CORRELATED ABNORMALITIES IN THE SCUTES AND BONY PLATES OF THE CARAPACE OF THE SCULPTURED TORTOISE.

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A TYPICAL carapace of the sculptured tortoise (*Chelopus insculptus* LeC.) is composed of fifty bony plates, so united as to form a strong dorsal shield, and of thirty-eight horny scutes covering this shield externally. These elements are arranged as shown in Fig. 1, in which the black lines represent the limits of the bony plates, and the lighter ones those of the scutes. The scutes form three series : first, a median set, which, beginning at the anterior end and proceeding posteriorly, consists of a narrow nuchal scute, five large central scutes, and a pair of pygal scutes, one right and the other left ; secondly, four pairs of large centro-lateral scutes,
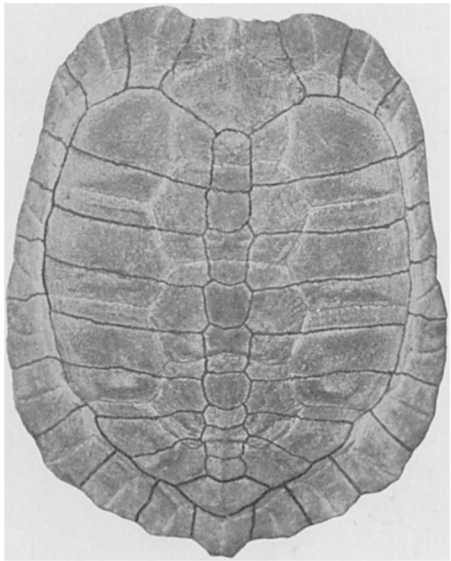

FIG. 1. — Dorsal view of a normal carapace of a male sculptured tortoise. The faint whitish lines represent the edges of the scutes, which were removed in making the preparation ; the black lines mark the margins of the bony plates. × ⅔.

which flank the median series, except at the anterior and the posterior ends ; and, thirdly, eleven pairs of marginal scutes,

which bound the periphery of the carapace, except where the nuchal and the pair of pygal scutes reach the edge.   The bony plates (Fig. 1, black outlines) are also arranged in three series. The median one is composed of twelve plates, which, beginning at the anterior end, are, first, a large nuchal plate ; next, eight neural plates ; and, finally, three pygal plates, one behind the other.   Eight pairs of costal plates abut with their central ends on the median series, and extend laterally well towards the edge of the carapace.   Excepting where the nuchal plate and last pygal plate reach the edge, the carapace is bounded by eleven pairs of marginal plates.   Although the scutes and bony plates are arranged upon similar plans, the two sets of elements do not coincide either in numbers or in exact positions.

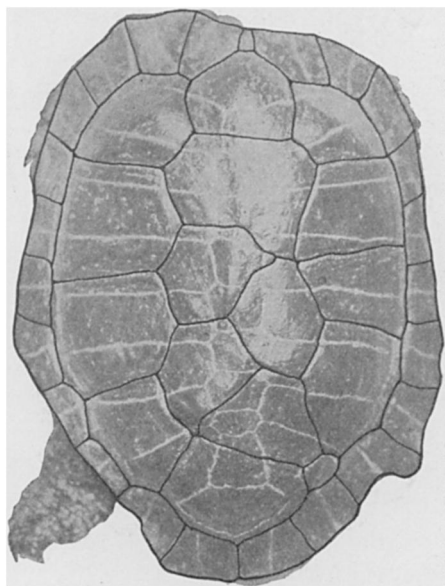The first abnormal specimen to be described is one (Museum, No. 1829) from the extensive series by which this species is represented in the collections of the Museum of Comparative Zoölogy at Harvard College, Cambridge.   It is a male and was collected at Lancaster, Mass.   My thanks are due Mr. Samuel Garman for having called my attention to it, as well as the authorities of the museum for their liberality in allowing me to dissect such parts as were needed.   The carapace, which was about 15 cm. long and 11.3 cm. broad, had suffered somewhat from marginal fractures, but in no instance had a whole scute or plate been lost through such injuries.

FIG. 2. — Dorsal view of abnormal carapace No. 1 (Mus. Comp. Zoöl.,No. 1829).   The black lines give the outlines of the scutes.   × ½.

The arrangement of the scutes is given in Fig. 2, an examination of which shows that there are two abnormal regions :

first, the middle and posterior parts of the median series; and, secondly, the anterior parts of the marginal series.

In the median series the nuchal and first central scutes are essentially normal. The second central is irregular on its posterior margin; the third and fourth centrals are apparently each divided in two by nearly parallel oblique lines; and the fifth central is irregular anteriorly. The second, third, and fourth centro-laterals of the right side are also irregular in form. To the right of the fifth central is a small supernumerary scute, which may represent a part of any one of the surrounding elements except the marginals. These are apparently not involved in the irregularity, whose center obviously lies to the right of the median line in the region of the third and fourth centrals.
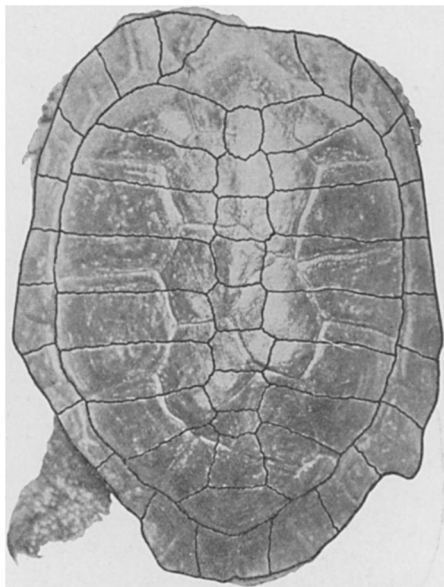

FIG. 3. — Dorsal view of abnormal carapace No. 1. The black lines give the outlines of the bony plates. × ½.

When the bony plates underlying the region of irregularity just described are inspected (Fig. 3) they are seen to present no features essentially different from the normal arrangement, and it is, therefore, clear that in this region the abnormalities are limited to the scutes and are not associated with any peculiarities of the underlying bony plates.

The second abnormal region in this carapace lies anteriorly and is easily recognized by peculiarities in the marginal scutes (Fig. 2). If the lines of separation between the first and second centro-lateral scutes of both sides are traced laterally, they will be found to be continuous with lines between marginal scutes. These intermarginal lines are undoubtedly a

natural pair, because posterior to each there are seven mar-
ginals and one pygal — a condition which is identical with that
in the normal carapace (compare Fig. 1).   Anterior to these
lines, however, the right and left sides of the carapace are dif-
ferent ; on the right side are three marginals, on the left four.
As the left side has the normal number of marginal scutes, the
abnormality may be described as a deficiency on the right side,
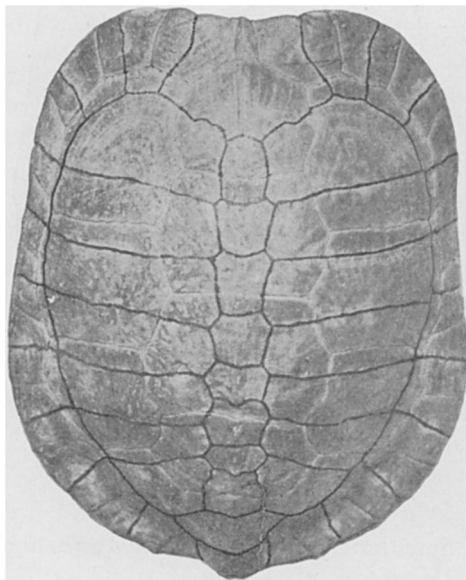an interpretation that is supported by the fact that the outline

of this side recedes more
than is usual in this
species (compare Figs.
1 and 2).   Since the
right side is normal from
the fourth intermarginal
line posteriorly, the de-
ficiency may with fair-
ness be said to lie in the
region covered in this
specimen by the first
three marginals.

An examination of the
bony plates in the mar-
ginal series of this cara-
pace (Fig. 3) shows a
condition substantially
like that just described.
The first four marginal
plates of the left side

FIG. 4. — Dorsal view of abnormal carapace No. 2.   The black
lines are the outlines of the bony plates.   × ½.

occupy a region which corresponds to that covered by the first
three marginals of the right.   The total number of marginal
plates on the left side is eleven, and this side may be described
as essentially normal, notwithstanding the fact that the first
marginal is triangular instead of quadrilateral.   The total
number of marginals on the right side is ten, and the deficiency,
as can be seen by a comparison with a normal specimen
(Fig. 1), lies in the region covered by the first three plates.
As this is the region from which a scute is absent, the con-
clusion is warranted that, in this instance, the absence of a

bony plate is accompanied by the absence of an overlying scute. Thus the first specimen illustrates two conditions: scute abnormalities *unassociated* with bony abnormalities, as seen in the median and right centro-lateral parts; and scute abnormalities *correlated* with bony abnormalities, as seen in the anterior portion of the right marginal series.

The second abnormal carapace was brought to my attention by Mr. C. E. Preston, to whom the specimen had been assigned for study, and who kindly prepared it for me. The animal was a male and came in all probability from Maryland. Its carapace, when prepared, measured about 15.7 cm. in length and 12.1 cm. in breadth.

At first sight the carapace (Fig. 4) does not seem to be abnormal, but a closer inspection shows that there must be at least two abnormal regions, one in the scutes and the other in the bony plates; in both instances the abnormalities form symmetrical areas. The scute abnormalities occur in the posterior part of the marginal series. On both sides marginals 1 to 8 are entirely normal. In typical specimens (Fig. 5, *a*) marginal 8 is followed on either side
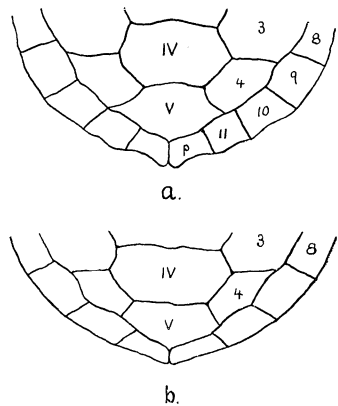

FIG. 5. — Outlines of the scutes on the posterior part of the carapace of (*a*) a normal sculptured tortoise and of (*b*) the abnormal tortoise No. 2. 3, 4, third and fourth right centro-lateral scutes; 8, 9, 10, eighth, ninth, and tenth right marginal scutes; *p*, right pygal scute; IV, V, fourth and fifth central scutes.

by four scutes, —marginals 9, 10, 11, and the pygal scute. In the abnormal specimen (Fig. 5, *b*), in place of these four scutes, only three are present. As it is impossible to state which scute of the four is absent, the condition may be described as a bilateral deficiency of one scute posterior to marginal 8.

The bony plates of this specimen in the regions where scute abnormalities occur are essentially normal (Fig. 4), and the same may be said of those at the anterior end of the carapace. In fact, judging from the number and shapes of the plates, normal conditions may be said to exist between the anterior edge of the carapace and the transverse line marked by the

posterior borders of the first costal plates, and between the
posterior edge of the carapace and the transverse line marked
by the anterior borders of the next to the last pair of costal
plates.   The rest of the carapace is made up of four bony seg-
ments instead of the five which are typical of normal individ-
uals (Fig. 1).   In this abnormal specimen, therefore, a whole
bony segment (a neural plate, a pair of costals, and a pair of
marginals) is absent, and the position of the deficiency is some-
where between the posterior edge of the first pair of costals
and the anterior edge of the next to the last pair of costals,
i.e., in the body of the carapace.

Such a suppression might be expected to be accompanied by
a shortening of the carapace, and, as a matter of fact, there is
some evidence that this is so.   The length of the carapace
under consideration is 15.7 cm., its breadth 12.1 cm.; the
length is, therefore, 1.298— times the breadth.   In ten normal
males taken at random the average length of their carapaces
was 16.65 cm., and the average breadth 12.68 cm.; the average
length was therefore 1.313 + times the average breadth.   It
thus appears that the abnormal specimen is somewhat shorter
than the average normal specimen, both absolutely and rela-
tively to its length, — a condition to be expected if the suppres-
sion of a segment is assumed.

Although the second specimen shows abnormal conditions
in both scutes and bony plates, the fact that the two abnormal
regions do not overlap even in part (for the most posterior
position assignable to the bony-plate abnormality is still ante-
rior to the most anterior position assumable for the scute
abnormality) might well lead to the inference that these two
irregularities were in no true sense correlated.   Such a con-
clusion, however, is probably incorrect.   The fact that neither
of the two abnormalities interferes with bilateral symmetry
at least suggests something more than an accidental relation,
though it in no wise meets the objection that the abnormalities
are not superimposed.   This objection, however, is not as
serious as at first sight it seems to be.   Harrison ('**98**) some
time ago showed by a series of ingenious experiments on
young tadpoles that in the growth of the posterior parts of

their bodies the germ layers undergo a curious change in posi-
tion.   The tail of a developing tadpole is composed of an outer
covering of ectoderm — which ultimately gives rise to the outer
layers of the skin — and of a core of mesoderm.   These two
masses of tissue grow in very different ways, so that as the
tail lengthens the ectodermic covering, which is most actively
produced anteriorly, slips posteriorly over the underlying meso-
derm, whose region of growth is chiefly at the posterior end.
Although this posterior migration of the ectoderm has been
actually demonstrated only in the tadpole, there is reason to
believe that it occurs in other vertebrates.   Admitting its
existence in the turtle, it affords an easy means of explaining
the conditions described.   The scutes of turtles are derived
from the ectoderm, the bony plates from the mesoderm.   In
the anterior part of the carapace these ectodermic and meso-
dermic derivatives, according to the peculiarity of growth just
explained, would not undergo any separation but would retain
their embryonic positions.   Hence, if the material from which
both scutes and plates arise were modified by any local influence,
the resultant scutes and plates would be found together, as in
the first abnormal specimen described.   In the posterior part
of the carapace, on the other hand, the ectodermic migration
would be excessive and any early local disturbing influence
that affected both scute and plate-producing tissue would leave
its trace in the adult in the form of a region of modified scutes
posterior to a region of modified bony plates, — a condition
realized in the second abnormal specimen.   Thus, from what is
known of the methods of growth of the integument and subjacent
parts in vertebrates, it is fair to assume that the abnormalities
of scutes and bony plates in the second specimen, though
separated in the adult, may be as truly correlated as those of
the first specimen, in which the modified areas still remain
superimposed.

The older anatomists have very generally pointed out the
superficial resemblances between the scutes and the bony
plates of the chelonian carapace, but they have as a rule
denied any close relation between these two sets of structures.
Gegenbaur ('**98**, pp. 1 3 2, 1 7 4), in his recently published volume

on the comparative anatomy of vertebrates, repeatedly empha-
sizes the idea of the independence of scutes and bony plates.
The conclusions to which the present studies lead do not favor
this view, but lend support to the opinion expressed in cautious
terms by Goette ('99, p. 430), and more radically by Gadow
('99), to the effect that in primitive turtles each bony plate was
associated with a single scute.   Supposing such relations to
have existed, it is easy to conceive how the present conditions
could have been brought about ; for, if the migration of the
ectoderm were to be so retarded as to take place after its divi-
sion into scutes, the posterior scutes would be carried away
from the bony plates to which they belonged, and in con-
sequence of crowding some of them might be suppressed, with
the result that a carapace with a given number of bony plates
would be covered by a smaller number of scutes.   Although
such an explanation of the present condition of the chelonian
carapace must be tested by experiment, the evidence derived
from the study of the abnormal specimens described above
shows that there is a closer relation between bony plates and
scutes than has been generally admitted heretofore.

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