AN

# ESSAY

ON

# ANIMAL REPRODUCTIONS.

BY

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AND

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TRANSLATED FROM THE ITALIAN.

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MDCCLXIX.

THIS little tract having been composed at my request, and sent me from the author, as a present to the Royal Society, I was encouraged to think a translation of it would not prove unacceptable to English Naturalists. Most of the experiments are entirely new, and, for that reason, as well as on account of the singular conclusions that may be deduced from them, deserve to be repeated by different hands, and seen by different eyes. This is what our Italian observer wishes may be done, both in his own country and in this, before he publishes his large work. Facts in appearance so little reducible to the known laws of animal œconomy, must be duly authenticated in order to be believed; and that evidence, which is sufficient in things more analogous to the general course of nature, can hardly be thought so in the case of discoveries, which seem to be deviations from it. But universal laws are few, and exceptions

to

to them are grown more and more common. In this age, when the talent of obſerving has been ſo much improved, and experience has taught us the vanity of opinions and ſyſtems, it would be imprudent to reject, without trial, obſervations, or even hints, which, at the ſame time that they enlarge our views of nature, tend to increaſe proportionally our admiration of its GREAT AUTHOR, and may become in time not only inſtructive, but uſeful to mankind.

British Muſeum,
June 20, 1769.

M. MATY.

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# E S S A Y

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# ANIMAL REPRODUCTIONS.

THE ſubject of Animal Reproductions, one of the moſt intereſting and extenſive in natural hiſtory, remains hitherto concealed under thick clouds, for want of a ſufficient number of experiments and obſervations. This truth appears the more evidently, as it is ſupported by the authority of an eminent philoſopher, whoſe genius and induſtry have been employed for a long time upon this ſubject, and who acquired the greateſt honor in

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the purſuit of this grand myſtery*. With candor equal to his merit, he owns that the regeneration of the polypes, and ſome other of the ſmalleſt and moſt ſimple inſects, renewed by ſections, is by no means ſufficient to elucidate the theory of reproductions, and that animals of larger bulk and more complicated organiſation are neceſſary to anſwer this purpoſe. As he had diſcovered jointly with Reaumur, that the earth-worm, cut in pieces, has the property of reproducing itſelf, he invites philoſophers to try experiments of the ſame kind, as his own eye-ſight, weakened by inveſtigating the moſt delicate works of nature, deprived him of that ſatisfaction; and that, by the death of the great French naturaliſt, the world had loſt the account of the experiments made by him upon that reptile. This advice, animated with the true ſpirit of philoſophy, is to be found in his Conſiderations upon organiſed Bodies, and is of too much conſequence not to be quoted.

" The reproduction, ſays he, † of the
" earth-worm is much more ſurpriſing than

* Mr. Bonnet of Geneva, F. R. S. and author of many important works, and particularly of the two following; viz. Conſiderations ſur les Corps organiſés, à Amſterdam, 1762; and Contemplation de la Nature, 1764.

† Contemplation, &c. tome i. p. 257.

" that

"that of the polype, as being of a ſize in-
" finitely greater, and much more compli-
" cated in its ſtructure. In him you find a
' large apparatus of viſcera, veſſels, tracheas,
" muſcles, &c. He has blood, and that
" blood circulates. But above all, the firſt-
" mentioned inſect is an *hermaphrodite*; it
" unites the organs proper to both ſexes,
" and theſe organs are of the moſt exquiſite
" ſtructure. The earth-worm, though in
" appearance the loweſt of animals, might
" exhauſt the induſtry of the moſt ſagacious
" obſerver, who with the ſteadineſs of a
" philoſopher ſhould confine himſelf to the
" examination of this one object alone.
" How much might not phyſiology be im-
" proved by ſuch an inquiry! how many
" truths, even beyond our expectations,
" might be added to our ſtock of know-
" ledge! To be admired, the earth-worm
" only wants to be inveſtigated with as much
" accuracy as the polype has been."

Is there any one who would not wiſh to obey ſuch an invitation, coming from a man univerſally allowed to be one of the firſt naturaliſts of the age? But how much more powerfully muſt I have been influenced by it, who, beſides theſe invitations in common with other philoſophers, was frequently and particularly ſolicited by him on this account, and who am alſo connected with him by the ſtricteſt friendſhip, which conſtitutes one of the chief bleſſings of my life?

From what I learned by the ſection of the earth-worm, I was induced to examine other animals, in which I likewiſe diſcovered the ſame regenerating power. Theſe ſeveral reproductions, as they are equally new and curious, I intend to enumerate briefly in this eſſay, and afterwards fully to deſcribe them in a larger work, which I hope will ſoon ſee the light. This work will conſiſt of many diſſertations, each of which, for the conveniency of the readers, will be ſubdivided into chapters. To lay down facts with the faithfulneſs of a true hiſtorian of nature; to paſs, as much as poſſible, from the moſt ſimple to the moſt complicated; to bring them together, to analyze and compare them both with themſelves and with the diſcoveries of other authors; to deduce with impartiality the immediate conſequences, either favorable or contrary to the explanations given of theſe extraordinary phenomena; to ſhew how far the limits of animal phyſiology are extended by, and what utility and advantage may be derived from, obſervations of this kind, will be the principal deſign of this work.

I ſhall

I ſhall not, however, deny myſelf the liberty of introducing ſome ſimilar circumſtances, and at times even ſome of a different nature, which fell in my way by chance, and may ſerve either to clear up ſome dark or controverted points, or to promote and confirm ſome evident and important truths. Such for inſtance is the diſcovery of the tadpoles, exiſting in the eggs of frogs, before fecundation by the male. This agrees exactly with Haller's obſervation on the chicken*, and helps to determine the great queſtion, ſo long in diſpute among philoſophers, on the firſt origin of the germ.

As ſeveral of the reſults of my experiments will appear ſingular, I ſhall make it my buſineſs to deſcribe them with preciſion, to mention the precautions and means I have uſed in making theſe obſervations, the temperature of the air, and the ſituation proper for the animals, together with the food I gave them; and in ſhort, to diſcloſe all the circumſtances which may contribute to the underſtanding, and eſtabliſhing of the facts, ſo, that the lovers of natural hiſtory, on repeating my experiments, may, if they pleaſe, confirm and extend them ſtill farther.

* Memoires ſur la formation du cœur dans le poulet.

I have thought a ſufficient number of figures would be of the greateſt importance to the ſubject: if they are generally ornaments in books of natural hiſtory, they may be ſaid to be the life and ſpirit of mine.

I ſhall endeavour to diſtribute my ſubjects in ſuch manner, as that the reproductions of the firſt claſs may give light to thoſe of the ſecond, and ſo on of the reſt. This order, indeed, I have not obſerved in this Eſſay, not thinking it neceſſary, as my ſole intention was partly to enumerate, for reaſons it would be needleſs to ſpecify, the mere reſult of many of my experiments, and partly to point out ſeveral queſtions propoſed to nature, in order to ſearch into her ſecrets, and find out her ways of acting in theſe wonderful operations: her anſwers ſhall be reſerved for my other work.

# THE REPRODUCTIONS OF THE EARTH-WORM.

THREE parts may be conſidered in an earth-worm, tranſverſely divided; the *fore part*, or head; the *hinder part*, or tail, and the *intermediate* part.

Having found that the anterior part, or the head, reproduced the tail, I was willing to try whether this took place, when the head was cut at different diſtances, and whether any difference in the method of dividing would prevent the uſual reproduction.

It was, therefore, neceſſary to obſerve, whether the regenerative power exiſted in the whole length of the worm, ſo that the head, however long or ſhort, would be equally fit to reproduce a tail. I found that nature has limits, which ſhall be determined in my work, and beyond which this reproduction of the tail can no longer be effected.

But as heads, differing in their length, (within certain limits) ſtill reproduce a tail, the following enquiries could not be omitted. 1. Are thoſe tails equal, that are produced from unequal heads? 2. Do they become ſo in the ſame length of time? 3. Does that equality of the tails take place at every point, within the limits aſſigned for the reproduction? 4. And does it continue during the whole courſe of this operation?

Theſe experiments, having firſt been made upon full-grown earth-worms, of one particular ſpecies, were repeated on others of the ſame ſpecies, young and ſtill growing; and proper compariſons were made between the reproductions of the firſt and thoſe of the laſt.

It was then proper to examine whether the heads in earth-worms of different ſpecies, likewiſe produce new tails. Having found it to be ſo, I inquired, 1. Whether there is any difference of time between the reproductions of the tails in different ſpecies. 2. And being convinced that there was a difference, what might be the reaſon of it. In the courſe of theſe reſearches, I met with one ſpecies of the earth-worm, diſtinguiſhed from all others, not only by the very long time it requires to begin this reproduction, but likewiſe by the reproduction itſelf, which is intirely different from any thing that has been obſerved, not only on the reproduction of earth-worms, but alſo on that of other animals,

animals. And thus far I proceeded on the reproduction of the tail from the anterior part, or the head.

The next inquiry was, whether the posterior part, or the tail, likewise could produce a new head. I found that, upon cutting off a certain number of rings from the anterior part, the reproduction of the head took place in every species of earth-worms known to me; and I did not fail to attend in great measure to the same things I had noted in the reproduction of the tail.

If the number of rings taken off is such, that the quantity of the anterior part separated be considerable, the reproduction of the head will not take place till after a long time, and then with difficulty; and not in every species of these insects. But as reproduction is only delayed, not prevented, by this kind of section, it may be concluded, that earth-worms, or at least some species of them, not only reproduce the tail, but the head.

To settle this point, I shall examine the little that has been written upon the cutting of the earth-worm by Count Ginnani*, Dr.

* Racolta Calogeriana, tome xxxvii.

Vandelli*, and Valiſneri, now profeſſor of natural hiſtory at Padua †.

When the rings cut off near the head are but few, the part reproduced is always equal to that which was taken off; but when there are many, the new head is commonly ſhorter, and has fewer rings, than the firſt.

The preceding facts deſerved to be ſtill more illuſtrated by the following queries. 1. Whether the reproduction of a ſmall portion of head appears ſooner than that of the tail? and as this is found to be true; 2. What proportion and what laws nature follows in the lengthening of theſe two productions? This having been found out, I examined, 3. Whence it comes to paſs, that head ſprings forth ſooner than the tail? 4. Why it happens, that, when much of the head is cut off, the reproduction is ſo much retarded, and ſo very quick when but little is taken off? 5. What is the reaſon, that in the firſt caſe the new head does not, for the moſt part, equal the firſt, either in its length, or the number of its rings? 6. Why in many other ſpecies of earth-worms the reproduction of the head does not take

* Dominici Vandelli, de Vermium terræ reproductione.

† Sopra alcune Riproductioni de' Lombrici terreſtri, Padua, &c.

place, when the ſeparated part is conſider-able?

Being, laſtly, come to the middle parts, I was deſirous to know whether both a new head and a new tail could be reproduced. I found that they really are both renewed, provided a large portion of the head be not taken off; for then the ſame thing will happen that we mentioned before. If a ſmall portion of the anterior part be cut off, both head and tail will ſpring forth; but as we have already obſerved, the head appears firſt, and then the tail, according to the law which nature was found to adhere to.

The difficulty, therefore, with regard to the intermediate parts, lies in the reproduction of the head; and although this often fails, the tail will ſtill begin to be regenerated; but this dies ſooner or later, together with the middle part.

But how comes it to paſs, when equal portions are cut off from the two extremities, viz. the head and tail, of an earth-worm, that, although both extremities periſh, yet if they are kept in a proper ſituation, the point of the tail ſurvives that of the head?

Theſe reproductions take place in the earth-worm, when it is cut acroſs with a pair of of fciffars; but what happens, 1. If inftead of being cut, the infect be torn afunder; 2. or if fire be applied to the divided part?

Hitherto the animal is fuppofed to have been cut in three parts, viz. the head, the tail, and the middle piece.

I was then induced to enquire what happened to the earth-worm, when cut in four, five, fix, or more parts, which I afcertained by a great variety of experiments.

I fhould not have done juftice to the fyftem of animal reproductions, had I omitted to confider three different ftates in the earth-worm; one preceding the fection; another attending the operation; and a third which fucceeds it.

As to the firft, we know that an earth-worm being placed upon loofe and moift ground, hides itfelf by boring it with its head. It avoids every obftacle in its way; it generally advances forwards, or with its head foremoft; it glides without any difficulty along the fides of vafes, &c.

Now do the fame phenomena appear in a head juft deprived of its tail? in the intermediate part? or in the tail alone?

The great artery runs, as was found by Bonnet, from the tail to the head, all along the back. Through this the blood circulates; and its pulſations may eaſily be counted.

Is the direction of this circulation the ſame from the tail to the head in the divided part? It was obſerved to be ſo, whether this part was the head, the middle piece, or the tail.

If the piece firſt cut off be farther ſubdivided, has this ſection any influence on the former direction of the circulation? By no means; and I was much aſtoniſhed to ſee that the blood proceeded regularly in its former courſe, when the portion of the head, the tail, or the intermediate part did not exceed the tenth part of an inch.

But does this diviſion retard at leaſt the velocity of the blood? does it diminiſh its quantity? does the blood flow copiouſly, or not, from the divided veſſels? What alteration do theſe veſſels undergo in their ſtructure? what change is produced in the other component parts of the earth-worm?

With regard to the conſequences of the ſection, I examined, 1. What new order and diſpoſition the divided fibres and veſſels acquire? 2. What time it takes up after the ſection, before a new production begins to make its appearance? 3. What is the form and ſtructure of the reproductions; and, in conſequence, how far they agree or diſagree with the firſt parts? 4. Whether the circulation in the great artery, formed by the reproduction, is analogous to that of the whole worm; viz. from tail to head? 5. In what manner are the great artery, the inteſtinal tube, and the other parts exiſting in the old animal, united to the new parts? 6. Whether, cæteris paribus, the reproduction grows in proportion to the length of time, and the warmth of the weather? 7. Whether all the parts, ſimilar or diſſimilar, which exiſted in the old, are alſo found in the new, worm? 8. Whether the reproduction, after ſections parallel to the plane of the rings, keeps the longitudinal direction of the worm. 9. Whether this direction varies with that of the plane of the ſection? 10. What interval of time is required before the new-produced parts are able perfectly to perform the functions of thoſe that were cut off? 11. Whether, on the lengthening of the reproduction, the trunk increaſes likewiſe? 12. Whether after a certain time the reproduction becomes equal to the old part, both in bulk and length?

But is this regenerating power exhaufted in the firft operation? I found the reverfe. A fecond reproduction being cut off, is fucceeded by a third; this by a fourth; that by a fifth; and fo on.

I procured thefe fucceffive reproductions, not only by cutting off, from time to time, the new-recovered parts, but by making the fecond divifion within the firft reproduction, the third within the fecond, the fourth within the third, &c. In this manner I obtained a fcale of reproductions united to the whole trunk, and becoming gradually younger, flenderer, and of a lighter colour.

It may be inferred from hence, that the reproductive power takes place not only all along the old animal, but likewife throughout the new one.

Is the bulk of the animal fenfibly diminifhed by a feries of fo many fucceffive reproductions? what proportion of the power is confumed in the laft? may we believe, that it would always continue, or at laft ceafe to act?

Inftead of dividing entirely a part of the earth-worm from the other by a tranfverfe fection, what would happen to him,

1. by cutting transverſely through one half of the body, and leaving the other untouched? 2. By cutting the worm almoſt entirely through, and leaving him hanging only by a thread?

From a tranſverſe, I proceeded to a longitudinal, diviſion, in order to find, 1. What would happen to the earth-worm from a longitudinal diviſion carried through his whole length? 2. By extending the longitudinal ſection to the length of an inch in the fore part? 3. By doing the ſame in the back part? 4. By taking away a longitudinal piece of the inteſtine? 5. By cutting off a piece of the great artery, and thus interrupting the circulation through it? 6. By opening part of the body longitudinally, either on the back or belly?

As many of theſe experiments ſucceeded on earth-worms, when whole, they were afterwards repeated on heads, middle-pieces, and tails.

It was neceſſary to prefix to the preſent inquiry an accurate anatomical deſcription of the earth-worm. It is not ſufficient to ſay that a new tail or a new head is reproduced, unleſs at the ſame time we deſcribe the number, diverſity, and nature, of the parts

parts concurring to form this new tail or this new head. The various relations theſe parts bear to each other, and to all the reſt, are likewiſe to be traced; and laſtly, the organical texture of the reproductions is to be compared with that of the parts that were cut off, with the niceſt exactneſs and greateſt circumſpection. This indeed is the beſt method of improving and illuſtrating this doctrine, but it could not be purſued without the aſſiſtance of the anatomical knife.

Rhedi * and Willis † have given anatomical deſcriptions of this animal. But to ſay the truth, as it was only occaſionally that they conſidered him, they did not trouble themſelves much about the mechaniſm of his organs. I have taken upon me to go a little farther, and have found ſome organs in theſe inſects unknown or undeſcribed by them.

To proceed regularly and with clearneſs in my anatomical deſcriptions of the earth-worm, I intend to treat particularly of the following organs; viz. Of the two ſexes found in the earth-worm; of the arteries and veins, and of their communication; of the muſcles;

* Degli animali viventi negli animali viventi.

† De anima Brutorum.

and of the tube, from whence the œſophagus, the ſtomach, and the inteſtines are continued. I ſhall examine afterwards, whether the earth-worm has a real heart, a brain, and ſpinal marrow; and whether it has nerves, and veſſels inſervient to reſpiration.

Under this laſt head I ſhall have occaſion to inſert a very great number of experiments concerning the reſpiration of caterpillars, made many years ago by Mr. Bonnet, and by him moſt obligingly communicated to me. I thought proper to give previous notice of this circumſtance, that, from the merit of the author, the public may form ſome idea of the value of the work.

The experiments of the naturaliſt of Geneva, will be joined to my own on the ſame ſubject; in order to judge (if I may be allowed ſo to do) of what the two celebrated naturaliſts, Malpighi * and Reaumur † have advanced about the very dark work of reſpiration in caterpillars.

* De Bombyce.
† Memoires pour ſervir à l'Hiſtoire des Inſectes, tome i.

# REPRODUCTIONS OF THE AQUATIC BOAT-WORM.

I Think it not inexpedient to give a ſlight idea of this inſect, which, if I am not miſtaken, is hitherto unknown to naturaliſts. It is compoſed of rings like the earth-worm, and by the help of theſe is able to ſhorten or lengthen itſelf as it pleaſes, and to move from one place to another. Its ſize towards the head is equal to one of the largeſt gooſe quills, and its length about a ſpan. The largeſt indeed may reach to the middle of the arm, eſpecially when ſtretched. The colour of their back is dark, but grows lighter towards the tail; the belly is of a pale fleſh hue.

They live in ſweet, ſhallow, and clear waters, either ſtagnating, or flowing gently. The fore part of the body is ſtuck in the mud, whence they draw their nouriſhment. The back part reaches the top of the water, and being ſtretched and hollowed out, forms a kind of boat, horizontally extended over the ſurface of the water. This boat, the cavity of which is towards the ſky, and whoſe ſides, riſing above the water, prevent its getting in, is extremely ſerviceable to the infect, as it enables him to hold out a great part of his tail, which he could not do without this contrivance, as the specific gravity of his body exceeds that of the water.

The usual position of the fore part of this animal, the element he inhabits, and his organisation, which, as we shall see hereafter, is like that of the earth-worm, have induced me to call him the aquatic boat-worm.

The fibres in this worm are very irritable. Upon the least swell or agitation of the water, the infect immediately undoes his boat, then shortening, and at the same time collecting his body together, he withdraws in the twinkling of an eye from the sight of the observer, and hides himself in the mud, his natural place of refuge. When the motion of the fluid ceases, and his fears are over, he rises again with his tail out of the water, and makes his boat afresh, which he keeps entire, till some new accident happens to disturb him. He delights so much in this boat, which enables him to feel the impression of the air, that he does not fail to make it, though the mud is removed, and he left with little water. Even when the worm is broken in several pieces, that which has the tail, or is the nearest to it, continues the same sport.

But for what reaſon does our inſect conſtantly form his tail into a boat, which lies ſecure on the ſurface of the water? Are we to ſuppoſe that this is done becauſe the organs of reſpiration are placed there, as we certainly know that other aquatic animals have them in the ſame part, which they lengthen out, till it reaches to the top of the water, and thus enjoy the benefit of the air? This was my firſt idea, and it was aftewards confirmed by anatomical diſſections.

Another curioſity, which I diſcovered in the ſaid boat-worm, is particularly intereſting, as it immediately relates to the animal œconomy. The canal, which runs all along the back of many inſects, would have been univerſally believed, from the nice experiments of two eminent academicans*, to be the great artery, ſupplying the place of the heart in them, if the wonderful caterpillar of Lyonet † had not appeared to call in queſtion this received opinion. An attentive inſpection of this canal in the boat-worm, may probably put this affair beyond doubt. The ſtate of perfect reſt in which the inſect is, the blood paſſing through the canal, and ſtriking the

* Reaumur and Bonnet.

† La chenille qui ronge le bois de ſaule: à la Haye, 1762.

eye by its lively purple color, and the number of blood-veſſels branching out from the ſides, give the obſerver an opportunity of making, at leiſure, the moſt important enquiries: an advantage not eaſily obtained in other inſects; as they are naturally of a very reſtleſs diſpoſition, and their blood is commonly ſo tranſparent, that it hardly makes any impreſſion upon the eyes.

Theſe remarks being premiſed, I now come to my principal object, concerning which, I have diſcovered, that my boat-worm is very eaſily reproduced; having tried upon him moſt of the experiments made upon the earth-worm. I ſhall not, therefore, enumerate either theſe experiments or the reſults, as moſt of theſe agree perfectly with thoſe of the preceding inſects, except in ſome particulars; three of which ſhall be mentioned at preſent.

The firſt is, that the aquatic -worms are quicker and readier in their reproduction than the earth-worms. It is therefore no wonder, 1. That they more eaſily recover their heads, even when conſiſting of many rings. 2. That this power exerts itſelf even in winter. 3. That upon repeated ſections of the ſame part, a greater number of reproductions is obtained in the ſame time.

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The ſecond particular is, the facility with which two thirds of the lower part of the body towards the tail may be broke; which is not to be obſerved in the remaining third part of the body towards the head. Hence, 1. reproductions of the tail, and theſe even very long, are frequently found in theſe inſects, when juſt taken out of the water. And, 2. reproductions of the head are very rarely met with in this ſtate.

The laſt particular concerns the origin and unfolding of the arterial veſſel, which manifeſts itſelf upon the trunk of a boat-worm, after his tail is cut off. At firſt, nothing is ſeen but the podex, of an elliptic form, except towards the upper part, where the angle is very acute. Hence a ſmall one becomes viſible, having the anus at its apex. The two ſides of the very acute angle form a very fine ſtraight line, of a red colour; this joins the trunk, in the direction of the longitudinal arterial veſſel of the inſect. The blood ſoon begins to ſhew itſelf at this line: we ſee it gently flow on through the whole length of it; hence it paſſes into the old artery, and this anaſtomoſes in a right line with the new veſſel, the developement of which clearly appears. In the mean while, the cone grows bigger, and the ſides of the podex appear tinged of a light brown, which gradually becomes deeper. The brown ſides change into two very fine arterial branches, which diſcharge their blood into the regenerated artery, from whence it flows into the old veſſel. Now as the artery of the tail, in its natural ſtate, appears to be produced in a ſimilar manner, although this is not ſo manifeſt on account of the opacity of the parts; it follows that, in my worm, the arterial veſſel is immediately produced from two arterial branches, united on the ſides of the oval which forms the anus.

But from whence do theſe two branches derive their blood? Perhaps from ſome ſmaller arterial ramifications? perhaps from a vein?

REPRO-

## REPRODUCTION OF THE TAIL IN THE TADPOLE.

THE tadpoles are thoſe aquatic animals, which grow into frogs or toads. The reproduction of their tail could not but take up a great part of my time, as much was to be learned from thence. The extreme tranſparency of the membranes is equivalent to the fineſt and moſt accurate diſſection; ſince, beſides ſhewing the texture of the ſolids, it gives the cleareſt view of the circulation of the fluids. On viewing therefore through a lens the tail newly produced, we have the advantage of examining how the fibres of the old part unite themſelves with thoſe of the new; at what time, by what means, and how the circulation paſſes on from the trunk to the reproduction; and laſtly, what order is obſerved by nature in the growth of theſe fibres, and the addition of the fluids. Every body muſt be ſenſible of the great importance of all theſe things in the preſent ſubject.

The circulation of the blood in the new-born tadpole ſhews itſelf ſooner in the bronchial veſſels, or organs of reſpiration, than in the tail. This blood is then compoſed of ſmall globules, of a pale yellow hue; this is likewiſe the color of the liquor which ſoon begins to run through the arteries of the tail; but the courſe of circulation is different. One half of the length of the tail is an aggregate of oblique muſcles, parallel to each other, but converging towards the axis. The ſides are compoſed of a membranous ſkin, ſpotted here and there in a very elegant manner.

Small rivulets, at firſt but few, afterwards in greater number, iſſue from the muſcles, make many ſerpentine turns in the membrane, and, by freſh windings, conceal themſelves behind the muſcles. A dark veil does not permit the eye to obſerve the origin of theſe rivulets. The tadpole being ſomewhat older, the veil diſappears, and the ſource of theſe ramifications ſhews itſelf in two real veſſels; the one arterial, the other venous. The firſt takes its origin from the root of the tail, and runs to the top; where, after ſome turns upwards, it forms the ſecond. Both run in a longitudinal direction all along, and very near the middle of, the tail. The vein iſſues forth before the artery.

The ramifications grow more and more numerous, and in a ſhort time fill the whole tail. The ſight of theſe numberleſs rivulets of blood affords real delight to the philosopher. This blood comes from the two great veſſels; and after a greater or leſſer number of turns, is brought back to them.

Theſe ramifications at firſt appear few, afterwards copious, and laſtly crowded; but were they ſucceſſively formed, or did they exiſt from the firſt, and require nothing but to be gradually unfolded?

A portion of the tail being taken off by a ſection perpendicular to the axis, we diſcover wonderful phenomena about the circulation, both in the part cut off, and in what remains of it. Theſe will be deſcribed in my book: I ſhall confine myſelf at preſent to ſome of the effects of the reproduction.

If the whole tail, or very near the whole, be cut off, the tadpoles go to the bottom of the water, and there lie down and periſh. But if a leſſer part be taken off, not one of them dies; and all without exception recover what they loſt.

Nature obſerves the following laws in the growth of theſe reproductions. They are more conſiderable, when a great part of the tail is taken off; not ſo large after a leſſer ſection;

fection ; and leaft of all, when a very fmall bit has been cut off. The greateft length feems however rather to take place, when the tail is divided in the middle, than when the fection is higher.

If the tadpoles were very young when cut, the reproduction appears very foon. In one fummer day it makes the moft rapid progrefs; and in a fhort time the new part not only equals that which was cut off, but the new part of the tail and the old one joined equal in every dimenfion the tail of unmutilated tadpoles born at the fame time. The reproduction, being arrived at this heighth, continues to increafe in the fame proportion as the tail of fimilar animals, to which nothing has been done.

When, therefore, this operation is performed at different periods upon tadpoles of the fame fpecies, the reproduction of the fecond period is equally quick with that of the firft.

But if the tadpoles be greatly advanced, the beginning of the reproduction is retarded; and all other circumftances being the fame, its progrefs will be flower. Hence follows this law, which I always found unvaried; that the quicknefs of the reproduction,

tion, both in its beginning and growth, is in an inverſe ratio to the age of the tadpole.

This rule equally takes place in the ſecond, third, fourth, &c. reproductions, which conſtantly follow upon a ſecond, third, &c. ſection; in a word, theſe ſucceſſive regenerations are never found to fail as long as the tadpole keeps its tail.

The differences obſerved in the manifeſtation and increaſe of the new-produced part, are analogous to what is found in the trunk. In the moſt advanced ſtate, the old part does not grow in the leaſt; in the middle ſtate or in youth it increaſes but little; but in infancy the growth is very rapid.

The tadpoles, to which no kind of nouriſhment is given, do not grow in ſize, at leaſt ſenſibly; the legs do not come forth, nor are the membranes of the infant ſtate caſt off. I have kept ſome in that ſtate of abſtinence during the greateſt part of the ſummer; and when theſe were ſtill no bigger than a ſmall pea, the tadpoles born at the ſame time, and continually fed, were, at leaſt, ten times fuller and bigger than their faſting friends; nay the greateſt part of the firſt had already got clear of their firſt envelopes,

velopes, and were converted into frogs. Hence the want of food retards in a frog the progreſs towards the ſtate of full growth; that is, in other words, it lengthens the periods of life in theſe animals, in the ſame manner that cold operated upon the caterpillars of Reaumur *, who were ſlower in becoming cryſallids; and, when cryſallids, longer in becoming butterflies. But yet I was not a little ſurpriſed to obſerve, that, in theſe abſtemious tadpoles, the tail was ſtill reproduced, and conſiderably increaſed.

Hitherto we have ſeen the phenomena of reproduction, as they appear with the naked eye in the tadpole; let us now take a microſcopical view of theſe appearances.

When any piece of the tail is ſeparated by a ſection perpendicular to the axis, the ſides, which, as we have ſeen, are formed of a membranous ſkin, are often the firſt that appear. The reproduction preſents itſelf to the eye as a prolongation of the old membrane; it is only ſomewhat finer and more tranſparent.

* Memoires pour ſervir, &c. tome ii.

Not long after this, a blackiſh thread iſſues forth from the axis or center of the trunk. Upon viewing it with a glaſs of a very great power, it appears to be nothing elſe but a contexture of longitudinal fibres, parallel to one another.

The blood of the great artery does not as yet reach the reproduction; but it comes cloſe to the ſection by means of ſeveral ramifications, opening into the great vein, into which it diſcharges itſelf.

The iſſue of longitudinal threads increaſes in the mean while, by the addition of many more fibres ariſing from the ſides; and growing larger in every dimenſion, it ſoon unites to the membranous ſkin. It then aſſumes the form of a ſmall ſlip or pyramid; the extremity of which is that of the tender new-born reproduction, and the baſis remains engrafted on the trunk.

The arterial blood then begins to paſs the limits of the ſection, and to advance a little way among the new fibres; but it ſoon takes a turn to the part whence it came, re-enters the trunk, and by other branches gets into the large venous veſſel. In proportion as the reproduction increaſes in bulk, the large artery throws more and more blood into it, by means of the increaſed number of its ramifications, which after ſome days become very conſiderable. The greateſt part of theſe branches having been carried on to the extremity of the tail, they all turn up again towards the trunk: from arterial, they become venous branches; and having been diſtributed by many circumvolutions throughout the whole extent of the reproduction, they diſcharge all their blood, as uſual, into the great vein. The ſame proceſs is afterwards continued by the aforeſaid ramifications; except only, that as their diameters increaſe, they carry, in conſequence, a greater quantity of blood.

Hence ariſes a very conſiderable difference between the circulation of the blood in the reproduction, and that in the original part. For although the two real veſſels in the original part, viz. the artery and vein, do ſend off from their ſides ſimilar and very fine ramifications, yet they both keep themſelves quite diſtinct from the root to the extremity of the tail; and, beſides their direction, have a much larger ſize. This happens whatever be the age of the tadpole. On the contrary, theſe two canals, in paſſing from the old to the new parts, become leſs, and dividing, as was before ſaid, into a vaſt number of ſerpentine ramifications, occupy the greateſt ſpace of the new produced tail.

It is alſo neceſſary to obſerve that this irregularity in the circulation does not only take place in the firſt reproduction, but is likewiſe obſerved in all the ſucceeding new tails of the ſame tadpole, when mutilated over and over again.

On conſidering the new organiſation with regard to the ſolids, the following phenomena preſent themſelves. As to the membranous ſkin, we have already ſaid that the new one only ſeems a continuation of the old, and this, at leaſt in appearance, is likewiſe the caſe with the longitudinal and parallel fibres. On the untouched part of the tail, the oblique muſcles, which unite in an angle at the axis, form at the ſame time a large bundle of fibres running towards the lower part of the tail, in a direction parallel to the axis, and this bundle remains cut by the mutilation of the tadpole. Now, if we examine the reproduction, when ſtill growing, beſides the evident regeneration of the oblique muſcles, we ſhall find that the new longitudinal *fibrillæ* coincide and join ſo well with the old divided fibres, that the firſt have all the appearance of being continued from the laſt.

Neverthelefs it fometimes happens that a fmall fold or deviation from the right line fhews itfelf at the point of union between the old and new fibres; but this blemifh in time is either removed, or is at leaft not fo apparent; and it is indeed very aftonifhing to fee the effect of time, in making the new and the original unmutilated tails fimilar to each other.

When the tadpole is fufficiently advanced, the increafed opacity of the natural tail prevents a microfcopical view of the vifcera inclofed in it; and the fame obftacle prefents itfelf in the part where the reproduction has been. This part being formed upon a trunk of fome thicknefs, is likewife pretty large in its origin, and therefore not an object of microfcopical obfervation. Diffection however, here fteps in to our affiftance, and fhews that nature proceeds in the reproductions formed on the trunks of tails in the more advanced tadpole, in the fame unalterable way as in thofe that are young, and whofe tails are ftill tender.

If, inftead of cutting off the tail in this manner, the membranous fkin be taken from the tadpole at any age, without touching the mufcles, another membrane, exactly like the former, fucceeds, and upon removing this a third.

third. The order only and poſition of the venous and arterial ramifications, differ from the ſituation of thoſe, which are found winding in the ſkins of unmutilated tails.

The tadpoles I examined, are ſuch as are changed into frogs and toads. Notwithſtanding the diverſity of ſpecies of theſe two animals, the organization of the tail is eſſentially alike, and the iſſue of my experiments was alſo the ſame.

## OF THE EXISTENCE OF THE TADPOLES IN EGGS BEFORE FECUNDATION.

IT is now ſufficiently known to naturaliſts, that the eggs of frogs and toads are not fecundated in the maternal womb, but at the time they iſſue from the mother. The male gets upon her back, embraces and holds her faſt, with his fore legs extended round about her breaſt; and, performing the office of a midwife, ſeizes the eggs of the parturient female with the toes of his hind legs, facilitates their coming out, and as they are ejected, ſprinkles and fecundates them with his ſeminal liquor. To the happy inveſtigations of the great Swammerdam * we are indebted for this curious diſcovery, which has ſince been fully confirmed by Roeſel † in his natural hiſtory of frogs, an elegant and famous work. From this diſcovery it is evident beyond a doubt that the eggs of frogs, ſo long as they remain within the body, are not in a ſtate of fecundation.

* *Biblia Naturæ.*

† *Hiſtoria Naturalis Ranarum.*

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I ſet out with this fact, when I undertook to make a particular and ſtrict compariſon between thoſe unfecundated eggs and others, that have been fecundated by the male; whatever the event might be, either contrary or favourable to the various ſyſtems on generation.

I firſt examined the fecundated eggs newly diſcharged from the female, and found them incloſed by their mucilaginous part, divided into a number of ſmall ſpheres, connected and glued together. An egg is placed in the center of each ſphere; it is ſurrounded by two circular delicate and concentric membranes, a little diſtant from each other, and eaſily diſcernible with the eye, on account of the infinite tranſparency of the ſmall mucilaginous ſpheres. On piercing the membrane neareſt to the egg, there follows a ſmall drop of a watery fluid, in which the egg always floats.

The egg being freed from its concentric membranes, and its mucilage, appears perfectly round, has a beautiful luſtre, and a ſmooth ſlippery ſurface, one half of which is blackiſh, and the other whitiſh. On pricking it with a needle, a half fluid and viſcid ſubſtance of a pale yellow color oozes from it. If a larger opening is made, a greater quantity of this ſubſtance comes out; ſoon after this the egg ſhrinks and ſhrivels up, and being at laſt entirely emptied of its contents, nothing remains beſides the dry, double colored ſkin, which being left to itſelf, liquifies and diſſolves.

The yellowiſh matter being viewed through a lens, appears compoſed of an infinite number of roundiſh particles of the ſame colour. It unites and incorporates with a drop of water, and gives it its tinct. When the eggs are hardened with ſpirit of wine, or boiling water, the internal parts, being examined with the greateſt attention, give no marks of organization. When ſoftened again and diſſolved in water, the round yellowiſh particles are again apparent. This, in ſhort, is the analyſis I made of eggs newly laid by frogs, and impregnated by the male.

I then proceeded directly to examine thoſe eggs, which ſtill remained in the body of the frog, and conſequently were not fecundated. The firſt frog I opened was in the act of copulation; all her eggs were already deſcended into the womb, excepting four or five, which ſtill remained in the oviducts, and two or three in the ovaries. Theſe contained moreover a very large quantity of immature eggs, no bigger than poppey ſeeds, and of a dark

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hue. The ufual gelatinous matter was not yet found furrounding the eggs of the ovaries, but it did encompafs thofe of the oviducts, and much more thofe that had already got into the womb.

Thefe laft were in great abundance, and upon a clofe examination, appeared not to differ in the leaft from the fecundated eggs examined before. Befides that the nature and fize of the vifcid fpheres was perfectly fimilar, that the pofition, figure, and colour of the two membranes were exactly alike, and that the liquor contained in the membrane neareft the egg was the fame, there was no circumftance, by which the unfecundated eggs might be diftinguifhed from thofe that were fecundated. No difference could be obferved in their fize, roundnefs and furface, or in their colour and fkin. The inclofed fluid iffued with the fame facility from this egg, when pierced with a needle, and the nature, property and characteriftics of this fluid were the fame. In fhort, if I had not been convinced that the firft eggs were fecundated, and that the laft were not, it would have been impoffible to find it out from the moft attentive analyfis and the moft accurate comparifon. I therefore was obliged to admit of the moft perfect fimilarity between eggs in thefe two different ftates.

The ſame concluſion was deduced from my examination of many more frogs which I opened. There was only this trifling difference to be obſerved, that the eggs of thoſe females, who had not yet ſuffered the embraces of the male, beſides being confined within the ovaries, and ſomething ſmaller on account of their being leſs advanced, were alſo deprived of the mucilage, which they take up, as it is well known, on paſſing through the long and intricate convolutions of the oviduct.

In order to compleat the compariſon I had begun between theſe two ſpecies of eggs, the changes, which were afterwards to take place in them, were now to be examined. As to the unfecundated eggs, they only ſpoil, diſſolve, and come to nothing. Little by little the mucilage ſeparates, the membranes ſhrivel, break, and diſappear, and the eggs, after waſting away, ſoon break into ſeveral pieces, which are ſcattered about the ſurface of the water. But the caſe is very different with the fecundated eggs. Round as they were before, they lengthen firſt without growing bigger, but afterwards with an evident increaſe of bulk. The ſuperficies of the whitiſh half grows ſomewhat darker, and on the blackiſh part there ſoon appears a ſlight longitudinal furrow, bounded by two riſings,

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which extend in a right line over the greater diameter of the lengthened egg. In proportion to its increaſe, the internal membrane dilates itſelf, and contains a larger quantity of fluid.

The ſmall furrow with its riſings grows longer, and ſoon after diſappears on one ſide of the egg. This ſtill keeps up the form of a lengthened ſphere, but has on one ſide of the elongated part a kind of ſtalk, or ſmall appendix. The oppoſite or deep coloured white part of the egg retains its color, but ſwells a little. The other blackiſh part is thrown into a curvature, the little appendix lengthens, and ſhews itſelf then, although more conſpicuouſly ſome time after, to be nothing elſe but the tail of the tadpole; the black curvature turns out to be its back, and the ſwelling on the oppoſite part its belly.

In fact, the part oppoſite to the tail then puts on an appearance ſo much reſembling the head of the tadpole, that it cannot be miſtaken. On the fore part of his head the form of the eyes is to be ſeen, although ſtill cloſe; thetwo ſmall buttons like prominences alſo ſhew themſelves, by which the animal, when tired with ſwimming, faſtens itſelf to bodies, even ſuch as are ſmooth. The be-

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ginning of an opening for the mouth likewiſe manifeſts itſelf; and laſtly, the two gills become apparent, and the blood is ſeen flowing within their ſubſtance.

In theſe early times the animal gives yet no ſign of life, either in moving or twiſting itſelf, if pricked with a needle, or ſuddenly expoſed to the rays of the ſun, even when concentrated by a lens. Theſe impreſſions indeed excite great feelings, in a more advanced ſtate of the organs; which, acquiring a greater firmneſs and ſtrength, enable the tadpole to break through its confining envelopes, and to ſwim freely in the water.

Such are the phenomena, which gradually make their appearance in the fecundated eggs. Hence it muſt be obvious, that theſe are not properly, as was imagined before, the eggs from which the tadpole grows, but rather the tadpoles concentrated and coiled up in themſelves.

This important fact is ſtill more fully eſtabliſhed by the perfect ſimilarity between the parts compoſing the internal ſubſtance of the fecundated egg, from the time it begins to lengthen, to the manifeſt developement of the tadpole, and the parts found in the ſame egg before it begins to unfold itſelf. We ſhall give the moſt authentic and indiſputable proofs of this ſimilarity in due time.

It appears therefore plainly, that the tadpoles exiſt before fecundation, which moſt intereſting truth may for the ſake of preciſion be thus demonſtrated. The unfecundated eggs do not differ in the leaſt from thoſe that are fecundated; theſe laſt are nothing elſe but the tadpoles themſelves coiled up and concentrated; the ſame is therefore equally true of the unfecundated eggs; and conſequently the tadpoles exiſt before fecundation, and require only the fecundating liquid of the male to unfold themſelves.

Hence it follows, that frogs ought not to be reckoned among the oviparous claſs of animals, as naturaliſts have ranged them, but that they more properly belong to the viviparous claſs. Indeed they would rather ſeem to conſtitute a ſeparate claſs, from the circumſtance of their fetuſes not ſhewing the form and features of their ſpecies before they are come to light. Thus nature ſeems to delight in diverſifying the modes of animal generation.

I would not, however, have the word egg entirely laid aſide, as it ſeems convenient enough to diſtinguiſh the immature tadpoles, under the form of ſmall eggs, from thoſe that are already diſcloſed, and ſhew their real make.

The preſent diſcovery leads on to other truths, which throw ſome light upon the obſcurities, in which the ſyſtem of generation is involved. I ſhall for the preſent only mention briefly one of theſe truths. The moſt eſteemed naturaliſts obſerve, that the firſt conſtituent parts of birds known to us, do not diſcloſe before the operation of the male. Hence they infer that the ſeminal fluid ſerves both as a ſtimulating and a nutritious juice to the germ. Before fecundation, the ſmall heart of the germ wants force ſufficient to overcome by its impulſe the reſiſtence of the ſolids. This force it receives from the fecundating liquor, which ſtimulates, gently irritates, and obliges the heart to propel with greater power the fluids through the ſmalleſt canals. The ſame liquid afterwards becomes nutritious, bringing about the developement of the germ, which implies nouriſhment.

It is evident from my obſervations, that this noble and ingenious theory cannot uni-

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verſally be received in regard to the great work of generation. The tadpoles, or if you pleaſe, the eggs of tadpoles, unfold themſelves conſiderably before fecundation. One of theſe, when in the uterus, is at leaſt three times bigger than the ſame, while ſtill attached to the ovaries. There are animals therefore, the germs of which are not diſcloſed at firſt by the ſpermatic fluid, but by the juices of the mother, and ſince this unfolding or increaſe of bulk is performed by nutrition, which muſt imply a circulation of fluids, and that ſuch a circulation cannot be carried on without the action of the heart, we are obliged to infer that theſe maternal juices are themſelves that kind of ſtimuluſs which the ſeminal liquor is ſuppoſed to be in birds. Conſequently the heart in the germ of the tadpole, muſt beat ſufficiently to produce a circulation of fluids, without an inſuperable impediment from the ſolids.

But if tadpoles are already animated by the action of the heart, if they have acquired a conſiderable increaſe of ſize before they come to light, how happens it that, without the intervention of the male ſeed, they ceaſe to grow, and periſh, notwithſtanding the liquor in which they ſwim, and which is certainly their nouriſhment in the firſt periods of life? If the aſſiſtance of the

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ſeminal liquor is neceſſary, in what does its efficacy conſiſt? What are the proper and diſtinguiſhing characteriſticks of this liquor? As it fecundates the young tadpole fetuſes in a particular manner, that is, after their coming out of the womb, does it perchance differ in its method of acting from the ſemen of other animals? How is the fecundation of frogs eggs brought about? Are there any openings, or holes for ſuction on their external ſurface, to be diſcovered by means of a very powerful magnifier, by which the ſeminal fluid may be internally abſorbed? Again, ſince this liquor acts externally, could not the eggs of frogs be fecundated artificially, by ſprinkling them before fecundation, with the liquor extracted from the ſpermatic veſſels of the male? What would happen if this liquor was uſed to ſprinkle the eggs of fiſh, which are commonly ſuppoſed to be fecundated in the ſame manner as thoſe of frogs? What would follow from ſprinkling the eggs of frogs with the ſeminal ſubſtance or the ſoft rows of fiſh?

The elucidation of theſe queſtions encouraged me to attempt others. Theſe experiments were too curious and intereſting not to be varied in ſeveral ways. The fecundation of our frogs eggs requires the aſſiſtance of the the males only at the time when they are emitted from the body of the females. Why therefore the continuation of these tenacious and amorous embraces, which sometimes last forty days, according to the observations of the indefatigable Swammerdam? * Do they serve to express the eggs from the ovaries, and to facilitate their descent through the oviducts to the womb? When the frogs are by chance disturbed in this amorous conflict, during the efforts of the males, and are obliged to keep to themselves, do they still lay their eggs? Do those who were never compressed by the males also deposit their eggs?

The eggs of toads, which form a string of about two feet in length, are, according to Roesel, † fecundated in the same manner as those of frogs. But what shall we say of these horrid and enormous monsters, when compared to other toads, whose females discharge at once many thousands of eggs? I shall not fail describing what I observed in regard to their copulation, and to compare my discoveries about the origin of the young ones of that species, with the small account

* Biblia Naturæ.
† Historia Naturalis Ranarum.

given of this matter by Valiſneri*. In this diſcourſe I ſhall likewiſe ſpeak of the judicious care the females take of their eggs, of the choice of the water in which they depoſit them, and of the ſurprizing power the mucilage has of preſerving theſe eggs.

* Tom. i. Iſtoria del Cameleonte Africano.

## REPRODUCTIONS OF THE HEAD AND OTHER PARTS IN THE LAND SNAIL, AND OF THE HORNS IN THE SLUG.

THE head of the ſnail is more complicated than I imagined. It has a brain of conſiderable bulk, conſiſting of two lobes, united in the middle. From the lower part of the brain, or that towards the body, two very remarkable nerves, which are only a bifid medulla ſpinalis, iſſue forth; ten other nerves take their courſe towards the upper part, diffuſe themſelves through the head, and ſome of them throw out many ramifications. Four of theſe ten nerves are placed within the four horns of the ſnail; and the two belonging to the large horns are very beautiful. At the top of their extremity, which ſpreads out into a bulbous form, the two eyes of this reptile are placed. In each of theſe eyes we may diſcern five parts; viz. two coats, and three humors; the aqueous, the criſtalline, and the vitreous.

The various and ſtrange motions of the head require the aſſiſtance of a great number of muſcles. Each horn is furniſhed with a particular muſcle, by which the animal draws it in, and hides it within its head at pleaſure.

The ſnail, beſides its mouth, has lips belonging to it, a tongue, a palate, a ſtomach, teeth, &c. Theſe teeth are of a horny ſubſtance; and being cloſely united to one another, ſeem to form but one tooth.

This multiplicity of parts, which compoſe the head of the ſnail, were clearly diſcovered by Swammerdam's diſſections. I found that his obſervations were true, and thought proper to mention theſe few particulars, in order to ſhew that the reproduction of the head in ſnails has in it ſomething very ſingular and great: but this will appear ſtill more evidently from an account of the facts.

In the firſt place, ſnails can reproduce their horns; and as this operation differs from any other in the manner in which it is performed, it throws new lights upon the theory of animal reproduction. Upon the trunk of other animals appears a ſmall cone or ſlip, the baſis of which is at firſt without any compariſon leſs than that of the trunk; and the difference is only removed in proceſs of time.

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The caſe is not the ſame when the ſnail's horns have been cut off. The trunk itſelf becomes roundiſh, like a ſmall knob, of a lighter color than the reſt of the horn. This knob grows bigger; its color becomes deeper; and from the top of it, if it is a large horn, ſprings forth a black point, which is the eye of the ſnail. In the mean while, the mutilated horn increaſes in ſize, and after ſome time equals that which has not been touched. This reproduction ſeems at firſt ſight to be nothing elſe but a prolongation of the trunk. The color of the new part is at firſt lighter thanthat of the old one. The reproduction of the two ſmall horns is carried on in the ſame manner.

Nature, however, does not always proceed in the ſame way in the production of theſe horns. It frequently happens, that the trunk, inſtead of becoming round, grows tapering into a point, and, in appearance, longer. From the top of this, the black point or eye is ſeen to ſqueeze out. The point afterwards ſpreads, and changes into a ſmall globe. The eye appears at top, and the reſt of the proceſs is the ſame as before. If it be aſked, whether the number of the conſtituent parts is exactly the ſame in the old and new horn? the anſwer is, that by the niceſt diſſection no difference can be found.

But does this reproduction conſtantly ſucceed, whatever be the number of the horns taken off, and in whatever ſituation they are cut? As nature deviates here from her uſual method of proceeding in other reproductions, ſo it will be ſeen, that ſhe does not always anſwer the obſerver's expectations.

If, inſtead of the horns alone, the head of the ſnail is quite cut off, a new one will ſucceed. But here again the reproduction is performed in a ſingular manner. When, for inſtance, an earth-worm loſes its head or tail, the ſucceeding reproduction is an entire organic body; that is to ſay, a part in miniature exactly ſimilar to that which was cut off, and wanting only a farther unfolding of its rings.

On the contrary, what appears on the trunk of a ſnail, is not an entire organic body, containing at once all the parts which conſtituted the head that was cut off. But theſe parts are often made ſeparately at firſt, or grow piece by piece at different intervals; and a pretty long time is required to unite and conſolidate them into one maſs,

very

very little, if at all, diſſimilar from the original pattern. Some inſtances I am going to mention will make this more clear.

Sometimes the reproduction appears like a ſmall round body, containing the primary parts of the two lips, and of the ſmall horns, which are united to the mouth and to the new-formed tooth. The little round body is placed on the centre of the trunk like a ſmall ball, reſting by ſome few points upon a ſubjacent plane. The other parts, as the large horns, and the fore part of the ſole or foot of the ſnail, which in the unmutilated animal are contiguous to the head, will be entirely wanting. Another trunk ſhews the larger horn on the right ſide more than one tenth of an inch long, already provided with its eye; and under this, at ſome diſtance, the firſt lineaments of the lips appear ſeparately. The reproduction in a third ſnail is a group of three horns; two of which are already arrived to their natural length, while the third is ſtill but juſt above the ſkin. Some ſnails only reproduce at firſt a ſmall knob, which is nothing but the firſt mark of the lip. Others are already provided with the whole head, wanting only one horn, or more. In others, the reproduction begins by the two large horns ſpringing from the trunk, or by the ſmall horns, or by one large and one ſmall horn.

Again, ſome ſhew nothing but the trunk, without any true ſign of reproduction, although the head was taken off at the ſame time with others, from which ſuch a number and variety of organs came forth, as were juſt now deſcribed. On the contrary, in ſome ſnails there is no difference between the head which was cut off, and that which is newly produced, except an aſh-coloured line perpendicular to the axis of the head, pointing out exactly the mark left by the ſciſſars in taking off the head of the ſnail.

This mark is not always a ſimple line. Sometimes there appears a deep cavity, conſtantly of a white color, perpendicular to the axis of the neck, or oblique, according to the direction in which the ſection has been made. In this laſt caſe it ſometimes happens, that on the ſide where the greateſt portion of the head has been cut off, the cavity will be much larger; and in ſome ſnails an enormous gap will be ſeen on one ſide, while nothing appears on the other, except perhaps the mark of the aſh-coloured line.

Though theſe cavities fill up in proceſs of time, yet the mark of the ſection, or the line juſt mentioned, is ſeen upon the neck of ſome ſnails, two years after. Even after ſo long an interval, the reproduction of the head is not quite completed in ſome: one or ſeveral horns may be wanting; they may not all, be come to their natural ſize, or they will appear full of tubercles, and monſtrous. Such appearances, conſiſting of an unnatural poſition of the newly-generated parts, have frequently occurred.

I have here given a ſpecimen of the ſingular varieties, which are obſerved in the reproduction of ſnail's heads, although cut off all at the ſame time. But are theſe ſingularities to be reckoned defects or *luſus* of nature, or ſhould they rather only be conſidered as ſingularities in appearance, and really founded upon conſtant and invariable laws? Should we be induced to think, that the circumſtances of the ſection, with regard to greater or leſs depth, or a difference in the obliquity of the diviſion, will determine the laws by which the future reproduction is to proceed; and conſequently, that an attentive and minute examination will at laſt diſcover to us the whole ſyſtem of theſe laws, ſo as to enable us to account for theſe ſeeming oddities ?

The uſe which the ſnails made of their reproduced heads in eating, ſeemed to be a certain proof that all the conſtituent parts of the head were regenerated. But yet I thought proper to aſcertain this point by diſſection. By this I obtained infallible proofs that the new head is perfectly well provided not only with the ſimilar and diſſimilar parts firſt mentioned, but alſo with many others which I ſhall deſcribe ſomewhere elſe; and which, joined to the former, make up the complete head. Hence it was alſo evident, that each of the new parts is ſo well united and inoſculated with the old ones, that nobody would ſuſpect the ſnail to have ever been mutilated, except by the aſh-coloured line which runs acroſs its neck.

The ſame effects followed from ſections above or below the brains, or through the medulla ſpinalis. In this laſt caſe, a part of the medulla is ſupplied, together with a new brain; from which the ten nerves before mentioned proceed.

The reproduction of the head having thus been obtained, it was natural to think, that the ſnail would recover other parts leſs complicated

plicated than this. Such are that projecting collar, which ſurrounds and adorns the neck, when the animal is out of its ſhell, and the flat and large foot, on which the body ſupports itſelf in its motions. Theſe two parts grow again perfectly after having been cut off.

But is the power of recovering parts, ſeparated in this manner, common to all the ſpecies of land ſnails? In all thoſe I have examined, the reproduction has always taken place: but there is one ſpecies I ſhall more particularly deſcribe, as being privileged by nature in a particular manner.

The naked ſlugs, whoſe manner of generating has been ſo elegantly deſcribed by Redi *, deſerved likewiſe to be examined. But my inveſtigations of the ſnail left me but little time to beſtow on them. The few experiments I made amount to this, that they are upon a par with the ſnails in the reproduction of their horns; but in that of the head ſeem to be much inferior.

* Degli Animali viventi negli Animali viventi.

## REPRODUCTIONS OF THE TAIL IN THE AQUATIC SALAMANDER.

THE wonderful things aſſerted of the Salamander, its terrible poiſon, and the pretended privilege which has been given to it of living unhurt in fire, have been entirely diſproved by the obſervations of curious and unprejudiced philoſophers *. This animal will now appear in a much higher light, and become more properly the object of our admiration. If a ſmall lizard excites our wonder, by the power of reproducing its tail, and lobſters or craw-fiſh by the recovery of their claws, how much more ſhould the ſalamander be admired, who, beſides other parts, may, as I have diſcovered, repair the loſs of both its tail and its legs? This regeneration is ſo much more ſurpriſing than that which takes place in the craw-fiſh and ſmall lizard, as the ſtructure of theſe parts in the ſalamander is infinitely more complicated and refined.

Our aſtoniſhment does not end here. The tail of the ſalamander, beſides a compleat

* Maupertuis Mem. de l'Acad. des Scien. de 1726. Valiſneri del Camaleonte Africano.

veſſels,

apparatus of nerves, muſcles, glands, blood-veſſels, &c. is furniſhed with vertebræ of real bony matter, and their legs do not differ from thoſe of the moſt perfect animals, in the number of the bones of which they are compoſed. Now when the legs and tail of this animal are taken away, new vertebræ, new bones are produced; a phenomenon as wonderful, as it is hitherto unknown. But before I deſcribe theſe regenerations, it will be neceſſary to premiſe ſome obſervations about the nature and properties of this reptile.

Mr. Du Fay reduced to three ſpecies all the ſalamanders which are found about Paris *. Whatever pains I have taken, I have not been able to meet with theſe three; but, on the other hand, have diſcovered ſome of a different kind. It appears therefore, that the ſpecies of Salamanders vary according to the nature of the climates. Thoſe I have examined I chuſe to call aquatic, as I always found them in the water. They can however live out of it, and even live well. I have alſo been told by perſons of veracity, that in the winter they have ſometimes been found in holes under ground, and under the turf; ſo that if any body

* Du Fay Mem. de l'Acad. des Sc. de 1729.

chuſes

chuſes rather that they ſhould be called amphibious animals, I ſhould hardly think it neceſſary to diſpute about it.

My ſalamanders keep alive for a conſiderable time under water; but they die at laſt, although ſooner in one ſeaſon than in another: air is therefore neceſſary for them. To aſcertain this, I made ſome experiments with the air-pump; ſometimes having the ſalamanders dry in the vacuum, and ſometimes keeping them under water in the ſaid vacuum. The ſame experiments have been made with frogs, in order to compare the nature of theſe different animals.

The notion that ſalamanders can live in the fire is, as we have ſaid, a mere fable. But do they bear it better than other animals? What degree of heat deſtroys them? This was not yet known; and I endeavoured to come at the truth, by expoſing the ſalamanders to the ſun-beams in ſummer, either on the ground, or in water. I encreaſed, by degrees, the heat of the water in which they were confined, by putting fire under it. At laſt I tried them with hot embers; and found, by the help of the thermometer, that theſe creatures can hardly bear the ſame degree of heat, which is borne by other animals

of

of the terreſtrial, amphibious, and aquatic kind.

Mr. Du Fay obſerved, that they reſiſt cold much better than heat *. Having put them in water, and made that water freeze, ſo that they were ſurrounded with ice, he found that they ſtill kept alive. This experiment deſerved to be repeated and improved. I ſhall therefore ſhew what degree of cold they can bear without dying; and it will appear, that as there is nothing marvellous in the power of the ſalamander (at leaſt of theſe of our country) in reſiſting heat; ſo the power of reſiſting cold is ſo far from being more conſiderable in them, that on the contrary, they can bear it leſs than many other animals.

Theſe experiments brought on others of the ſame kind. It is well known, that not only inſects, but many animals, commonly called perfect, paſs the winter in a kind of torpor or ſleep, which ties and benumbs their limbs in ſuch a manner, as to make them incapable of performing any of the functions of the body. Such are dormice, bats, marmots, frogs, &c.

* Ibid.

Sala-

Salamanders are in the ſame claſs. The immediate cauſe of this lethargy is by philoſophers attributed to the exceeding ſlow motion of the fluids, which being congealed to a certain degree, probably can no longer circulate, except in the large veſſels. This opinion was very plauſible, but ſtill wanted to be confirmed by experience. I therefore made ſeveral trials, not only on ſalamanders, but likewiſe upon ſeveral other animals of cold blood, as they are called. In order to procure the beſt lights, I thought proper to examine this in different ways. I obſerved that an equal degree of cold did not benumb every ſpecies of theſe creatures equally; ſome require a greater, ſome a leſs, degree of it. The ſame thing takes place with regard to the death of thoſe animals, occaſioned by an increaſe of cold. The limbs are the firſt parts that congeal and grow hard. The centre is the laſt part. When that is froze, the animal never comes to life again; whereas the limbs, after being thawed, become as uſeful as before. Theſe experiments, together with many others I made, by means both of natural and artificial cold, were intended to obſerve the change or want of equilibrium in the circulation of humours, which begins, increaſes, and comes to its heighth, and afterwards takes the oppoſite turn, increaſes, and dif-

difappears in proportion as the animal, from a moderate degree of cold, paffes to the extreme, and from hence, by degrees, returns to the temperate.

Our falamanders are oviparous, contrary to the terreftrial, which are viviparous *. Their eggs are of a dun color, and furrounded with a glutinous matter, not unlike that of frogs. Naturalifts are ftill ignorant, whether falamanders copulate as the more perfect animals, or as frogs and fifh. The doctrine of generation being concerned in enquiries of this kind, I have given myfelf a good deal of trouble about them, and will take notice in my book of every thing that fell under my obfervation relative to this fubject. My obfervations about the eggs of the falamanders paffing from their ovaries into the oviducts, a point which has been hitherto in the dark and not well underftood, fhall be expofed at the fame time; and I fhall mention the changes thefe eggs undergo in this paffage.

Mr. Du Fay † fays, he could never fucceed in bringing the falamanders out of the eggs, nor fee them in their earlieft ftate of infancy. I have been more fuccefsful in

* Maupertuis, ibidem.

† Ibidem.

both

both theſe inſtances. In the firſt moments after the birth of theſe animals, the circulation of the blood through their gills is very beautiful. Beſides the bronchia deſcribed by Du Fay, and ſuppoſed to have been diſcovered by him, I have found ſome others, which afterwards periſh. Thoſe, which were deſcribed by the French obſerver, diſappear entirely in three weeks time; but in my ſalamanders they laſted an equal number of months.

The tranſparency of theſe very ſmall ſalamanders enabled me to find out diſtinctly how the arteries of the tail become veins; in what manner, from the two principal veſſels, viz. the vein and the artery, ſmaller and ſmaller branches gradually come forth, and how the blood, which was yellow at firſt, afterwards acquires a red color. I have diſcovered ſome other particulars, which have been of no ſmall uſe to me in comprehending the regeneration of the tail.

My chief experiments about the cutting off the tail, may be compriſed under the following queries.

I. Does the reproduction take place, 1. in every known ſpecies of the ſalamander? 2. And at any period of their life? 3. Does it

happen

happen in whatever ſituation they are kept, upon the earth, or in water? 4. Is it brought about, let the length of the divided part be greater or leſs? The reſult of my experiments on theſe ſeveral points has conſtantly been in the affirmative.

II. Is the regenerated part equally long, when much or little of the tail has been cut off? and is it ſo in all ſalamanders of the ſame ſpecies and age? Is it equal when the ſalamanders are of the ſame ſpecies, but of a different age? Is there no inequality when both ſpecies and age are different? A difference in each of theſe particulars occaſions a diverſity in the reproduction.

III. Do the conſtituent parts of the new tail differ from thoſe of the part that was cut, in number, ſtructure, or connexion? By no means; notwithſtanding the union of ſimilar and diſſimilar parts. The chief of theſe conſtituent parts are the *cuticle*, the *ſkin*, the *glands*, the *muſcles*, the *vertebral bones*, the *oblongated medulla ſpinalis*, and the *blood veſſels*.

IV. Is the number of the reproduced vertebræ equal to thoſe that were cut off? Are they formed, one after another, at the end of the tail? What time is required to bring the new vertebræ to the ſize and firmneſs of the former? In the courſe of the laſt enquiry, I found that a whole year was not ſufficient to render the new part equal to that which was cut off, eſpecially when much was taken away. It is however proper to obſerve, that, during one half of the year, or the winter, the regenerating power ceaſes in the ſalamander.

Hitherto the ſection was made perpendicular to the axis of the tail. It was therefore neceſſary to give it a different direction, which led me to enquire,

V. What happens to the tail by cutting it, 1. all along the middle part of the ſpine, beginning from the extremity of the tail, and extending the inciſion upwards to the roots, in order that the tail may be divided in its whole length into equal portions, without being ſeparated from the body? 2. What is the conſequence of ſuch a ſection, when not extended ſo far? 3. What happens when the ſection is in an oblique direction to the axis of the tail? 4. What happens when either two, or only one ſlip is cut off lengthways from the tail, without damaging the ſpine?

VI. How far is the tail affected, 1. if the ſpine only is cut in two or three places? 2. When it is cut acroſs, either cloſe to the ſpine excluſively, or beyond it, ſo that the part cut remains attached by a ſmall ſlip? 3. When ſeveral inciſions have been made here and there upon the muſcles? 4. When a whole ring, or ſlice of the fleſh, is cut off tranſverſely? The reſults of theſe laſt reproductions were exactly ſimilar to thoſe of the foregoing.

VII. When the new reproduction is cut off, is it ſucceeded by another? Does this laſt proceed in the ſame manner as the former? The ſame proceſs takes place not only in a ſecond reproduction, but alſo in a third, in a fourth, &c. and the ſalamanders deprived of many ſucceſſive reproductions, ſtill follow in the formation of new parts, the ſame unalterable laws.

# REPRODUCTIONS OF THE LEGS IN THE AQUATIC SALAMANDER.

DISCOURSING on this reproduction, I cannot avoid being more particular than I have been hitherto. Naturalists might even accuse me of being much too concise, if the summary of my experiments was not much less than the detail in my journals. An animal of the most perfect class, which, in the reproduction of its limbs, always presents something to satisfy the curiosity of a nice observer, justly deserves to be studied very assiduously, and to be attended to with much accuracy and reflection. Whoever is in the least acquainted with these matters, evidently sees how much light the consideration of this animal alone may throw on many obscure parts of physiology and natural history.

In whatever place the salamander's legs are cut off, the regeneration is equally well performed. It succeeds alike, whether one or all the four legs be cut off at once, or at different times. This reproduction is obtained in the same manner, when either one or all the legs are intirely disjointed close to the body of the animal. And as I have found it to be an universal law of nature, that it only repairs the lost part; so I have observed, that when the legs are taken away, the reproduction consists in the pushing forth of entire legs; but that when one or more of the legs are cut, through the middle, for instance, nothing is reproduced but the part taken away.

When the legs have been disjointed close to the body, the new-produced legs keep in their whole length the just and exact proportions observed in the natural legs. But when they have only been partially cut off, the reproduction seems, at their union with the trunk, to be straightened and deformed. This however does not take place in the salamanders of the small species, though already grown up; and I have never observed it in the young animals.

The legs are reproduced, without any exception, in all the different species of salamanders I know, and of whatever age they are. I have never found it otherwise, in any one instance out of many hundred animals I have cut in this manner. Yet, 1. the reproduction happens sooner in young salamanders; and in such the growth of the leg is ſo quick, that in a very ſhort time it appears in all reſpects the ſame as the old one. 2. When the four legs are cut off cloſe to the body, the anterior ones commonly appear firſt. What may be the cauſe of this phenomenon? 3. In full-grown ſalamanders, the reproduction is quicker when they are of the ſmall ſpecies, than when they are of the larger. 4. When the toes of one leg (the right, for inſtance) are cut off, the reproduction is ſo ſlow, that if the whole of the left leg has been taken away at the ſame time, the toes, which unfold themſelves in the new leg, become equal, in the ſame ſpace of time, to thoſe that grow from the right leg.

The beginning of this reproduction is a cone, which is nothing but the leg in miniature, and only wants to be unfolded. At firſt the cone is of a gelatinous ſubſtance, endued with the moſt exquiſite feeling; and though the new leg be ſtill very ſmall, the articulations are viſible, and the ſalamander uſes them very ſoon. This is likewiſe obſerved in new-born unmutilated ſalamanders, juſt beginning to ſhew their legs.

Some other reſemblances are obſerved in the growth of the natural and of the artificial legs. All ſalamanders have four toes on on their fore-legs, and five on their hind-legs. I have found that theſe toes, both in the fore and hind-legs, do not come out all at once. At firſt, the ſmall legs are only four cones, ending in a point. On either ſide of this are ſoon ſeen two ſmaller cones; which, together with the middle point, are nothing elſe but the three middle toes, as it appears afterwards. Then the remaining toes, viz. one in each of the fore-legs, and two in the hind-legs, unfold themſelves nearly in the ſame manner. The ſame appearances are obſerved in the reproduction of the legs that have been cut off.

Moreover, as the natural legs take their greateſt increaſe when they are ſtill ſoft, and lengthen leſs when they begin to harden, the ſame thing happens in the reproductions.

It is neceſſary to note the following periods, at leaſt when we ſpeak of ſalamanders already come to their growth, viz. the *conſiderable time*, which paſſes after the cutting off of the leg, *before the reproduction begins*; *its ſlowneſs in the firſt period*; *its quick progreſs afterwards*; *and, laſtly, its tardineſs* when the leg begins to harden.

There is ſtill this difference between the natural and the reproduced leg, that not only the cone, but the leg itſelf during its reproduction and unfolding, appear much larger than the firſt cone and leg produced by nature. The reaſon of this difference is obvious. Both the cone and natural leg come out from the ſalamander when yet very ſmall, or new-born; whereas the new cone and leg come out from a full-grown and much larger ſalamander. In this caſe the juices, which contribute to the unfolding and increaſe of the leg, muſt be more powerful and more abundant than in the former.

Hence the reaſon may be deduced why the reproduced cone and leg are bulkier when both the animal and trunk from which the cone iſſues are larger; this I found conſtantly in every animal reproduction.

The circulation of the blood, viewed through a microſcope, appears the ſame in the natural and the reproduced leg. This indeed can only be thus viewed in ſmall ſalamanders; as the opacity of the larger kind prevents ſuch an examination. Recourſe was therefore had to diſſection; and this being carefully performed without hurt-

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ing the principal veſſels, gave an opportunity of tracing, without the help of a lens, the arteries which bring the blood to the legs, and the veins which carry it back to the heart.

Beſides the ſimilarity of the circulation in the natural and reproduced legs, an enquiry was made, whether the ſame was obſervable among the conſtituent parts of the leg, viz. the *cuticle*, *ſkin*, *glands*, *muſcles*, *bones*, and *nerves*.

I firſt began by analyſing the parts entering the compoſition of the cone, which comes out of the trunk, and is the ſmall leg, concentrated in itſelf. The reproduction of the bones had the greateſt ſhare in this analyſis. I ſhall deſcribe the manner in which theſe bones are formed and unfolded in my large work; beginning from the day of their firſt appearance, to the time of their perfect growth. This deſcription will comprehend both the bones which are to be reproduced entirely, and thoſe which are only to be reproduced in part. This will give me an opportunity to ſpeak of the effects of the madder root given to ſalamanders; a root to which we are indebted for ſo many curious diſcoveries, on account of its ſurpriſing property in dying the bones of animals

animals red, without affecting any of the other parts. I ſhall take the liberty of deſcribing, on this occaſion, what I have obſerved on the famous queſtion debated between thoſe two eminent philoſophers, Haller* and Du Hamel†, on the formation of the bones. From the bones, I ſhall paſs to the formation and unfolding of the other parts, viz. the muſcles, the nerves, the glands, &c. Theſe were next the objects of my analyſis. I have not neglected, in this minute and laborious diſquiſition, to enquire principally into the law, which nature follows in uniting and adapting the tender ſtamina of the growing reproduction to the divided and conſolidated fibres of the trunk.

At preſent I ſhall only ſpeak of the reproduced bones, as being ſuppoſed to have already acquired a ſufficient degree of maturity and firmneſs. There are in all ninety-nine bones, which enter into the compoſition of the four legs of an unmutilated ſalamander; and the ſame number has likewiſe moſt commonly been found in the four regenerated legs, after the old legs have been taken off at the *articulation*, cloſe to the trunk. The form, portion, and internal

* Memoires ſur le formation des os.

† Mem. de 1739, 1741, 1743, &c.

ſtructure of the reproduced and natural bones is the ſame; but the color of the new bones is ſomewhat different, and their ſubſtance more tender.

The regenerated bones do not acquire their due powers and neceſſary length in the ſpace of a whole year; as they are found, even after ſuch a length of time, ſomewhat ſhorter than the natural bones. This however muſt be underſtood of ſalamanders which are come to their full growth. In ſuch as are ſtill young and growing, the new bones are not to be diſtinguiſhed from the original bones, in a few days after the operation.

The reproduction of ſo many bones (and this may likewiſe be ſaid of the other conſtituent parts of the legs) is not only obtained in the ſame way when food is given to ſalamanders, but even when they are kept faſting during the whole time of this great proceſs. By comparing minutely, after two of the hotteſt ſummer months, bones reproduced in ſalamanders which had been conſtantly fed, with thoſe that grew in ſalamanders which had not partaken of any food, no difference whatſoever could be found. The ſame thing was obſerved in the reproduction of the tails.

More-

Moreover, after ſuch a length of time, there was no viſible difference between the ſize of the firſt and the laſt ſalamanders. This is an evident proof of the great regenerating powers of this animal, and of their perſpiring little. Yet when ſalamanders are kept faſting a longer time, they begin to grow more lean and tapering than thoſe that are fed. But the reproduction continues ſtill in the ſame way.

If we compare bones reproduced in the ſaid two ſummer months with the correſponding natural bones; for inſtance, thoſe that were reproduced in the right hind leg, with the natural bones of the left leg in the ſame ſalamander, we ſhall find, that although the larger bones of the reproduction, viz. the thigh-bone and the tibia, are ſhorter than the natural correſponding bones; yet the diſproportion between them is leſs than between the ſmaller bones; as thoſe of the metatarſus reproduced in the ſame leg, and the natural ſmall bones of the fellow-leg.

But is this odd phenomenon likewiſe obſervable in the legs of young unmutilated ſalamanders? Does it take place in other animals? What is the cauſe of it? Is it

perhaps,

perhaps, that the larger bones of the reproduction are quicker in their growth than the leſs; as the firſt have already acquired a conſiderable degree of firmneſs when the latter are ſtill very ſoft?

But although the new bones were found after two ſummer months conſiderably ſhorter than the natural correſponding bones, yet they always were equal in thickneſs, and oftentimes even thicker; a circumſtance which deſerves to be particularly attended to.

Having ſpoken of the reproduction of whole bones, let us now ſay ſomething of thoſe which are reproduced in part. If, inſtead of taking off the whole leg from the body, part of it only is ſeparated; no bones are reproduced but ſuch as were taken off. If, for inſtance, a leg be cut off at the articulation of the radius, the new joint will be reproduced with the preciſe number of bones contained under that joint. If the radius, the os humeri, or the tibia, be cut in the middle, the lower half will be reproduced, together with all the leſſer bones ſeparated with it.

Upon conſidering attentively in this laſt, and in ſimilar inſtances, the portions of the old and new bones united together, it will be found, 1. that the old bone (at leaſt in full-grown ſalamanders) did not lengthen in the leaſt, and that it preſerved, when united with the new part, the ſame figure it had acquired by the ſection. 2. That the nature both of the old and new bones, except in color and firmneſs, is the ſame. 3. That after a certain time the old bone unites with the new one in ſuch a manner, that the baſis of the firſt is equal to the baſis of the laſt. 4. That it often happens however, that the diameter not only of the baſis, but of the whole of the new bone, is larger than that of the old bone. 5. That ſometimes the old bone is in a manner ſheathed within the new one. 6. That when longitudinal ſlips are cut with a knife from the old bone, and that this diviſion is continued to the upper part of the new bone, the longitudinal fibres are found to run in the ſame direction from the one to the other. 7. That the marrow of the old bone is produced along the new one. 8. That ſometimes the new bone deviates, at the point of union with the old one, from the ſtraight line, and forms an obtuſe angle. 9. That when this irregularity or deviation at the point of contact does appear, the bones reproduced below this, are, in general, perfectly regular as well as the old bones.

We

We have aſſerted, that when the legs of ſalamanders are cut off, the preciſe number of parts which were ſeparated is commonly reproduced. It cannot however be denied, that ſuch diviſions have ſome influence in producing monſtrous appearances in the new legs. 1. The ſame number of toes is not always produced. 2. Some parts are wanting in ſome inſtances; in others there are too many. 3. Irregularities of the laſt kind are more common than the former. 4. Even when the ſame number of toes is produced, there may not be the ſame number of joints, nor conſequently of ſmall bones entering into the compoſition of the toes. The unfrequency of theſe monſtrous appearances in the toes of the unmutilated ſalamanders is a ſufficient proof of their being occaſioned by the ſection.

If the four reproduced legs be cut off again, four new legs will make their appearance the ſecond time as they did the firſt; and this is repeated ſeveral times. In fact, when ſalamanders were quite young, at which time the reproduction is ſooneſt performed, I have obtained in the courſe of the months of June, July and Auguſt, ſix ſucceſſive reproductions of the four legs, and an equal number of ſucceſſive reproductions

of

of the tail at the ſame time. In one of theſe ſalamanders, the reproduced bones of the legs and tail amounted in theſe three months to ſix hundred and eighty-ſeven. This number of reproductions ſeemed not to haveleſſened in any conſiderable degree the regenerating power, as the laſt was obtained in the ſame number of days as the former. As this power manifeſts itſelf from April to September, it is very probable, that, by beginning theſe ſections in April, and continuing them during all that time, one might obtain in theſe ſix months twelve reproductions both of the legs and tail.

If, inſtead of being cut, the ſalamander's legs are broken, a callus will be formed in the uſual manner; this afterwards hardens, unites, and knits together the extremities of the fractured bone. But the loſs of the legs is commonly leſs injurious to the animal than a mere fracture. In the firſt inſtance they are completely reproduced, and the ſalamanders make the ſame uſe of them as before: but in the ſecond caſe it often happens, that they cannot recover the uſe of them, but are forced to drag their legs after them, and to limp.

The

The ſame obſervations, which I made on the formation and increaſe of the reproduced bones, I thought proper to repeat on the callus, and at the ſame time ſtrictly to compare the nature of this callus with that of the reproduced bones.

But in order to follow more cloſely the progreſs of nature, and the means ſhe employs in bringing about the ſurpriſing reproduction of the ſalamander's legs, I endeavoured to find out how to check her operations, or, if poſſible, to put a ſtop to them entirely. I ſhall therefore, point out in the courſe of my work, the effects produced; 1. When, after having cut off the leg at the joint either of the *radius* or *tibia*, a portion of the os humeri or of the thigh bone was left naked, and without any fleſh upon it. 2. When a ring or circular ſlip of fleſh was cut off ſomewhat above the trunk, and cloſe to the bone. 3. When ſmall pieces were cut off here and there over the trunk. 4. When a circular inciſion was made on the ſame place quite to the bone. 5. When a tight ligature was made on the trunk, ſo as to prevent or retard the deſcent of the humors to it. 6. When the bone of the leg above the trunk was broken in one or more places. 7. When only a ſmall piece of the tibia and *os femoris*, or of the *radius* and *os humeri*, was taken off. 8. When, after having broken a leg at the *tibia* or the *radius*, the lower part was raiſed, and faſtened gently with a thread to the upper part of the ſame leg.

REPRO-