 x 17 mm. (forebrain-length 117 mm.), while the base of a *Sus scrofa* cast, with a forebrain of 86 mm. in length, is quite flat and unaffected by the gland, which measures in the pig 8-10 x 7-8 x 6-7 mm. (Trautmann). Most endocasts of artiodactyls bear some impression of a sella, but again that of a giant—the Pleistocene giant deer, *Megaceros*—is arresting for its distinctly modelled, large pituitary protuberance; this has a steep front of 13 mm. depth, a length of 28 mm., and a breadth of 22 mm., but it is, of course, not so well delimited laterally as in the other directions (forebrain-length 125 mm.).

The rhinocerid sella space is confluent with the chiasmatic groove; it thus cannot be measured on casts. In Milne-Edwards' sagittal sections of skulls of the Pleistocene *Rhinoceros tichorhinus* and a *R. unicornis*, the sella is deeper and longer (in relation to forebrain length: 161 and 131 mm., respectively) in the larger animal. Prof. W. K. Gregory of New York was so kind as to examine together with the present writer the base of the endocast of the largest known land-mammal, the Oligocene rhinocerid *Baluchitherium*. This giant had a forebrain only 125 mm. long in its 125 cm. skull. We found the PB ill-defined but apparently large. It seems to have extended over a space of approximately 45 mm. behind the optic foramen; the deepest point of the sella, 5 mm. below the brainbase, is 25 mm. behind the base of the optic foramen. This statement will, of course, become of value only when the PBs of the variously sized living rhinoceroses will have been investigated.

The sella of living horses is known to be extremely shallow; endocasts have no pituitary prominence. No endocast of the little ancestor *Eohippus* is known, and the descriptions of the *Mesohippus* brain neglect the base. When we

compare Trautmann's sagittal sections of the PB of ass and horse, we note a difference significant in the light of the present investigation. The diameters may be said to correspond to the different body-sizes: 17–19 x 16–18 x 4.5 in *Asinus*, and 17–24 x 20 x 6.5–8 in Trautmann's and 21 x 25 x 8.5 in Lothringer's *Equus*-specimens. But *the glandular proportion is much greater in the larger genus*; the pars nervosa is embedded in it like a stone in a fruit, whereas in the smaller genus it really is a posterior lobe, enveloped by the anterior lobe only at its rostral extremity. The same difference in composition is obvious from de Beer's sections of pig and ox PBs ('26); the pars glandularis is far larger in relation to the pars nervosa in the ox than in the pig. This phenomenon is most strikingly illustrated in the whales.

The order Cetacea contains, in the living whalebone-whales, the largest animals of all times. The reader who has followed our exposition so far will therefore learn without surprise that the cetacean PB is very markedly different from all other mammalian PBs in gross as well as microscopical anatomy. Rather will he be amazed at statements such as: "The underlying significance of the differences ... remains obscure"; the suggestion that the pituitary modification meets needs of marine life; and the construction of a genetic linkage between those peculiarities of the PB in whales and the loss of their pelvic extremities —all published in the last decade.

The pituitary depression in the cetacean sphenoid is shallow in extant forms, and transverse processes are either hardly perceptible or else absent. Hence the pituitary region of endocasts of living whales is either smooth or shows a slight indistinct prominence. But on endocasts of the earliest whales one finds, apparently as one more trace of their carnivore parentage, an oval prominence at the site of the PB—in the Middle Eocene *Prozeuglodon* as well as in the Upper Eocene *Zeuglodon* (Dart; no measurements). In the Miocene *Prosqualodon*, the pituitary region of the brain case is flat.

The peculiarities of the cetacean PB are: the absence of a pars intermedia and of a residual lumen, and the *great size of the extremely vascular glandular lobe* which is completely separated by a dural fold from the small avascular neural lobe.

The total weight of the whale PB naturally is very small indeed if expressed in percentage of body-volume: 0.0027–0.0034 (man: ♂, 0.010; ♀, 0.014). But Valsö weighed anterior and posterior lobes of several *Balaenoptera sibbaldi* separately; maximum, minimum and medium numbers are 53.3–16.7–32.5 and 1.9–1.0–1.4 g., respectively. From these numbers the present writer has calculated the ratio of neural lobe to glandular lobe, as: maximum, 1:28; minimum, 1:16.7; medium 1:23. The last-named (medium) proportion also results from Wislocki and Geiling's weights found in a *Physeter* of 45,000 kg. body-weight: pars posterior, 0.55; pars anterior, 12.7 g. (1:23), and likewise from their *Balaenoptera physalus* weights: 1.4 and 32.5 (1:23). Great though the variability in these weights is, *no such ratio is found in any other PB investigated*. From values compiled by Wislocki and Geiling, and van Dyke, the following ratios were calculated for comparison: man: ♂, 1:3.0–3.3, ♀, 1:4.5–4.8; cat: ♂, 1:2.2, ♀, 1:1.8; rabbit: ♂, 1:3.6, ♀, 1:5.1; rat: ♂, 1:4.5–7.5, ♀, 1:5.7–12.2.

If Geiling and Robbins' dorsal views of the intact PB of adult specimens of five cetacean genera (*The Pituitary Gland*) are viewed from our present standpoint, they at once show that the peak of size discrepancy between the two pituitary lobes is reached in the largest genera. Each figure shows the neural lobe lying on a glandular lobe of similar contours like a small object on a large cushion. But the transverse diameters of the neural and glandular lobes, as taken from the figures, are: Denticeti:

Tursiops truncatus (maximum body-length: 4 m.): 6 and 10 mm. = 1:1.7

Delphinapteras leucas (6 m.): 11 and 23 mm. = 1:2.1

Physeter macrocephalus (23 m.): 3.5 and 21.5 mm. = 1:6.1

Mysticeti:

Balaenoptera physalus (24 m.): 7.5 and 24 mm. = 1:3.2.

Second specimen: 8.5 and 26 mm. = 1:3.1

Balaenoptera sibbaldi (31 m.): 7.5 and 35 mm. = 1:4.7.

These proportions of transverse diameters are not, of course, the proportions of lobe volumes, the discrepancy of which is far greater. In a side view of a *Physeter* PB, the neural lobe is seen as a thin tongue lying on the huge ball of the glandular lobe. But even the diameters show that the characteristic described as particularly *striking* and *obscure*, namely the relative size of the growth-promoting lobe, is the *more striking* within each suborder, the larger the body-size attained in the species, and

therefore *not obscure*. The phenomenon is, in the writer's opinion, fully explained by the fact that the order in which these peculiar PBs occur is the order in which the largest animals developed. Judging from the anatomy of the PB in the porpoise, it seems that a group which is prone to develop giant forms may be provided with a relatively large glandular lobe in its smaller representatives too.

The largest known primate was the Pleistocene *Megaladapis* whose skull was over 30 cm. in length—like *Aepyornis*, a native of Madagascar. Unfortunately, an endocast exists only of the upper part of the brain case. The endocranial casts of *Homo primigenius* likewise do not include the PB.

V. THE RELIABILITY OF THE PALAEO-ENDOCRINO-LOGICAL CONCLUSIONS

Doubts have been expressed regarding the reliability of the palaeontologists' inference from the size of the pituitary fossae to their contents. They can now be considered resolved by the data given above, at least in so far as the size differences between the fossae of small ancestors and truly gigantic descendants are concerned. The increase in size, relative to brain size, of the latters' pituitary fossae cannot be due to anything but an enlargement of the growth-promoting glandular lobe of the PB.

Certainly the fossa contains, apart from the pars glandularis proper: meninges, vessels, sometimes cartilage, (in mammals) part of the tuber cinereum, sometimes part of the infundibulum which may contain a cavity, two further but smaller epithelial parts, viz., pars intermedia (absent, e.g., in birds and whales) and pars tuberalis (absent in certain lower vertebrates and in sloths), and, always, a pars neuralis. The latter has recently been found to be another gland of internal secretion (van Dyke, II, p. 291); its hormones, however, influence but the movements of the uterus, blood pressure, and diuresis—on experimental removal of the neurophysis alone, no visible function is suspended, and of course the body is not changed. The changes in body build consequent on radical hypophysectomy are, therefore, due to the loss of the pars glandularis.

Outstanding among these changes is the cessation of growth, although about 15 different hormones are ascribed to the gland. Outstanding among the differences between fossil vertebrates, in

the phylogeny of which the increase in fossa hypophyseos volume far surpasses the increase in volume of the rest of the neurocranium, is the difference in body-size.

It is true that differences have been found between the PBs of small and large related living animals which evade palaeontological investigation, namely, different proportion of the lobes within the pituitary compound, and differences in the histological structure of the glandular lobe. No volumetric comparison of PB or fossa would reveal an increasing preponderance of the glandular, growth-promoting lobe such as is observed in a comparison of the PBs in the whales with increasing body-size. The same would, of course, apply to the two pigeon races of 28 and 55 cm. body-length, the PBs of which have been compared by Rost. He found a considerable amount of colloid-filled cysts in the PB of the smaller race which he regards as holding back in the gland hormones not needed in the formation of the smaller body. Rost's following statement recalls our comparative observations on whales:

"Der Vergleich des glandulären Anteils der Hypophyse lässt zunächst einen wesentlichen Unterschied im Hinblick auf ihre Volumina erkennen, welche in einem Verhältnis von etwa Rö:Mö [larger to smaller race] = 3:2 stehen. Dieses Verhältnis ist in Übereinstimmung zu bringen mit dem Unterschiede der Körperdimensionen" (p. 263).

Unfortunately, neither in rabbits, whales, nor pigeons (apparently the only living animals in which so far PBs of small and large representatives have been compared) has the size ratio between PB and brain been investigated. While these comparisons furnish no direct parallels to our results of endocranial cast measurements, the finding of extraordinarily large glandular lobes in the giant whales and pigeons indirectly stresses our assumption that a larger pituitary fossa of a larger animal signifies an enlargement of no other part of the PB than the glandular lobe.

It follows from the various evidences now at hand that Nopcsa was perfectly right when correlating dinosaurs' giantism with their hypertrophic PB. Yet only recently an objection to Nopcsa's theory has been voiced which must be discussed since it comes from the discoverer of the largest reptilian PBs, Janensch. "Die bekannte Hypothese, die die Riesengrösse der Sauropoden mit einer angenommenen Hypertrophie der Hy-

pophyse in Zusammenhang bringt, scheint mir bei zahlenmässiger Prüfung an Wahrscheinlichkeit einzubüssen."

It is true that the biggest of the three contemporaneous sauropods investigated by Janensch did not have the largest fossa, neither absolutely nor in relation to brain-size. But not even Nopcsa would have expected this; even when referring to established ancestry, he qualified his statement of increase in PB volume to "on the whole".

Apart from his specific discovery that the PB of the largest sauropod individual was not the largest in the suborder, Janensch's general reason for doubting Nopcsa is his objection to comparisons of brain volume and PB volume. This he thinks misleading because the brain of the giant sauropods "naturgemäss relativ klein war"—as, let us add, was any part of their relatively tiny head. While we regard it as fortunate to find the growth-promoting organ so near to the brain, the prototypal organ which is least involved in body enlargement, Janensch stresses the importance of comparing PB-volume with body-volume. His above-quoted conclusion rests on the fact that the PB compares to the body: in pigeons, in the proportion of 1:23,000; domestic fowl, 1:110,000; ducks, 1:200,-000; but 1:800,000 in *Barosaurus* and 1:1.800,-000 in *Brachiosaurus* whose PB thus appears to be small.

To relegate these figures to their right place in our argument, it is hardly necessary to point to the mechanical impossibility of finding room, in the miniature head of a bulky sauropod, for a PB as large in relation to body-size as is provided for in the big skull of a slender bird. It is sufficient to stress the ordinary variability of the volume of the PB, the relations of which are far from being restricted to growth alone. For instance, the ♂/♀ difference in children from birth to five years of age is no less than a PB-weight:body-weight ratio of ♂♂ 1:44994/♀♀ 1:3252 (Lucien). The average weight of the PB in a nulliparous woman is 61.8 centigrams, in primiparae it is 84.7 cg., in multiparae, 106 cg.; the enlargement takes place in the anterior lobe only, does not affect the length of the PB (hemmed in by the sella), but increases the breadth from 14.4 to 17.5 and the height from 5.9 to 8.0 mm. (Erdheim and Stumm, quoted from Wittek). Wittek's examination of 734 cattle showed that while there is a steady increase of pituitary weight with increase of body-weight in both sexes, two 3-year-old bulls of the

same body-weight had PBs of 1.90 and 3.02 g., respectively; two such cows, even 2.6 and 6.2 g., respectively.

It follows that comparison of conditions in related, contemporaneous, single individuals cannot impair a statement which applies to extensive phylogenetic development: namely, that small dinosaurs had relatively small PBs while PB-volume increased, on the whole, in direct proportion to the development of their giantism.

Consequently, it may well be that when the suggestions made in this paper are carried out by neozoologists, the differences in structure and in size relative to the brain between the PBs of small and gigantic genera expected by the palaeozoologist will fail to be found. Such cases are already established; but they only recall the palaeo- and neo-zoologists' different views of the inheritance of "acquired characters": the palaeozoologist firmly believes that he can follow this phenomenon *throughout the ages*, to which the neo-zoologist retorts that it cannot be demonstrated *in our lifetime*.

The difference between the PB of a small ancestral genus and that of its gigantic descendant does indeed not seem to be paralleled in the volume of the PB of *Felis domestica* and *Felis tigris*, our contemporaneous species of one genus on the same evolutionary level. Robb has already denied any difference between the relationship of PB-weight and that of eyeballs, etc., to body-weight, on the ground that there is no difference in the mass of the PB that can be correlated to the size differences attained in two breeds of one and the same living species, the domestic rabbit. In both these cases, the composition of the PB is not known; furthermore, the animals compared differ exclusively by their size. It is, however, not only size by which *Aepyornis* is distinguished from *Mullerornis*, but there is also a progressive increase of, for instance, bone density in the family. Not only because of their size are the sauropods called "dragons". A long evolution led them away from the unspecialized reptilian type and size of their ancestors. The hippopotamus is not just an enlarged pig as the tiger is an enlarged cat; the sperm whale is not an enlarged porpoise but a porpoise further developed in many ways. It remains to be investigated which kind of size differences are always paralleled by definite size differences of the PB.

No external cause can be made responsible for the development of either individual or phylo-

genetic hyperpituitary giantism. Bailiff's experiments have shown that the PB actually is influenced by external agents: microscopic changes and hypersecretion were produced in the glandular but not in the neural lobe by exposure of rats to cold for 9–56 hours. But human as well as animal giants with extraordinarily active PBs have been observed to develop in their normal surroundings. The sudden manifestation of human hyperpituitarism is a pathological phenomenon to the medical profession whose object is present-day man; yet the palaeontologist notes that it is apt to become a hereditary disposition. The occasional occurrence of chickens with ostrich-like feather pecularities, however, is a mutation for the zoologist (Murphy); PB and thyroid may be supposed to be the primarily affected organs. Likewise, one tadpole of one frog family in Hahn's aquarium grew to double, and three tadpoles grew to $3\frac{1}{2}$ times the size of the others, and they exhibited very marked anterior lobe hyperplasia.

Phylogenetic trend towards giantism also developed in every kind of environment, through such still unexplained changes in the germ plasm. Its occurrence can all the less be intrepreted in terms of Lamarckism since the accompanying bone changes vary from retardation of epiphysis ossification with increased massiveness of the long bones (sauropod dinosaurs) to an abundance of bony outgrowths of the skull (ceratopsid dinosaurs, giant titanotheres, and rhinoceroses) and osteosclerosis (whales). This recalls the different response of different animals to experimental hyperpituitarism.

Whichever conditions may one day be found to start and pave the way for the formation of giant animals, the fact can to-day be considered established, by the palaeontological evidence described above, that phylogenetic evolution of definitely gigantic types is accompanied by a conspicuous enlargement of the anterior pituitary lobe.

VI. SUMMARY

Clinical experience shows that in human giants the glandular lobe of the pituitary body is abnormally enlarged. Experimental administration of glandular lobe extracts stimulates body-growth to such an extent that the animals may grow beyond the maximum normal size of their species. The present investigation furnishes some parallels in natural evolution: phylogenetic development of giantism in reptiles, birds, and mammals was found to be accompanied by a striking enlargement of the pituitary fossa which can only be due to an enlargement of the glandular lobe which secreted the growth hormone.

In giant Jurassic dinosaurs, the volume of the fossa hypophyseos may amount to 10 per cent of the brain-case volume.

Among the subfossil aepyornithids, pituitary volume compares to forebrain volume as 1:102 in the ancestral genus *Mullerornis* (body-height:148 cm.); within the genus *Aepyornis*, the ratio rises from 1:82 in *A. hildebrandti* (160 cm.) to 1:36 in *A. medius* (211 cm.), and to 1:24 in *A. maximus* (221–300 cm.). While body-height was about doubled, the volume of the forebrain increased by four fifths, but PB- volume became eightfold. The extraordinary size of the aepyornithid eggs and the loose luxuriant plumage of the large ratites now appear as signs of hyperpituitarism.

Similar hypophyseal development as in the aepyornithids is observed in the dinornithids. The small dinornithid *Anomalapteryx* had a relatively larger PB than the larger ostrich; the same was the case in the aepyornithid of ostrich size, and the composition of the porpoise PB points in the same direction: phyla apt to develop giant forms may be provided with a proportionately large glandular lobe also in the smaller representatives. The extraordinary size of the cetacean, particularly of the giant whales' anterior lobe is unparalleled.

Although the sirenian skull usually possesses no pituitary groove, the PB of the 10 m.-long subfossil *Rhytina* left an extensive impression in the sphenoid bone. A comparison of a large series of mammalian endocasts has shown that the PB of giant forms may model the skull base in orders which possess no sella.

The present report is mainly based on endocranial casts, mostly of single representatives of the species. Its significance remains to be tested, as far as this is possible within the extant animal world, by comparative investigation of pituitary glands.

preliminary manuscript; also to Dr. A. J. E. Cave, Assistant Conservator of the Museum of the Royal College of Surgeons, for permission to study this museum's collection of endocranial casts (the brain collection was stored in a bomb proof cellar). Prof. C. Lamberton, of the Académie Malgache, and Prof. C. Wiman, Upsala, my collaborator on the Académie's aepyornithid specimens, were so generous as to allow me to mention data not yet published in the Académie's Memoirs.

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