The Internal Factors in the Regeneration of the Tail of the Tadpole.

By

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With 11 figures in text.

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The object of the following experiments was to determine whether both the nerve-cord and the notochord are necessary for the regeneration of the tail of the tadpole, or whether one or the other of these structures will suffice, or in the absence of both structures at the cut-end whether a new nervous system and notochord will regenerate.

Method: Large tadpoles of *Rana palustris*, measuring about 55 to 70 mm were used. After etherization the tail was cut off squarely somewhat distal to the middle, then by means of two longitudinal cuts, as shown in Fig. I, a piece of the middle of the tail was cut out and separated from the rest. The part removed included in some cases both the nerve-cord and notochord; in other cases only

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one of these structures. This operation was carried out in two different ways. In the first series the middle piece was cut out only from one side. While this operation succeeded for the notochord it was not well suited for the removal of the nerve-cord. In later operations the two longitudinal cuts extended through the entire thickness of the tail (as shown in Fig. I). The middle piece

was then cut off at its proximal end. We found it better to draw together the upper and lower parts of the tail by means of one or two stitches through one side.

The tadpoles were kept in water in glass dishes, and killed at intervals of from five weeks to three months. Those individuals in which the tail failed to heal, or in which the cut-region sloughed off were eliminated. The tadpoles were killed in corrosive-acetic solution, stained, imbedded, and cut into sections.

Results: The experiments fall into three categories; A, in which both the nerve-cord and notochord were removed; B, in which only the nerve-cord was removed; C, in which only the notochord was removed.

A. In one case in which both the nerve-cord and notochord had been taken out, neither grew down through the cut-region of the

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old part, (Fig. II). The notochord had however, begun to grow out into the cut-region, and the new part was rounded but had not made a new tail. It was covered by ectoderm and contained connective tissue in its interior. There was an entire absence of nerve-cord and notochord in the new part. There were three other cases of this sort.

In another case the notochord had extended backward through the cut-region, and had then continued on into the new part, which

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was longer than in the last case, and appeared to be forming a new tail, (Fig. III). The nerve-cord had not extended through the cut-region, and consequently there was no nerve cord in the new tail.

In a third case the notochord had slipped out of its sheath, and the latter was left in the middle of the cut-region, and extended to the cross-cut surface. From its end a very small rod of new cells representing a new notochord had extended into the new tail, which was quite long, Fig. IV. The nerve-cord had extended for

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only a short distance, if at all, into the cut-region, and had not reached back to the cross-cut surface.

B. In the first case in which the nerve-cord had been cut out a long, new tail (Fig. V) had grown out from the cross-cut surface. It contained a prolongation of the notochord. The nerve-cord in this case had not grown out through the cut-region. There were three other cases of this sort. In the next case, Fig. VI, a long new tail had also grown out from the cross-cut surface and contained a new notochord. The distal end of the tail was subdivided into lobes. In this same case a lateral outgrowth of the notochord extended into another tail-like lobe that arose from the proximal end of the

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cut-region. It is probable that the notochord had been injured when the nerve-cord had been cut off at this level, and that the notochord sent out a lateral growth, around which the lateral tail formed. The new nerve-cord followed this lateral outgrowth, and extended nearly to its tip. There is no nerve-cord in the new tail at the distal end.

In another case, Fig. VII, a new tail, forked at its end, had grown out from the cross-cut surface, and contained a prolongation of the notochord. The nerve-cord had not extended beyond the level at which it had been cut off. There was another case like this

one. In a fourth case a long new tail, also forked at its end and containing a notochord, had developed. The nerve cord had been incompletely removed, and pieces had been left at three points along the cut-region, (Fig. VIII). Nevertheless a new nerve-cord had not been formed.

C. When the notochord had been taken out and the nerve-cord left, the result, in one case, Fig. IX, showed that the notochord failed to regenerate, and consequently it was absent throughout the cut-region. The nerve-cord left in this region extended to the cut-end, but, although its end formed a rounded knob, a new tail had not developed. There was another case of this sort. In another case a slender notochordal rod had regenerated from the cut-end of the old notochord and extended through the cut-region. It had not yet, after five weeks, grown into the new part, Fig. X. This new

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part is still short. Whether if the new notochord had grown into it a new tail would have later developed we have no means of determining. The nerve-cord had not grown beyond the level at which it had been cut off.

In two other cases the notochord had grown through the cut-region and into a new tail, Fig. XI. The nerve cord had also grown into the new tail.

In another case a piece of the notochordal sheath had been left accidentally in the cut-region. From its end a new notochord had developed, which extended into the new forked tail. Lastly in one instance although a piece of the notochord had been left in the cut-region a new notochord had not developed and a new tail had not been formed.

Conclusions.

The foregoing results show that the presence of the notochord at the cut-surface is necessary for the regeneration of a new tail of the tadpole. In the absence of the notochord, the nerve-cord, if present at the cut end, is insufficient for the regeneration of a new

tail. And in the absence of both notochord and nerve-cord at the cut-surface a new tail is not formed. In those cases in which the notochord is not present at first at the cut-surface (Fig. XI), it may regenerate and extend through the cut-region, and after reaching in this way the level of the cross-cut surface a new tail may then regenerate (Fig. XI).

Zusammenfassung.

Die vorstehend geschilderten Ergebnisse zeigen, dass die Gegenwart des Notochords an der Schnittfläche nöthig ist, wenn sich bei der Kaulquappe ein neuer Schwanz regeneriren soll. Beim Fehlen des Notochords ist der am Schnittende vorhandene Nervenstrang für die Regeneration eines neuen Schwanzes nicht ausreichend. Fehlen beide, so bildet sich an der Schnittfläche kein neuer Schwanz. In denjenigen Fällen, in denen zunächst kein Notochord an der Schnittfläche vorhanden ist (Fig. XI), kann es sich regeneriren und durch die Schnittregion ausdehnen. Nachdem es auf diesem Wege das Niveau der Querschnittsfläche erreicht hat, kann sich dann noch ein neuer Schwanz regeneriren (Fig. XI).