

THE COMPARATIVE ANATOMY OF THE THYROID AND ADRENAL GLANDS IN WILD ANIMALS

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The hypothesis underlying the investigation described in the following pages is that the adrenals and the thyroid are the energy-controlling glands of the body; that the energy characteristics of the animal depend primarily on the thyroid-adrenal relationship. Being a gland of steady and continuous activity, one would expect that the thyroid gland would be large in the more highly sensitized and active animals, and that it would be relatively small in those animals that are slow or that carry special means of protection, such as poison, carapace or offensive odor.

In the human being the thyroid gland has more than twice the weight of the adrenal glands. Since man differs in his energy characteristics from animals in the wild state, the question arises whether such animals differ widely from man and from each other with respect to the development of these energy regulators.

The adrenal glands are emergency glands (Cannon), which are called into action for sudden needs rather than for long cycles, like the thyroid gland. Therefore, it may be assumed that the adrenal glands control the explosive outbursts of energy. The secretion of the adrenal gland, discharged into the blood stream, empowers the animal for a short time with a strength and speed far beyond that of its ordinary range.

From the above considerations we inferred that the relative sizes of the adrenal and thyroid glands of animals might vary according to the energy characteristics and habits of the animals. In fact, we believed that the energy characteristics of animals, so far as activity is concerned, might almost be determined by a comparative study of the relative sizes of the thyroid and the adrenal glands and by their relations to the body weights.

To test these points, during the past three years, I have obtained specimens of the thyroid and adrenal glands of a widely separated variety of animals, in order to determine the relationship between the size of the animal and the weights

of these important glands as well as the energy characteristics of the animals. The research, although not completed, would seem to support the theory that such relationships exist.

The Crile-Bole-Fuller Expedition was organized in October, 1931. Although the main objective was to secure specimens of the fauna of the Southwestern States, one objective was to secure evidence whereby to test the validity of this theory. The members of the expedition were: Arthur B. Fuller, George W. Phillips, and Benjamin P. Bole, Jr., of the Staff of The Cleveland Museum of Natural History; Harold L. Madison, Jr., and myself, my purpose being to secure weights of the brain, thyroid and adrenal glands of as many species of animals as possible. The research has included three collections:

First: The glands of wild animals collected in Arizona.

Second: The glands of domestic and of wild animals collected in the vicinity of Cleveland, and of wild animals collected from importers and zoological gardens in Cleveland, New York, Detroit, California, etc.

Third: The glands of domestic and of wild animals collected in Cumberland Island, Georgia, and the extreme South of Florida.

All these glands were preserved in Klotz Solution. They were weighed and photographed and submitted to Dr. Allen Graham, of the Cleveland Clinic Foundation, for microscopic examination. Only normal glands are used in the averages given in the following section, entitled, "Findings."

The first collection was secured October-December, 1931, at Agassiz Peak in the Coconino Forest Reserve, near Flagstaff, Arizona; in the San Francisco Crater, immediately overlooking Flagstaff; at Schultz Pass; at Seligman; at Oakland, Arizona; in the Kaibab Forest; in Oak Creek Canyon; in The White Tank Mountains (near Flagstaff, Arizona) and in the Catalina Mountains, at altitudes varying from 2,000 to 12,000 feet. One hundred and seventeen sets of glands were collected in the Southwestern Expedition, including those of small rodents varying in size from the small mountain meadow mouse to the large Mexican pack rat; of the gopher, the prairie dog and the rabbit; of many varieties of squirrels and chipmunks; of several varieties of skunks; of the lynx, coyote, mountain lion, peccary (wild pig); mule deer and white-tailed deer.

On my return to Cleveland, I continued this study of the comparative size of the thyroid and adrenal glands and col-

lected thirty-three sets of glands of such domestic animals and wild animals as could be found about Cleveland, as well as of animals from the zoological gardens of Detroit and Cleveland. However, inasmuch as the thyroid glands of the domestic animals from the slaughterhouses in Cleveland were goiterous, as were those of the wild animals from the Zoological Gardens of Cleveland and Detroit, such as a black bear (*Euarctos americanus*), a baboon (*Cynocephalus hamadryas*), a chita (*Acynonyx jubatus*), an axis or spotted deer (*Cervus axis*), and lions (*Felis leo*) and since Dr. Graham, of the Cleveland Clinic Foundation, found that the thyroid glands of the Arizona white-tailed deer, the peccary, and the coyote collected in Arizona were goiterous, it seemed as if it might be interesting to compare the observations of animals in goiter belts with those of animals that had been bred in a comparatively "goiter-free country," such as Florida which, having ocean on both sides, should not be lacking in iodine.

Through the courtesy of Dr. T. S. Field, Dr. F. W. Beck, and Farris and Company, of Jacksonville, Florida, I had the opportunity to collect eighteen sets of glands of cattle, including bulls, steers and cows, pregnant and non-pregnant animals which in appearance were sleek and rugged. The glands were collected immediately after death. In only four instances out of the series of eighteen, i. e., in 22 per cent of the cases, did the weight of the thyroid gland exceed that of the adrenal glands. In Cleveland, out of a series of twenty-eight, in twenty-two instances, 75 per cent, the weight of the thyroid gland exceeded that of the adrenal glands.

In the winter of 1933, through the courtesy of Dr. P. C. Perry and by permission of Mr. Morrison Carnegie, Mr. Fuller of the Cleveland Museum of Natural History, who was a member of the Southwestern Expedition, and I had the added opportunity of collecting various types of wild animals from Cumberland Island, one of the most southern of the Golden Islands of Guale. Cumberland Island afforded an untouched wild life from which were collected specimens of the Florida white-tailed deer, wild pig, raccoon, pocket gopher and alligator. From Southern Florida we secured a crocodile as well as an alligator, representing the sluggish, inactive type of animal, a direct contrast to the alert, habitually active deer.

FINDINGS

MICE

(*Microtus alticola alticola*; *Peromyscus*; *Sorex vagrans monticola*;
Onychomys—Mountain Meadow Mouse; Deer Mouse;
 Shrew; Grasshopper Mouse)

Characteristics: These four types of mice differ considerably in characteristics. Where we found them, the Shrew (*Sorex vagrans monticola*) is the smallest, the Deer Mouse (*Peromyscus*) is next in size, and the Mountain Meadow Mouse (*Microtus alticola alticola*) and the Grasshopper Mouse (*Onychomys*) are the largest. I understand, however, that in different parts of the country the relative sizes of these four types vary.

The *Sorex vagrans monticola* and the *Onychomys* are faster and more active than the *Microtus* or the *Peromyscus*. The *Peromyscus* travels on top of the ground; the *Microtus* moves in tunnels. The *Onychomys* lives largely in trees, and, like the *Sorex*, chases and eats the others.

The Thyroid Gland: In all of these varieties of mice the thyroid lobes appeared as long, reddish bodies, lying one on either side of the larynx and a little below it. There was probably an isthmus but it was broken by the slightest pressure. The lobes lay close to the trachea and usually were bound down by a little overlying tissue.

The Adrenal Glands: The adrenal glands in these four types of mice lay at the upper tip of the kidneys. In the *Microtus*, the *Peromyscus* and the *Onychomys* they were so closely attached to the kidneys by a thin membrane of tissue that they seemed to be a part of the kidneys. In the *Sorex* they were separated from the kidneys, lying nearer the blood supply. In shape the adrenal glands were oval or more nearly round; in color, greyish.

Relative Sizes of the Thyroid and Adrenal Glands: In the *Onychomys* (Grasshopper Mouse) the average weight of the thyroid gland was 1.23 mg.; of the adrenal glands, 29.16 mg.; the adrenal glands thus being 23.7 times as large as the thyroid gland (Plate I, Figure 1). In the *Sorex vagrans monticola* (Shrew), the weight of the thyroid gland was 1.6 mg.; of the adrenal glands, 6.2 mg., the adrenal glands being 3.9 times as large as the thyroid gland (Plate I, Figure 2). In the *Microtus alticola alticola* (Mountain Meadow Mouse) the average weight of the thyroid gland was 2.2 mg.; of the adrenal glands, 8.12 mg., the adrenal glands being 3.7 times as large as the thyroid glands (Plate I, Figure 3). In the *Peromyscus* (Deer Mouse), the average weight of the thyroid gland was 2.25 mg.; of the adrenal glands, 6.4 mg., the adrenal glands being 2.8 times as large as the thyroid gland (Plate I, Figure 4).

SQUIRRELS

(*Sciurus fremonti mogollonensis*, *Sciurus arizonensis*, *Sciurus aberti*—
 Pine or Red Squirrel, Grey Squirrel, Abert's Squirrel)

Characteristics: The Pine or Red Squirrel (*Sciurus fremonti mogollonensis*) is extremely alert, not timid, and very active, leaping about in the trees at high speed all day and far into the night. It does not hibernate.

The Arizona Grey Squirrel (*Sciurus arizonensis*) is larger than the Pine or Red Squirrel. In activity it ranges between the Pine or Red Squirrel and the Abert's Squirrel and is more wary than the Pine Squirrel. It partially hibernates in the winter.

The Abert's Squirrel (*Sciurus aberti*) is larger and less active than either the Pine or Red Squirrel or the Arizona Grey Squirrel. In comparison, the Abert's Squirrel is a fat and lazy animal, not alert and not timid.

The Thyroid Gland: In the Pine or Red Squirrel, the lobes of the thyroid gland were long and red and were connected by an isthmus. The position of the lobes was the same as that of the thyroid glands in mice, but the gland was larger in relation to the size of the animal.

In the Arizona Grey Squirrel the lobes of the thyroid gland were long and were connected by an isthmus.

In the Abert's Squirrel the thyroid gland was a little larger than in the Pine or Red Squirrel.

The Adrenal Glands: In the Pine or Red Squirrel the adrenal glands were grey. They lay almost under the kidneys and out of sight. They were long and sausage-like in shape, and were so closely attached to the kidney that they were often flat on one side.

In the Grey Squirrel the adrenal glands were yellowish and long. They lay at the inner side of the kidneys.

In the Abert's Squirrel the adrenal glands were roundish but small. They lay at the upper-inner tip of the kidneys and extended downward.

Relative Sizes of the Thyroid and Adrenal Glands: The average weight of the thyroid glands of the *Sciurus fremonti mogollonensis* (Pine or Red Squirrel) was 9.5 mg.; of the adrenal glands, 86.9 mg., the adrenal glands being 9.15 times as large as the thyroid gland (Plate I, Figure 5).

In the *Sciurus arizonensis* (Grey Squirrel) the weight of the thyroid gland was 26 mg.; of the adrenal glands, 197 mg., the adrenal glands being 7.58 times as large as the thyroid gland (Plate I, Figure 6).

In the *Sciurus aberti* (Abert's Squirrel) the average weight of the thyroid glands was 30.1 mg.; of the adrenal glands, 204 mg., the adrenal glands being 6.77 times as large as the thyroid gland (Plate I, Figure 7).

CHIPMUNKS AND GROUND SQUIRRELS

(*Eutamias*, *Ammospermophilus*, *Citellus*, *Callospermophilus*—
Chipmunk, Antelope Chipmunk, Ground Squirrel,
Mantle Ground Squirrel)

Characteristics: The Chipmunk (*Eutamias*) is very alert. It is not quite so active as the Pine or Red Squirrel, but is more active than the Abert's Squirrel. It is vegetarian and migratory.

The Antelope Chipmunk (*Ammospermophilus*) is about the size of the Chipmunk and is fully as active, if not more so.

The Ground Squirrel (*Citellus*) is about the size of the Chipmunk and the Antelope Chipmunk, but is not so active as either.

The Mantle Ground Squirrel (*Callospermophilus*) is less active than the Pine or Red Squirrel, more active than the Abert's Squirrel, and less active than the Chipmunk. In size, it is about twice as large as the Chipmunk.

The Thyroid Gland: In the Chipmunk the thyroid gland consisted of two lobes lying one on either side of the larynx, and it had an isthmus.

In the Antelope Chipmunk the lobes of the thyroid gland were long and red but small, and lay below the larynx.

In the Ground Squirrel the lobes of the thyroid gland were long and red, but small.

In the Mantle Ground Squirrel the lobes of the thyroid gland were light red, long and large, and were connected by an isthmus.

The Adrenal Glands: In the Chipmunk the adrenal glands were long and grey and lay under the kidneys like those of the Pine or Red Squirrel. In comparison with the adrenal glands of the Pine or Red Squirrel, they were smaller but were larger than those of the Abert's Squirrel.

In the Antelope Chipmunk the adrenal glands were large and grey and long. They lay at the upper-inner tip of the kidney, extending almost to the center of the kidney.

In the Ground Squirrel the adrenal glands were brown in color, long and small. They lay at the upper-inner tip of the kidney and extended down toward the center, lying very close to the kidney.

In the Mantle Ground Squirrel the adrenal glands were yellowish in color, long and large. They lay at the upper-inner side of the kidney.

Relative Sizes of the Thyroid and Adrenal Glands: The average weight of the thyroid glands of the *Eutamias* (Chipmunk) was 2.03 mg.; of the adrenal glands, 15.08 mg., the adrenal gland being 7.4 times as large as the thyroid gland (Plate I, Figure 8).

The average weight of the thyroid glands of the *Ammospermophilus* (Antelope Chipmunk) was 6.4 mg.; of the adrenal glands, 39 mg., the adrenal glands being 6.09 times as large as the thyroid gland (Plate I, Figure 9).

The weight of the thyroid gland of the *Citellus* (Ground Squirrel) was 4 mg.; of the adrenal glands, 19 mg., the adrenal glands being 4.75 times as large as the thyroid gland (Plate I, Figure 10).

The weight of the thyroid gland of the *Callospermophilus* (Mantle Ground Squirrel) was 9.5 mg.; of the adrenal glands, 35 mg., the adrenal glands being 3.68 times as large as the thyroid glands (Figure 11).

PRAIRIE DOG

(*Cynomys*)

Characteristics: Although the Prairie Dog (*Cynomys*) is supposed to be an active animal and covers quite a bit of ground in the vicinity of its hole, it is a timid animal and depends upon its ability to get into its hole quickly in order to escape its enemies. So, although its activity is limited in range, it is alert and runs rather fast for its size. The Prairie Dog begins its hibernating season in November, and at the time of our expedition many of them were in hibernation.

The Thyroid Gland: The thyroid gland of the Prairie Dog was large, red and long, usually lying below the larynx.

The Adrenal Glands: The adrenal glands were brown, oval and small, lying on a level with the upper-inner tip of the kidney, but quite separated from the kidney.

Relative Sizes of the Thyroid and Adrenal Glands: The average weight of the thyroid gland of the *Cynomys* (Prairie Dog) was 25 mg.; of the adrenal glands, 28 mg., the adrenal glands being 1.12 times as large as the adrenal glands (Figure 12).

POCKET GOPHER

(*Thomomys*)

Characteristics: The Pocket Gopher (*Thomomys*) relies entirely upon its digging powers for food and escape. It is not a very active animal, that is, it does not cover much ground, but is alert and possesses a well-developed pair of front legs with which it digs for roots and digs tunnels in which to store them.

The Thyroid Gland: In each of the series of 39 gophers examined, the thyroid gland consisted of two lobes, dark reddish in color and almost oval in shape. The lobes were not very long and were flat on the inner side. They lay on either side of the larynx, but below and entirely separated from it.

The Adrenal Glands: The adrenal glands were dark grey in color, and almost oval in shape. They were larger in some animals than in others and were sometimes flat on one side and occasionally on both sides. They usually lay at the upper-inner side of the kidney, but separated from it by tissue.

Relative Sizes of the Thyroid and Adrenal Glands: The average weight of the thyroid gland of the *Thomomys* (Pocket Gopher) was 3.95 mg.; of the adrenal glands, 11.88 mg., the adrenal glands being three times as large as the thyroid gland (Plate I, Figure 13).

RATS

(*Neotoma*, *Dipodomys*, *Mus Norvegicus*—Mexican Pack Rat, Kangaroo-Rat, and Gray Norway Rat)

Characteristics: The Mexican Pack Rat (*Neotoma*) is a bold, lumbering animal with large teeth. It does not show any excessive degree of speed, but works all night carrying away objects which are often in excess of its own weight.

The Kangaroo-Rat (*Dipodomys*) is about the size of the Chipmunk, and its cheek pouches resemble those of the Pocket Gopher. The Kangaroo-Rat burrows beneath rocks. It is more active than the Mexican Pack Rat and has elongated hind legs, large eyes, well developed ears, and a long tail.

The Thyroid Gland: In each of our series of sixteen Mexican Pack Rats the lobes of the thyroid gland were long, reddish-brown in color and were connected by an isthmus. One lobe lay on either side of the larynx, half its length extending over the trachea. In every specimen there was a very definite isthmus.

In the Kangaroo-Rat the lobes of the thyroid gland were dark red and flat. They were wide at the top, narrower toward the base and lay right over and extended below the larynx and were connected by an isthmus.

The Adrenal Glands: In the Mexican Pack Rat the adrenal glands were light grey in color. They were long and often were attached to the kidneys, being flat on the attached side and rounded on the other. In most cases they were attached at the middle of the upper end of the kidneys and were held down by a thin membrane, but in some instances they lay near the inner side of the upper end of the kidneys and were separated from them by tissue.

In the Kangaroo-Rat the adrenals were grey and oval. They lay at the inner-lower end of the kidneys, separated by tissue.

Relative Sizes of the Thyroid and Adrenal Glands: In the *Neotoma* (Mexican Pack Rat) the average weight of the thyroid gland was 11.1 mg.; of the adrenal glands, 61.7 mg., the adrenal glands being 5.56 times as large as the thyroid gland (Plate I, Figure 14).

In the *Dipodomys* (Kangaroo-Rat) the average weight of the thyroid gland was 1.15 mg.; of the adrenal glands, 6 mg., the adrenal glands being 5.22 times as large as the thyroid gland (Plate I, Figure 15).

In the ordinary *Mus Norvegicus* (Grey Norway Rat) which is large, alert, and fierce, the thyroid gland was 8 mg.; the adrenal glands, 62 mg., the adrenal glands being 7.75 times as large as the thyroid gland (Plate II, Figure 16).

MUSK-RAT OR MUSQUASH

(*Ondatra zibethica*)

Characteristics: The Musk-Rat is largely a water animal. It is slow and massively built, the average weight being about two pounds. In character it is sly but, like the brown rat, it may be very savage. Its food consists of grasses, fish, and even carrion.

Relative Sizes of the Thyroid and Adrenal Glands: In the *Ondatra zibethica* (Musk Rat) the weight of the thyroid gland was 43 mg.; of the adrenal glands, 156 mg., the adrenal glands being 3.63 times as large as the thyroid glands (Plate II, Figure 17).

WOODCHUCK

(*Marmota monax monax*)

Characteristics: The Woodchuck does not store food for the winter. It hibernates completely. Its average weight is from eight to ten pounds. Although we had several Woodchucks in our series, those in hibernation and just out of hibernation were of special interest.

Relative Sizes of the Thyroid and Adrenal Glands: One of our specimens of *Marmota monax monax* (Woodchuck) was dug out in early winter while still asleep, and was killed instantly. The weight of the thyroid gland was 197.5 mg.; of the adrenal glands, 172.5 mg., the thyroid gland being 1.14 times as large as the adrenals.

A second Woodchuck was caught in February, just as it was coming out from hibernation. It moved slowly, was easily caught, caged and brought to the Cleveland Clinic where it showed little activity or desire to eat. After three days it was killed. The weight of the thyroid gland was 240 mg.; of the adrenal glands, 404 mg., the adrenal glands being 1.68 times as large as the thyroid gland.

Thus in two animals of practically the same weight the thyroid and adrenal glands weighed respectively 42.5 mg. and 231.5 mg. more in the animal just out of hibernation than in the animal in hibernation, while in the animal in hibernation the thyroid gland was larger than the adrenal glands and in the animal out of hibernation this relation was reversed, the adrenal glands being larger than the thyroid gland.

RABBITS

(*Silvilagus auduboni*; *Lepus californicus*—
Cotton Tail Rabbit; Jack Rabbit)

In the Cotton Tail Rabbit (*Silvilagus auduboni*), caught near Cleveland, the average weight of the thyroid gland was 3.7 mg.; of the adrenal glands, 86.3 mg., the adrenal glands being 23.3 times as large as the thyroid gland (Plate II, Figure 18).

In our one Jack Rabbit (*Lepus californicus*) of Arizona, the thyroid gland weighed 147 mg., the adrenal glands 256 mg., the adrenals being 1.74 times as large as the thyroid gland (Plate II, Figure 19).

The average weight of the Cotton Tail Rabbit is 2.5 pounds; of the Jack Rabbit, 6 pounds.

RACCOON

(*Procyon lotor*)

Characteristics: The Raccoon (*Procyon lotor*) is carnivorous. It hibernates during the severe part of the winter. It is about 36 inches long, including its eight to ten-inch tail, and weighs from fifteen to twenty-five pounds.

Relative Sizes of the Thyroid and Adrenal Glands: In the *Procyon lotor* (Raccoon), collected in Cumberland Island, Southern Georgia, in December, the weight of the thyroid gland was 222 mg., of the adrenal glands, 1,651 mg., the adrenal glands being 7.4 times as large as the thyroid gland.

FOXES

(*Urocyon cinereoargenteus scotti*; *Vulpes fulva*—Grey Fox; Red Fox)

Characteristics: Our series of Grey Foxes was collected in Arizona. The Grey Fox (*Urocyon cinereoargenteus scotti*) is an active, carnivorous animal, but does not depend on sudden outbursts of energy as does the deer. Its average weight is seven pounds.

The Thyroid Gland: The thyroid gland was long and lay below the larynx.

The Adrenal Glands: The adrenal glands were greyish-yellow in color, flat on one side and round on the other. They lay on the inner side of the kidneys but were separated from them. In two out of our six specimens the adrenal glands were not found in the same position in relation to the kidneys, and were constricted in the center, like a peanut.

Relative Sizes of the Thyroid and Adrenal Glands: The average weight of the thyroid glands of the *Urocyon cinereoargenteus scotti* (Grey Fox) was 112.8 mg.; of the adrenal glands, 279.1 mg., the adrenal glands being 2.48 times as large as the thyroid gland (Plate II, Figure 20).

Our one specimen of the Red Fox (*Vulpes fulva*) was secured near Cleveland.

The Thyroid Gland: The thyroid gland seemed to be relatively large.

The Adrenal Glands: The adrenal glands were dissimilar in size, in form, and in their position in relation to the kidneys.

Relative Sizes of the Thyroid and Adrenal Glands: The weight of the thyroid gland of the *Vulpes fulva* (Red Fox) was 405 mg.; of the adrenal glands, 420 mg., the adrenal glands being 1.04 per cent larger than the thyroid glands.

CATS

(*Bassariscus*; *Felis domesticus*—Ring-Tailed Cat, Domestic Cat)

An interesting comparison was that between the adrenal-thyroid ratio in a Domestic Cat (*Felis domesticus*) and in the Ring-Tailed Cat (*Bassariscus*) secured in Arizona. In the latter the average weight of the thyroid gland was 88 mg.; the adrenal glands 353.5 mg., the adrenals being four times as large as the thyroid gland (Plate II, Figure 21). In the domestic cat the thyroid gland weighed 216 mg.; the adrenal glands 518 mg., the adrenal glands being only 2.4 times as large as the thyroid gland (Figure 22).

SKUNKS

(*Spilogale*; *Conepatus mesoleucus*; *Mephitis*; Civet Cat or Spotted Skunk; Hog-Nosed Skunk; Common or Hooded Skunk)

Characteristics: Skunks are slow and deliberate; even when frightened they do not move rapidly. They are carnivorous and hibernate only in severe winters.

The Civet Cat or Spotted Skunk (*Spilogale*) is smaller than the Hooded or Common Skunk and is largely arboreal.

The Hooded Skunk (*Mephitis*) is about the size of a cat, but is heavier and more stockily built.

The Hog-Nosed Skunk (*Conepatus mesoleucus*) is the largest of the three and the least active.

Relative Sizes of the Thyroid and Adrenal Glands: The average weight of the thyroid gland of the *Spilogale* (Civet Cat) was 17.8 mg.; of the adrenal glands, 79.2 mg., the adrenals being 4.4 times as large as the thyroid gland.

The weight of the thyroid gland of the *Mephitis* (Common Skunk) was 96 mg.; of the adrenal glands, 348 mg., the adrenal glands being 3.62 times as large as the thyroid gland (Figure 23).

The average weight of the thyroid gland of the *Conepatus mesoleucus* (Hog-nosed Skunk) was 93 mg.; of the adrenal glands, 277.5 mg., the adrenal glands being 2.98 times as large as the thyroid gland (Figure 24).

PORCUPINE

(*Erethizon dorsatum*)

Characteristics: The Canadian Porcupine (*Erethizon dorsatum*) weighs from fifteen to twenty pounds. It is slow, clumsy and unafraid.

It is largely nocturnal and does not hibernate. Its food consists of leaves, bark, pods, etc.

Relative Sizes of the Thyroid and Adrenal Glands: In the *Erethizon dorsatum* (Porcupine) procured from Canada, the weight of the thyroid gland was 360 mg.; of the adrenal glands, 375 mg., the adrenal glands being 1.04 times as large as the thyroid gland.

COLLARED PECCARY

(*Pecari angulatus*)

Characteristics: The peccary (*Pecari angulatus*) is very agile and alert. It climbs mountains like a mountain goat and has great endurance. It moves rapidly for short distances and covers long distances at a time, sometimes twenty miles without a stop. It may be quite savage.

The Thyroid Gland: The lobes of the thyroid glands in our two specimens were very long, varying from three inches in length in one, to four and a half inches in length in the other. In both specimens the lobes were flat and hard and were connected by a wide isthmus.

The Adrenal Glands: The adrenal glands were bluish-grey, large, and approximately oval in shape except that one end was larger than the other and they were well separated from the kidneys.

Relative Sizes of the Thyroid and Adrenal Glands: The thyroid-adrenal ratios of these specimens are invalid as Dr. Allen Graham found both thyroid glands hyperplastic, in fact, in one the hyperplasia was "sufficient to be considered an exophthalmic goiter."

The weights, however, are interesting, if for no other reason than the size of the goiter.

Total Thyroid including isthmus	Total Adrenal
1200 mg.....	1800 mg.
20000 mg.....	2600 mg.

DEER

(*Homionus odocoileus*, *Odocoileus couesi*, *Odocoileus virginianus*—
Mule Deer, Arizona White-Tailed Deer, Florida
White-Tailed Deer)

MULE DEER

Characteristics: The period when we were in Arizona was the mating season for the very active migratory Mule Deer (*Homionus odocoileus*) which depends upon speed for its escape from its enemies. It moves in leaps and bounds, all feet leaving the ground simultaneously. For short distances the Mule Deer maintains a very rapid pace. Its weight ranges from 150 to 250 pounds.

The Thyroid Gland: The lobes of the thyroid gland of the Mule Deer were light or dark red in color, long, and with rounded ends. They lay far beneath the larynx with the lower ends out of sight, and had a large blood supply running throughout the gland. In none of our specimens did I find an isthmus.

The Adrenal Glands: The adrenal glands were dark grey, almost brownish in color, and oval in shape. They lay at the upper-inner side of the kidneys which were close to the vena cava.

Relative Sizes of the Thyroid and Adrenal Glands: The average weight of the thyroid glands was 2,725 mg.; of the adrenal glands, 5,425 mg., the adrenal glands being 1.99 times as large as the thyroid gland (Figure 27).

ARIZONA WHITE-TAILED DEER

Characteristics: The Arizona White-Tailed Deer (*Odocoileus couesi*) is only half the size of the Mule Deer. Like the Mule Deer, it covers the ground in leaps and bounds and in comparison with the Mule Deer would seem to be more active. It climbs mountains with the ease and agility and endurance of a mountain goat. The weight of the Arizona White-Tailed Deer ranges from 100 to 150 pounds.

The Thyroid Gland: The lobes of the thyroid glands of the Arizona White-Tailed Deer were red, large and long and had a large blood supply.

The Adrenal Glands: The adrenal glands of the Arizona White-Tailed Deer were dark, bluish-grey in color. They were large, were flat on both sides and had rounded edges. In some specimens they lay in different positions in relation to the kidneys, but usually they lay at the upper-inner side of the kidneys and were separated from them.

Relative Sizes of the Thyroid and Adrenal Glands: The relative sizes of the thyroid and adrenal glands of the Arizona White-Tailed Deer (*Odocoileus couesi*) are invalid, as Dr. Allen Graham found that all the thyroid glands showed hyperplasia. The weights are interesting, however, the average weight of the thyroid was 2,125 gm.; of the adrenals, 2,550 gm., the adrenal glands being 1.2 times as large as the thyroid gland (Plate III, Figure 26).

FLORIDA WHITE-TAILED DEER

Characteristics: The climate in Cumberland Island where these deer were collected is tropical. The animals live in a jungle of palmetto, underbrush and marsh. They were in poor physical condition, owing to drought, and were infested with parasites.

The Thyroid Gland: The thyroid glands of all of our specimens were pathologically enlarged.

The Adrenal Glands: The adrenal glands in all specimens were solid, roundish bodies.

Relative Sizes of the Thyroid and Adrenal Glands: Although the pathologic enlargement of the thyroid gland of the Florida White-Tailed Deer (*Odocoileus virginianus*) invalidates the thyroid-adrenal ratio, it is worth mentioning that even with pathologic enlargement of the thyroid gland, the average weight of the thyroid glands was 2.46 gm., of the adrenal glands, 2.67 gm., the adrenal glands being 1.08 times as large as the thyroid glands (Plate III, Figure 27).

SEAL

(*Phoco richardii geronimensis*)

This seal had been in captivity for some years in the Brookside Zoo, Cleveland. Its death was due to violence.

Relative Sizes of the Thyroid and Adrenal Glands: The weight of the thyroid gland was 5,204 mg.; of the adrenal glands, 6,003 mg., the adrenal glands being 1.15 times as large as the thyroid gland in spite of the fact that pathological examination by Dr. Allen Graham revealed hyperplastic goiter (Plate III, Figure 28).

BIRDS

(*Buteo borealis*, *Bubo virginianus virginianus*—
Chicken Hawk, Horned Owl)

In a group of birds we found the following relationships between the thyroid and adrenal glands.

Relative Sizes of the Thyroid and Adrenal Glands: In the Chicken Hawk (*Buteo borealis*) the weight of the thyroid gland was 106.5 mg.; of the adrenal glands, 113.5 mg., the adrenal glands being 1.06 times as large as the thyroid gland.

In the Horned Owl (*Bubo virginianus virginianus*) the weight of the thyroid gland was 85 mg.; of the adrenal glands, 165 mg., the adrenal glands being 1.94 times as large as the thyroid gland.

BAT

(*Myotis lucifugus* or *Eptesicus fuscus*)

Relative Sizes of the Thyroid and Adrenal Glands: In the Bat (*Myotis lucifugus*) the weight of the thyroid gland was 3.3 mg.; of the adrenal gland, 5 mg., the adrenal glands being 1.51 times as large as the thyroid gland.

RHESUS MONKEY OF INDIA

(*Macacus rhesus*)

Relative Sizes of the Thyroid and Adrenal Glands: In three specimens of Rhesus Monkey (*Macacus rhesus*) the thyroid glands were normal in position and color, and there was no isthmus. The average weight of the thyroid glands was 194 mg.; of the adrenal glands, 467 mg., the adrenal glands being 2.45 times as heavy as the thyroid gland.

ALLIGATOR

(*Alligator mississippiensis*)

We have had three alligators at the Cleveland Clinic, one which was killed in the wild at Cumberland Island, Southern Georgia, and two which had been in captivity for several years in Florida. All were between nine and ten feet long and weighed from 250 to 300 pounds.

The alligator, though apparently a slow, sluggish animal, is capable of quick action when securing its prey, and at times is very aggressive and savage. In captivity, alligators often fight each other.

The Thyroid Gland: The thyroid gland of the alligator consisted of two small reddish cylindrical lobes with an isthmus and lay just below the bifurcation of the trachea.

The Adrenal Glands: The adrenal glands of the alligator were long and slender and grey. They lay close to, in fact, were almost imbedded in the testes or ovaries and were difficult to locate and to dissect.

Relative Sizes of the Thyroid and Adrenal Glands: The average weight of the thyroid glands was 5,200 mg.; of the adrenal glands, 4,900 mg., the thyroid and adrenal glands thus being about the same weight (Plate III, Figure 30).

CROCODILE

(*Crocodilus americanus*)

Characteristics: The crocodile is more savage and more swift in action than the alligator.

The Thyroid Gland: The thyroid gland in the crocodile was bi-lobed and lay at the bifurcation of the trachea, one lobe on either side.

The Adrenal Glands: The adrenal glands were long, slender bodies and lay near the testes or ovaries. In shape, they were very much like the adrenals of the alligator.

We have had two crocodiles at the Cleveland Clinic, both of which had been in captivity at Musa Island, Florida, from two to three years.

Relative Sizes of the Thyroid and Adrenal Glands: In the case of one of these specimens the dissection was made out-of-doors under difficult conditions, and I was unable to secure all the adrenal tissue. The weight of the thyroid gland was 3,770 mg.

Another crocodile was shipped from Musa Island to the Cleveland Clinic where it was dissected under favorable conditions. The weight of the thyroid gland of this crocodile was 5,200 mg.; of the adrenal gland, 4,300 mg., the thyroid gland being 1.2 times as heavy as the adrenal glands. Pathologic examination of the thyroid gland revealed no hypertrophy or hyperplasia.

MOUNTAIN LION OR PUMA

(*Felis concolor*)

The Mountain Lion was secured in Arizona.

Characteristics: The Mountain Lion (*Felis concolor*) is an alert, lithe, active animal. It covers a large range of territory, is stealthy in its hunting, finally rushing upon its prey in a series of leaps, or springing down upon it from an elevation. It averages from three to four feet in length from the head to the root of the tail.

The lobes of the thyroid gland of the Mountain Lion were long and were connected by an isthmus.

The adrenal glands were triangular in shape. They were flat on both sides, but wide at the top. The left adrenal gland lay below the central line of the kidney, while the right adrenal gland lay above the central line of the kidney.

Relative Sizes of the Thyroid and Adrenal Glands: The thyroid gland in our specimen weighed 1,600 mg.; the adrenal glands, 4,100 mg., the adrenal glands being 2.56 times as large as the thyroid gland (Plate III, Figure 29).

AFRICAN LION

(*Felis leo*)

This research into the comparative anatomy of the thyroid and adrenal glands began in 1927 when Dr. George Crile, on a hunting expedition in Africa, made rough dissections of lions and antelopes in the field, finding in every instance that the adrenal glands were noticeably larger than the thyroid gland, exactly opposite to the relative sizes of these glands in man in whom the weight of the thyroid gland is approximately twice that of the adrenal glands. It was this observation that led to my participation in the Southwestern expedition of the Cleveland Museum of Natural History.

In all, we have dissected five lions at the Cleveland Clinic. The first was a full grown female of jungle-born parents, which was bred in captivity. It was purchased from the Detroit Zoological Gardens, which are within the goiter belt. Dr. Allen Graham examined the thyroid gland and found a colloid goiter with hyperplasia.

The second lion was a female, six months old, bred in California. In this lion also Dr. Graham found a large colloid goiter with hyperplasia.

The third lion was a young female killed in combat. The glands were given to the Cleveland Clinic Research Department through the courtesy of Mr. Clyde Beatty. Dr. Allen Graham found a colloid goiter with hyperplasia.

The fourth lion was a mature male, weighing 356 pounds. It was secured from a zoological garden in Pennsylvania where it had been born seventeen years before. It was in good condition. Dr. Graham found a large colloid goiter with hyperplasia.

The fifth lion was a young female, only a year and a half old. It had a goiter.

The data regarding these goiterous animals collected from zoological gardens are introduced merely for general interest, but have no bearing upon our research.

	Thyroid	Adrenals
Lion No. 1.....	23,500 mg.	14,500 mg.
Lion No. 2.....	7,418 mg.	7,247 mg.
Lion No. 3.....	9,170 mg.	5,750 mg.
Lion No. 4.....	1,412 mg.	24.9 mg.
Lion No. 5.....	165 mg.	150 mg.

SUMMARY

1. In the wild state, the adrenal glands are larger than the thyroid gland, with a ratio as high as twenty-three to one in certain small rodents. In a human, the thyroid gland is larger than the adrenal glands, the ratio being two to one.

2. According to our data, a larger size of the thyroid gland in relation to the adrenal glands would seem to be a characteristic of the human being only.

3. Domestic animals from the territory in which goiters appear in man had goiters. Wild animals in captivity in these regions also had goiters. Therefore, a comparison of the weights of the thyroid and adrenal glands of these goiterous animals were not of value.

4. In Florida, domestic and wild animals were free from goiter.

APPRECIATION

I wish to express my appreciation to my father, Dr. George Crile, for making these expeditions possible and for permitting me to participate in them. To him I am indebted for the theory to test the validity of which this research was undertaken.

To Dr. E. S. A. King, formerly of the Cleveland Clinic Foundation, and to Dr. E. L. Walsh, I am indebted for their aid in preparing and photographing these specimens. To Dr. Allen Graham, of the Cleveland Clinic Foundation, I am indebted for the pathological examination of the specimens. To Daniel P. Quiring, Ph. D., of Western Reserve University, I am indebted for advice and supervision, and finally, I cannot adequately express my appreciation of the co-operation of every member of the Crile-Bole-Fuller Expedition.

PLATES I TO IV: PHOTOGRAPHS AND RELATIVE WEIGHTS OF THE THYROID AND ADRENAL GLANDS IN A SERIES OF THIRTY ANIMALS

(The numbers correspond to the numbers on the plates.)

No.	NAME OF ANIMAL	WEIGHT IN GRAMS			THYROID-ADRENAL RATIO
		Thyroid	Adrenals	Kidneys	
1	<i>Onychomys</i> (Grasshopper Mouse)	.0014	.04	.392	1 to 28.57
2	<i>Sorex vagrans monticola</i> (Shrew)	.0012	.0062	.221	1 to 5.17
3	<i>Microtus alticola alticola</i> (Mountain Meadow Mouse)...	.0032	.0054	.172	1 to 1.69
4	<i>Peromyscus</i> (Deer Mouse).....	.0015	.0068	.24	1 to 4.53
5	<i>Sciurus fremonti mogollonensis</i> (Pine or Red Squirrel).....	.008	.091	1.626	1 to 11.37
6	<i>Sciurus arizonensis</i> (Grey Squirrel).....	.026	.197	3.335	1 to 7.58
7	<i>Sciurus aberti</i> (Abert's Squirrel)	.051	.222	3.536	1 to 4.35
8	<i>Eutamias</i> (Chipmunk).....	.0012	.020	.608	1 to 16.7
9	<i>Ammospermophilus</i> (Antelope Chipmunk).....	.0028	.038	.807	1 to 13.57
10	<i>Citellus</i> (Ground Squirrel).....	.004	.019	1.09	1 to 4.75
11	<i>Callospermophilus</i> (Mantle Ground Squirrel).....	.0095	.035	1.415	1 to 3.68
12	<i>Cynomys</i> (Prairie Dog).....	.025	.028	2.564	1 to 1.12
13	<i>Thomomys</i> (Pocket Gopher)....	.0012	.0085	1.172	1 to 7.08
14	<i>Neotoma</i> (Mexican Pack Rat)...	.019	.137	2.353	1 to 7.21
15	<i>Dipodomys</i> (Kangaroo Rat).....	.01	.04	.947	1 to 4
16	<i>Mus norvegicus</i> (Gray Norway Rat).....	.008	.062	.....	1 to 7.75
17	<i>Ondatra zibethica</i> (Musk-Rat of Musquash).....	.043	.156	5.16	1 to 3.63
18	<i>Sylvilagus auduboni</i> (Cotton-Tail Rabbit).....	.030	.090	4.630	1 to 3
19	<i>Lepus californicus</i> (Jack Rabbit)	.147	.256	19.34	1 to 1.74
20	<i>Urocyon cinereoargenteus scotti</i> (Grey Fox).....	.160	.371	29.4	1 to 2.32
21	<i>Bassariscus</i> (Ring-Tailed Cat)...	.080	.387	10.25	1 to 4.84
22	<i>Felis domesticus</i> (Domestic Cat)	.216	.518	23.9	1 to 2.4
23	<i>Mephitis</i> (Common or Hooded Skunk).....	.096	.348	6.91	1 to 3.62
24	<i>Conepatus mesoleucus</i> (Hog- Nosed Skunk).....	.054	.211	7.51	1 to 3.9
25	<i>Hemionus odocoileus</i> (Mule Deer)	2.00	5.750	.....	1 to 2.87
26	<i>Odocoileus couesi</i> (Arizona White-Tail Deer).....	1.650	2.400	85.00	1 to 1.45*
27	<i>Odocoileus virginianus</i> (Florida White-Tail Deer).....	2.460	2.670	.....	1 to 1.08
28	<i>Phoco richardii geronimensis</i> (Seal).....	5.204	6.003	.....	1 to 1.15
29	<i>Felis concolor</i> (Mountain Lion)...	1.6	4.1	140.00	1 to 2.56
30	<i>Alligator mississippiensis</i>	3.5	4.0	.....	1 to 1.14

*Histologic examination showed a marked hyperplasia of the thyroid gland.



