XIV.—CONTRIBUTIONS TO THE BIOLOGY OF THE RHINE SALMON.*

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[Reprint from the Swiss literary contributions to the International Fishery Exposition at Berlin, 1880.]†

The following description is based on various statistics and on—

(1.) Measurements, weighings, and notices as to the external appearance of 1,933 Rhine salmon, taken between Basel and Laufenburg, and 229 Lower Rhine salmon from Holland and Wesel, 2,162 fish in all; which observations were continued without interruption from November, 1877, till the spring of 1880.

(2.) Observations, weighings, microscopical, and also chemical investigations relative to the condition of the muscles, intestines, and especially of the growing sexual glands (made at all seasons of the year, during the years 1876–1880) of 97 male and 99 female salmon (196 in all); besides numerous observations—made for the sake of comparison—on sea salmon.

It is well known that the salmon caught in the Rhine at different seasons of the year vary greatly as to the looks and condition of the flesh. In comparing, in December or January, a male salmon, the so-called *winter salmon*, with the well-known *hook salmon*—the *former* with its bright, bluish scales, its well-rounded body, its short nose (about 4 to 5 per cent. of the whole length of the body, measured from the nostrils to the root of the tail), without the slightest trace of a hook and hardly distinguishable from a female; the *latter* with its nose of twice the length, an entirely different physiognomy on the front part of the head, with its thick skin resembling in its red and black spots a tiger's skin, made dark by the superabundant development of the epithelium, and with its flat body and thin flabby abdominal walls—it is difficult indeed to become convinced that these two fish are specimens of one and the same species.

*Zur Lebensgeschichte des Rheinlachses im Rhein. Translated from the German by Herman Jacobson.

† *Statistische und biologische Beiträge | zur Kenntniss | vom Leben des Rheinlachses, | unter Mitwirkung von | Herrn F. W. Glaser, Sohn, | Fischermeister in Basel, | bearbeitet von | Dr. F. Miescher-Rüsch, | Prof. der Physiologie in Basel. | Separatabzug aus der schweizerischen Litteratur sammlung zur | internationalen Fischerei-Ausstellung in Berlin.*

In the female the difference is less apparent. There is not much difference in the length and shape of the nose; the red spots on the body and head, which are entirely wanting in the "winter salmon," are not as strongly developed in the female as in the male salmon; the skin is dark and looks as if it was covered with impurities, but is not as thick. The principal difference in the outward appearance is caused by the different development of the ovaria, which in the winter salmon weigh 4 per cent., and in the spawning salmon fully one-fourth of the total weight of the body, so that they bloat the belly very considerably, making the back appear particularly thin. As soon as the eggs have been emptied out, the thin, limber walls of the abdomen make the leanness still more apparent.

It is well known that there is a considerable difference in the quality of the flesh, which in the winter salmon is peculiarly red (caused by coloring matter, which is soluble in alcohol and ether, but not in water, and which—partly at least—is inherent in the muscle-fibers) and interlarded with strips of fat; in the spawning salmon it is of a dirty white color. After the spawning season it becomes more transparent. The intestinal canal of the winter salmon is covered with fat; the appendages of the duodenum are actually enveloped in layers of fat, whilst in the spawning salmon it looks as if all the fat had been peeled off and at the same time the intestinal canal itself thinned, so that in the former the entire weight is about 2½ per cent. and in the latter one-half to three-fourths per cent. of the total weight of the body.

Although it cannot have escaped an attentive observer that between these two extremes (the winter salmon and the spawning salmon) there are different intermediate varieties, the mutual relations of all these fish have not yet been perfectly cleared up. Although it was known long since that those salmon which immigrate from the sea do not reach their full maturity till they have reached the Rhine, some people think that their stay in the fresh water is confined to a few months. The circumstance that in November and December there are caught, besides the mature fish, a few very fat fish, with very small and hardly developed sexual organs, has led people to suppose that besides those salmon which ascend the Rhine for the purpose of spawning, there are also found, temporarily or permanently, barren fish, which for some very strange reason occasionally stay in the Rhine, and which, when caught, of course, do not thereby interfere with the propagation of the species.

This opinion seemed to be further corroborated when *Barfurth** brought to the attention of science a view which had long since been entertained by practical men, such as Mr. Glaser, and which had also been made known to the scientific world by *His*,† viz, *that the Rhine salmon, during its stay in fresh water, does not take any food. Barfurth* has reached this

*TROSCHEL'S *Archiv für Naturgeschichte*, vol. xli, i, 122, 1875.

†HIS: *Untersuchungen über das Ei und die Eientwickelung bei Knochenfischen*. Leipzig, 1873, p. 24.

opinion by the examination of a number of intestines, and, in view of the enormous increase in the size of the ovaria, he reaches the conclusion that the winter and spring salmon and the spawning salmon do not belong to the same immigration. The stay in the Rhine of both kinds is much shorter than had been supposed hitherto. Immature salmon come and go, and are finally replaced by almost mature salmon, which ascend the river direct from the sea.

For my own part I feel that, after having for 4 years examined the intestines of Rhine salmon of both sexes, at all seasons of the year, I cannot but agree with the opinion expressed above, *that the Rhine salmon, from the time it ascends the river from the sea until it has finished spawning, never takes food, and that, as a rule, it does not take any food afterwards.* Even in winter and spring-salmon from Holland I have thus far looked in vain for any remnants of food. In comparison with the wide stomachs of the salmon from the Baltic and the North Sea, which had thin walls and were generally stuffed with fish almost to repletion, the *Kralingen* (Dutch) salmon had universally a contracted œsophagus, and the walls of their stomachs were laid in folds; the opening was very narrow; the appendages, not taking into consideration the contents and the layers of fat, were likewise thinner and not nearly as large as in the sea salmon. Occasionally I found a small stone, a piece of a blade of grass, or a stalk of some plant, which had entered with the river water and had been swallowed. Once I found in the small intestines a tolerably large larva of an insect, but entirely undigested and intact. Of secretion I found in the intestines proper sometimes a small, and at other times a large, quantity of slime, of more or less bilious color, although the gall-bladder was invariably empty. The bile, therefore, seems to flow from the liver direct into the intestines. The œsophagus and stomach did not, in most cases, contain anything, at least nothing but a faint trace of a sticky and almost transparent slime, which was only occasionally more plentiful and somewhat thinner, but never *acid*. The duodenum, with its appendages, occasionally (but not always), more especially in very flat fish which had recently come from the sea, contained a more plentiful secretion in the shape of a sticky, slimy mass, which, by numerous detached epithelium cells, had become turbid, and somewhat resembled pus. But in no case did I find traces of digestion, of a softening and dissolving influence on the walls of the stomach and the intestines, of these secretions. Although the glycerine extract from this pus-like substance, when dissolved in diluted hydrochloric acid, occasionally dissolved fibrous matter to a small extent, it must be said that, with the exception of the bile, *no effective gastric juice is secreted.*

It is, moreover, worthy of note, that even in the *Kralingen* (Netherlands) salmon there is no tendency whatever to early putrefaction, such as is found in the intestines of every animal which, with its food, introduces from outside germs of putrefaction. This seems to indicate that

the salmon have not eaten anything for some time prior to their ascending the Rhine.*

So far I have only found one exception to this rule. On the 3d of January, 1879, I received from an *Istein* fisherman a male salmon which had been caught in the Rhine. It weighed 1.5 kilograms, had emitted all its milt, and was exceedingly lean. The transparent flesh had the smallest percentage of dry substance ever found by me in any fish—but 13.56 per cent. In its flabby, wide stomach it had two tolerably large fish, to judge from their scales, *Cyprinoids* (probably *Leuciscus*), whose forepart had been digested. In another male salmon, which had emitted its milt, I found no remnants of food, but at least a somewhat extended stomach, containing a small quantity of a thin secretion possessing *acid* reaction. In the majority of male fish, however, as well as in all the female fish of this stage, I found nothing of the kind. Necessity, which is the mother of invention, and which occasionally teaches the male salmon to eat, is probably not felt so much by the female salmon, because at the time when *they* begin their homeward journey to the sea (December to the beginning of February), they find a substitute for food in the numerous eggs which have not been emitted, and which often number several hundred.

I have been repeatedly assured that during the spawning months salmon are occasionally caught with the hook and line in the small streams such as the *Wiese* near *Basel*, whilst otherwise they will not bite. Although I have not been able to obtain positively trustworthy data with regard to this subject, I cannot, when thinking of my own experience, deny it entirely—only, however, for the time *after* spawning.†

Although it has been settled *beyond a doubt* that the Rhine salmon does not take any food whatever during the time it is ascending the river, including the spawning season, the facts which are given below compel me to maintain that at least in that portion of the Rhine which extends *from Basel to Laufenburg all Rhine salmon are of one and the same kind, and that all of them, from the (supposed to be) barren winter salmon to the emaciated spawning salmon, represent stages of one and the same development, which—without an interruption—is completed in the Rhine.*

I base this opinion upon the following facts:

(1.) There are in the different stages of development of the male and female sexual organs of our Rhine salmon no gaps which might justify the supposition that the barren winter salmon are replaced by comparatively much maturer salmon ascending from the sea. *Barfurth* has noticed this fact, but he has not followed it up to its last consequences. The instances given herewith in Table I show how the ovarium

* According to my experience, I must urgently advise to clean all sea salmon which are destined for a long journey, whilst with river salmon this is not necessary.

† According to Mr. Glaser it seems to be more certain that in the basin below the falls of the Rhine, near Schaffhausen nearly every year 1 to 4 salmon are caught with the hook and line, sometimes as early as October.

steadily increases in weight in geometrical progression. Table II contains an analogous tabular statement, relative to the increase in weight of the male sexual glands, in which statement small individuals, weighing less than 4 kilograms, and actual giants among the salmon tribe are not taken into consideration, as they exhibit an abnormal proportion between the sexual glands and the weight of the body.

TABLE I.—*Growth of the ovarium.**

	Salmon from—	Date.	Weight of the ovarium in per cent. of the weight of the body.		Salmon from—	Date.	Weight of the ovarium in per cent. of the weight of the body.
1	Holland	Dec. 21, 1877	0.38	15	Basel	July 28, 1879	5.30
2	Basel	Dec. 10, 1877	0.49	16	... do	Aug. 24, 1879	5.84
3	....do	Dec. 31, 1877	0.52	17	....do	Aug. 7, 1879	3.13
4	....do	Mar. 30, 1880	0.77	18	....do	Aug. 23, 1879	11.63
5	....do	May 8, 1880	1.13	19	....do	Aug. 25, 1879	6.52
6	....do	May 10, 1880	1.14	20	....do	Aug. 27, 1879	6.69
7	....do	June 9, 1879	1.31	21	....do	Aug. 27, 1878	9.81
8	....do	June 14, 1877	1.93	22	....do	Sept. 4, 1877	8.50
9	....do	June 22, 1878	3.44	23	....do	Sept. 6, 1877	9.89
10	... do	June 26, 1879	2.84	24	....do	Sept. 6, 1878	9.84
11	... do	July 1, 1879	2.03	25	....do	Sept. 5, 1878	10.39
12	....do	July 2, 1879	3.09	26	....do	Sept. 10, 1878	10.59
13	....do	July 9, 1879	3.40	27	....do	Sept. 13, 1878	12.49
14	....do	July 21, 1879	3.32	28	....do	Sept. 30, 1878	15.23

*As to the weighing of the ovaria of salmon in different stages of development see also *His*, I, 28.

Mature ovaria, November 1 to 16, 1877–1879.

Date.	Weight of the ovarium in per cent. of the weight of the body (eggs not yet ready for emission).	Date.	Weight of the ovarium in per cent. of the weight of the body (eggs not yet ready for emission).
Nov. 8, 1879	19.21	Nov. 1, 1879	24.37
6, 1879	19.23	8, 1878	25.06
4, 1879	19.24	1, 1879	26.10
16, 1879	20.12	3, 1879	26.36
10, 1879	23.80	10, 1879	26.72
15, 1879	24.00		

Average of the 11 ovaria = 23.09 per cent. of the weight of the body.

TABLE II.—*Increase of the male sexual glands in percentage of the total weight of the body.*

[Fish of 3,500 to 10,500 grams.]

Date.	Per cent.	Date.	Per cent.
Mar. 12, 1880	0.105	Sept. 15, 1879	2.07
May 3, 1880	0.182	18, 1878	4.91
12, 1880	0.099	19, 1878	1.34
26, 1880	0.100	19, 1878	3.90
June 4, 1878	0.26	20, 1874	2.48
5, 1879	0.26	24, 1874	1.89
26, 1879	0.23	26, 1874	1.54
30, 1879	0.31	26, 1870	4.75
July 7, 1879	0.41	27, 1878	5.58
Aug. 5, 1879	0.58	27, 1879	4.28
13, 1877	0.16	28, 1878	2.32
20, 1877	0.90	Oct. 1, 1876	5.00
23, 1877	0.59	1, 1879	[2]8.31
23, 1877	1.57	4, 1879	5.58
24, 1877	0.86	6, 1879	5.31
29, 1870	1.15	7, 1876	3.86
30, 1877	0.43	11, 1872	[3]5.90
30, 1877	1.45	15, 1878	4.34
Sept. 2, 1878	[1]0.48	16, 1872	6.10
8, 1876	0.82	18, 1873	5.25
13, 1879	1.13	Nov. 4, 1879	4.64

[1]Few spots; small hook. [2]Fish only weighed 4,350 grams. [3]October 14, 1872, 3.33.

The October weights are equal to the weights of mature fish, very probably even larger, but contain less firm substances. The highest grades of maturity (November and December) have not been taken into consideration on account of the loss of milt.

From these two tables it appears that during summer both testicles and ovaria of almost the same stage of development can show very considerable differences of weight. But the greater and lesser weights, each classed by themselves, can be chronologically arranged, and it will then be seen that the differences gradually cease with the females in August and with the males at the end of September and beginning of October, leaving those differences, however, which are found even among mature fish, and which, especially with the males, are very considerable.

According to Mr. Glaser's experience, which extends over many years, and which is corroborated by my own observations, extending over a period of eight years, *the normal spawning season* at Basel for the overwhelming majority of all fish may be said to last from the middle of November till the middle of December. From about the 1st of November Mr. Glaser keeps his fish alive in fish-boxes (tanks); at that time their ovaria do not emit anything when pressed. Generally about the 10th to the 15th of November artificial impregnation may be begun. As early as the 16th to the 24th of December it will be hard to find many, if any full females, and the occurrence of eight full females from the 5th to the 13th of January, 1880, and of one as late as the middle of February, must be considered as rare exceptions, caused possibly by some irregularity consequent upon the unusally severe cold. The occurrence of an empty female on the 26th of October, 1877, must also be considered as a very rare case.

According to my own observations, the maturity of the males sets in

somewhat earlier. Beginning on the 20th of October, some seed may be squeezed out of a few, and from the 1st of November out of nearly all normally-developed males, which, however, cannot be considered as a sign of absolute maturity in the whole organ. All the data relative to the spawning season of both sexes have been fully corroborated by Mr. Glaser.

To return to the development of sexual maturity, it is very instructive to compare the respective tables with the following table, showing the monthly results of the fisheries in the Rhine between Basel and Laufenburg:

TABLE III.

Of 100 salmon caught during the year, there were caught in the month of—	1872.	1873.	1874.	1875.	1876.	1877.	1878.	1879.	Average of all the monthly percentages, 1872–1878.
January	.....	0.58	.....	0.14	0.08	0.61	0.16	0.49	0.28
February	.....	0.03	.....	0.14	.....	1.35	0.32	0.49	0.29
March	1.60	2.78	0.36	0.19	0.55	3.71	1.69	1.26	1.45
April	1.52	2.19	5.41	0.37	2.34	3.03	3.98	1.36	2.52
May	4.57	7.77	5.78	2.12	4.72	5.86	8.04	2.04	5.11
June	11.36	18.77	27.36	13.40	5.89	15.29	14.26	7.57	14.24
July	21.32	17.97	18.34	10.05	19.57	29.38	19.32	11.86	18.41
August	10.78	7.18	14.24	12.01	8.62	10.18	10.59	24.08	12.21
September	13.70	16.08	19.64	8.14	29.24	17.18	16.09	21.46	17.69
October	15.70	14.62	1.88	24.80	19.18	3.17	17.24	19.42	14.50
November	15.06	9.69	3.10	20.89	7.25	4.45	5.81	9.03	9.41
December	4.98	2.87	3.83	0.65	2.57	5.79	2.59	1.46	3.78

If, really, as *Barfurth* supposes, the spawning salmon ascend the river from the sea only a short time before the spanwing season, "with eggs the size of peas," why does the large increase in the number of salmon caught, amounting to six times that of April, appear in June and July, at a time when the ovaria have reached 1.3 to 5.3 per cent. of the total weight of the body—therefore only about 5 to 22 per cent. of their weight when fully matured—and not in September and October? Do these July salmon make way again for other salmon? If, furthermore, in August and September, there is in the Rhine a mingling of returning salmon and new immigrants, why did the individual differences in the weight of the ovaria decrease instead of increase?

I am therefore of opinion, and shall adduce further proof of my assertion, *that our winter salmon, which arrive in the neighborhood of Basel from November to March, remain in this neighborhood all during summer and autumn, and that they reach their sexual maturity gradually, in common with the large schools of later immigrants, which begin to ascend the river from May on, so as to spawn at the same time, from the middle of November till the middle of December.* Mr. His, in his varied observations, has reached the same opinion.*

If we suppose, by way of approximation, that the majority of the

* I, § 25.

Basel spawning salmon* have again reached the sea about the middle of January, and if we, moreover, take into consideration the period of migration from Holland up the river, I feel justified in maintaining that the large majority of our Basel salmon stay in the Rhine between 6 and 9½ months, a small number staying 9½ to 12 months, and a few even 15 months, their sexual organs developing all this time, whilst they abstain from all food. I cannot, of course, positively deny that, in exceptional cases, a few individuals return to the sea in an immature condition; but nothing which has come under my observation points in that direction.

I shall also, for the present at least, be careful not to apply my data to the Lower Rhine. As I have not been able to observe the Dutch and North Sea salmon during this season of the year, I cannot decide whether, as *Barfurth* says, numerous large salmon in an almost mature condition immigrate from the sea late in summer and during autumn. All I maintain is this, that such *belated immigrants*, with the exception, perhaps, of a few male fish, *do not come up as far as Basel.*

The great differences in the degree of development of the sexual organs I interpret as indications of the dates of immigration. The later immigrants very possibly have entered upon the first stage of their ovarian development whilst still in the sea,† but still they seem to lag behind the earlier immigrants, and only catch up with them very gradually, but under all circumstances by the time the spawning season commences. Thus, two Dutch salmon had, on the 31st May, 1879, ovaria weighing 0.61 per cent. of the entire weight of the body, therefore less than half the weight of the ovaria of Basel salmon of the same period. The smallest fish furnished particularly numerous instances of this catching up of the young with the older immigrants. On the 19th of August, 1879, I found in three small salmon from Wesel ovaria weighing 0.56 and 0.80 per cent. of the entire weight of the body (therefore corresponding to the Basel March and April salmon) and testicles weighing 0.91 per cent. of the weight of the body, therefore corresponding to the Basel June testicles. The hook-formation (according to 20 measurements of the length of the nose) had been decidedly retarded. Five weeks later another batch of fish of the same size from Wesel

* Mr. Glaser supposes that the time occupied by the salmon in returning is very short, because, owing to the impetus which they receive, many of them land on sand banks and in shallow places, and thus fall into the hands of man.

† How far this development has advanced can only be decided by data from the Lower Rhine. How many per cent. of the total weight of the body are occupied by the ovaria of salmon caught near the mouth of the Rhine from the beginning of May till the middle of June? How many per cent. of the male organs from May till the middle and end of July? So far, only one individual (caught August 1, 1879) has given rise to the suspicion that it had finished a considerable period of its ovarian development while in the sea. This fish (differing in this entirely from other fish caught at the same time) had an ovarium weighing 7.2 per cent. of the total weight of the body, and muscle-flesh containing much (18.7 per cent.) albumen and fat.

showed ovaria and testicles of at least the same degree of maturity as the Basel fish (testicles weighing 7.7 and 6.1 per cent. of the total weight of thebody); and the small male fish of the spawning period, which had reached us, were fully matured.

The weights of the respective organs are not the only proofs in favor of the further development, in fresh water, of the semen and the ovarium. The microscopic examination of these organs shows lively growth and transformation, the detailed description of which, however, does not belong here. As regards the ovarium: Mr. His has, as early as 1873,* described the different stages of development, from the protoplasm-net with pale pellets in the meshes of the small eggs of the winter salmon, through several stages, to the mature egg, the size of a pea, with its skin delicately marked with small vessels, with its germ ready for impregnation, and the live plasm skin, half-sticky and half fluid, which incloses the clear and highly concentrated egg-fluid. I myself have watched the transformations of the male organ through all the varying seasons. When still resembling an insignificant, shriveled-up little strap, the testicles of the winter salmon often weigh only $\frac{1}{1000}$ to $\frac{1}{700}$ of the total weight of the body; with the first warm spring-days, however, towards the end of March—sometimes not till May—new life seems to be imparted to this organ; more blood is introduced into it; the small one-grained cells, in the diminutive shriveled-up canals, separate, become larger, form several grains, and finally form large bodies, full to repletion with numerous grains. From June to August we find dark-red organs, looking as if they were inflamed, and the looks do not deceive; for numerous pus-cells—probably originally colorless blood particles—are at this period found, between the seminal cells proper, in the canals; through their decay they furnish ample food for the further growth of the many-grained bodies, and for the further swelling of the organ. At the same time the inter-tissue and the walls of the canals grow luxuriantly. Rather late, in September, and even in the beginning of October, after the organ has reached a weight equal to one-half, three-fourths, and even more, of the total weight when matured (about 5 per cent. of the weight of the body), the transformation of the immature masses, of the many-grained cells to genuine *seminal cells*, takes place, not merely by bundles or "nests"—as occasionally in former months—but on a large scale. This is a very interesting process, and is accompanied by the most radical chemical changes, new substances making their appearance, whilst old ones vanish. In the beginning of November the testicles are snow-white, and consist of hardly anything but semen, which at every cut oozes out like cream; it is difficult to recognize this organ as the same which was observed some months previous, say about the beginning of October, when the testicles, though of nearly the same size, were a gray jelly-like mass; and still it is the same organ, which has only undergone a change.

* In the work already quoted.

From what has been said, it must be supposed that the early, and very immature, immigrants complete their entire sexual development in the Rhine. For the present, however, my assertion that this also applies as a rule to the later immigrants, lacks proof. There, is however, still a possibility that, besides these, more mature fish immigrate from the sea.

THE LOSS OF MATTER SUSTAINED BY THE BODY.

In order to decide with absolute certainty whether this course of development in fresh water, applies to the Rhine salmon from Basel to Laufenburg, not only in many cases, but *in all cases*, we followed another course.

The building-up of the mature ovarium of the winter salmon from very insignificant beginnings, is—viewed merely as a material process—a most astonishing performance. The weight amounts to from 19 to 27 per cent. of the total weight of the body, with 40 to 43 per cent. dry substance (at 110°), of which, taking the average of two fish, not quite one-fourth (equal to) about 9 per cent. of the fresh ovarium is oily *fat*. As at this period the muscle substance of the body contains only about 20 per cent., and often even less, dry substance, and as the fat of the intestines and the skin has nearly vanished, the assertion that fully *one-third of all the firm substance of the body is, during the spawning season, found in the ovarium* makes the proportion too low rather than too high.

If the entire development of the ovarium, in fresh water, is going on while the fish is fasting, the body of the average spawning salmon, compared with the body of the average spring or summer salmon, must show a decrease of the matter in the other organs, at least sufficient for building the entire ovarium, and even (on account of the self-consumption) more than sufficient for that purpose. As during the few months, from the end of July to the beginning of November, when the ovarium increases from 4 to 25 per cent. of the total weight of the body, the vertebral column of the fasting fish will hardly grow much in length, and as there are no indications (hyperdermic) to be seen in cuts, with the naked eye, all that should be done would be to examine fish of equal length at different seasons.

Those salmon, however, which bring a three-fourths or entirely mature ovarium from the sea, produced by the ample and rich food found there, must, even if the muscle-flesh were somewhat leaner and reduced in weight, show a larger weight and a greater amount of substance (including the ovarium) than the spring and summer salmon of equal length and equal ovarium.

There would, moreover, be noticed a very decided difference between such spawning-salmon and those which (according to what has been said above) undoubtedly supply the substance for the entire ovarium from their own body. But this is certainly not the case. *There are not two categories* of spawning-salmon. Whenever a spawning-salmon is, exceptionally, somewhat stouter when compared with its length than

the rest, its ovaria will certainly be found to be below the average size, and its eggs will in some cases be small, probably retarded in their growth.'

If, moreover, it could be shown that these salmon, which have reached their sexual maturity in the sea, constituted an anyway considerable fraction of all the salmon which ascend from the sea, it ought to be impossible to prove that the summer salmon, up to the spawning season, lose as much flesh as they gain in ovarium substance; there certainly ought to be a deficit on the side of the summer salmon.

On account of the extraordinary scientific importance attaching to a certain proof of such a change of substance in the animal kingdom, I have for two and a half years (since November, 1877), as long as the salmon fisheries lasted, with hardly any interruptions, daily weighed and measured salmon, and portions of salmon, on the most extensive scale; the rich material on which I could operate being very kindly furnished by Mr. Glaser. In weighing I used altogether an admirably constructed pair of English spring scales, which through many years showed no sign of variance, and which in 10 kilograms distinctly indicated a difference of 20 grams. The measurements were made with a very simple apparatus, consisting of a board with a scale marked upon it, and another piece of board attached to it at a right angle, which could be moved up and down until it reached the back point of measuring (now recognized as the most reliable)—the point where the body tapers off and where it again begins to spread a little to form the caudal fin. From September, 1878, I also invariably determined the length of the nose (respectively, its horizontal projection, when the head is fixed in a horizontal position). In the male fish I considered as the "length of the fish" only the distance from the nostril to the root of the tail. The observations were taken very carefully every morning by Mr. *Jacob Weidmann*, the assistant of our Physiological Institute, generally in Mr. Glaser's presence, and were tested by frequent observations of my own, which were entirely satisfactory. No error of any consequence was discovered among a hundred figures thus examined; and if ever statistical data deserve to be called reliable, this term must certainly apply to the data obtained in the manner described.

From among the female fish of one and the same year (1878), beginning with May or June, when the sex could be distinctly recognized, I selected specimens as nearly as possible of equal length, the greatest difference of length not amounting to more than 10 to 12 millimeters. The total number was divided into 2 to 4 groups, arranged in chronological order, and for every group the average date was calculated. The comparison of the averages of the groups furnished the average change of weight of the fish in the periods included in the average dates. The same operation was gone through with six groups of as many different lengths, comprising in all 470 fish, all belonging to the same year (1878), and all caught between Basel and Laufenburg. From the changes of

weight (in per cent.) of the six groups—the weight on the 1st of November being counted as 100—the average weights of different periods were calculated, and from these data a curved line was constructed, showing the average changes of weight.

The large figures are by no means superfluous; for from June to November the individual differences are very considerable, and salmon of the same length, the same date, and the same state of maturity frequently differ 25 and even 30 per cent. The question is not one of degrees of emaciation, but of differences in the build of the skeleton. There are thick-set and slender figures among salmon as well as among men. Not until we compare all six groups are the differences sufficiently equalized, and do we realize the change of weight, which in its almost mathematical regularity bears the undoubted impress of absolute truth.

TABLE IV.—*Average change of weight of female Rhine salmon caught between Basel and Laufenburg during the summer and autumn of 1878, six groups, all the fish of one and the same group being of equal length, 470 fish in all.*

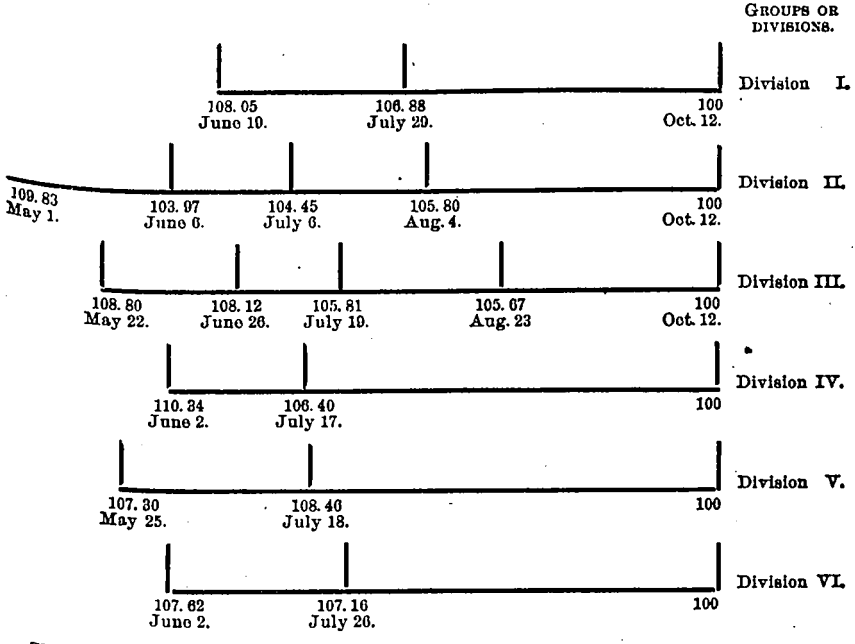
Number of group.	Maximum and minimum length; weight of body calculated October 12.	Limits of date when the fish were handed in for examination.	Average date of the group.	Average difference of time.	Number of fish in the group.	Average length of the group.	Average weight of the body of the group.	Average decrease of weight of body from group to group.			
								Total decrease in grams.	Daily decrease in grams.	Daily decrease in per cent. of the final weight (October 12).	
				Days.		*Mm.*	*Grams.*				
I.	Length, 840 to 851 Weight, 7426	May 27 to July 1	June 19	39.6	19	845.3	8028				
		July 6 to August 28	July 29	65.0	18	847.2	7941	+87	+2.20	+0.296	.....
		September 9 to November 4	Oct. 12		16	845.6	7501	+440	+6.77	+0.911	.....
II.	Length, 855 to 865 Weight, 8073	April 5 to May 6	May 1	46.6	18	859.8	8810	+473	+10.15	+1.258	.....
		May 21 to June 22	June 16	20.1	18	860.2	8337	−68	−3.38	.....	−0.419
		June 24 to July 14	July 6	30.9	20	859.7	8405	−109	−3.52	.....	−0.436
		July 16 to September 3	Aug. 4	68.6	17	860.8	8514	+455	+6.63	+0.846	.....
		September 6 to November 11	Oct. 12		17	859.0	8059				
III.	Length, 873 to 884 Weight, 8447	April 16 to June 4	May 22	36.7	22	877.8	9190	+57	+1.55	+0.164	.....
		June 11 to July 4	June 26	22.6	18	878.2	9133	+195	+8.63	+1.022	.....
		July 6 to August 3	July 19	34.7	20	877.3	8938	+12	+0.34	+0.040	.....
		August 5 to September 13	Aug. 23	50.3	18	879.2	8926	+479	+9.52	+1.127	.....
		September 23 to November 11	Oct. 12		23	878.5	8447				
IV.	Length, 895 to 895 Weight, 8886	May 2 to June 25	June 2	45.1	23	889.7	9790	+343	+7.61	+0.857	.....
		July 3 to August 26	July 17	66.1	38	790.4	9447	+568	+8.60	+0.743	.....
		September 7 to November 11	Oct. 12		26	890.3	8879				

TABLE IV.—*Average change of weight of female Rhine salmon caught between Basel and Laufenburg, &c.*—Continued.

Number of group.	Maximum and minimum length; weight of body calculated October 12.	Limits of date when the fish were handed in for examination.	Average date of the group.	Average difference of time.	Number of fish in the group.	Average length of the group.	Average weight of the body of the group.	Average decrease of weight of body from group to group. Total decrease in grams.	Daily decrease in grams.	Daily decrease in per cent. of the final weight (October 12).	
				Days.		*Mm.*	*Grams.*				
V....	Length, 896 to 906.................. Weight, 9233..........................	April 20 to June 25..............................	May 25		27	900.3	9937				
				53.5				−107	−2.00	....	−0.217
		June 28 to August 30	July 18		33	901.3	10044				
				85.7				+781	+9.11	+0.987	....
		September 14 to November 19.................	Oct. 12		19	900.8	9263				
VI...	Length, 907 to 917.................. Weight, 9491..........................	April 13 to June 29............................	June 2		18	910.0	10233				
				54.1				+44	+0.81	+0.055	....
		July 2 to August 26	July 26		21	912.0	10189				
				79.1				+688	+8.70	+0.917	....
		September 21 to November 6	Oct. 12		21	912.0	9501				

The following table, with its different horizontal lines, will give a still clearer view of the subject. On these lines, counting from the starting points of the six groups, placed perpendicularly, the figures of the excess of weight (in per cents) over the final weight (=100), reduced for the 12th October, are given in intervals proportionate to the differences of time:

TABLE V.—*Average change of weight of female Rhine salmon, caught between Basel and Lauffenburg, from the beginning of June till the 12th of October, six divisions, each containing fish of equal length, in 3–5 groups each, 470 fish in all.*



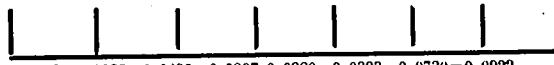
The figures show the weights of the respective average date of a group when the weight on October 12 was 100.

If, supposing that the change of weight between two average dates took place in a straight line, we calculate approximately the average proportion to the final weight (October 12 =100) for a number of suitably-selected periods of time, of all the six divisions, we obtain the following course of changes of weight, in which the individual differences are very well equalized; so that, in spite of the retarding influence of later immigrants on the emaciation (as indicated in figures) of the earlier ones, a slight decrease in weight may be perceived from the very beginning, which, resembling a parabola, describes a curved line convex towards the top.* If nothing else, this form, instead of the line (at first concave towards the top and then straight, indicating the emaciation by hunger), points to a connection of an organ growing in geometrical progression, with the demand for subsistence.

* The large tables of curves have not been reproduced.—EDITOR.

TABLE VI.—*Average change of weight of female Rhine salmon.*

Date.	May 22.	June 4.	June 19.	July 4.	July 19.	Aug 3.	Aug 23.	Oct. 12.
Days from May 22....	0	15	30	45	60	75	95	140
Weight.....	108.17	107.74	107.39	107.08	106.66	106.7	104.61	100



d=0.0287=0.0233=0.0207 0.0280=0.0393=0.0730=0.0922

The principal result, which is apparent in all six divisions, obtained from Tables IV to VI, is this, that from the end of July or the beginning of August, when the ovarium weighs on an average one-fifth of its mature weight, till the spawning season, there is, in spite of the growth of the ovarium, not only *no* increase of weight, but even up to October 12 a *decrease* of weight of 6 per cent. (weight on the 12th October =100); for every pound of ovarium more than a pound of flesh has vanished. As the intestinal fat has mostly disappeared about the beginning of August, and as the changes of the intestines (as has been proved by numerous observations of weight) are of very little consequence, the muscle flesh alone must be the source from which the substances come.

The quantity of albumen contained in the large side-muscle of the body was, therefore, determined by observations taken on a number of July and August salmon and compared with a series of similar observations taken on November salmon (*i. e.*, the quantity of the dry residue which, at a temperature of 110°, remained, after complete exhaustion by means of hot alcohol, ether, and water).

TABLE VII.—*Decrease of the quantity of dry substance and albumen in the large side-muscle of the female Rhine salmon from July and August till November and December.*

	Length.	Weight of body.	Ovarium in per cents of weight of body.	Contents of the side-muscle.	
				Albumen, per cent. of.	Dry substance, per cent. of.
	Millimeters.	*Grams.*			
Dutch salmon, March 18, 1880	885	9,580	0.045	18.8	34.0
Basel salmon, March 30, 1880	860	9,030	0.077	18.1	32.6
Average				18.45	33.0
July 9, 1877	865	8,700	4.04	17.2	24.2
9, 1879	874	8,560	3.40	18.2	27.5
21, 1879	908	10,270	3.92	17.7	28.9
Aug. 1, 1879	940	11,130	7.21	18.7	29.0
4, 1879	858	7,340	4.20	17.3	26.6
7, 1879	878	8,930	3.13	16.7	29.7
25, 1879	883	7,740	0.52	16.5	21.8
Average of the Basel salmon during July and August			4.78	17.5	26.8

TABLE VII.—*Decrease of the quantity of dry substance and albumen, &c.*—Continued.

	Length.	Weight of body.	Ovarium in per cents of weight of body.	Contents of the side-muscle.	
				Albumen, per cent. of.	Dry substance, per cent. of.
	Millimeters.	*Grams.*			
Dec. 8, 1876	.....	5,530	{Empty, ovar. 80 grs.}	13.5	19.3
Nov. 3, 1879	877	7,740	26.37	13.6	19.3
4, 1879	932	9,620	18.90	15.2	21.4
8, 1879	912	8,900	19.21	13.0	18.3
10, 1879	820	7,650	26.72	13.4	18.4
22, 1879	891	7,290	*Empty..	13.4	20.2
25, 1879	874	5,865	{Empty. 135 grs.}	12.7	16.8
27, 1879	846	4,930	{Empty, 55 grs.}	11.0	14.1
Average of the salmon of November and December	.....	.....	.....	13.2	18.5

Considering all the circumstances, viz: (1) the positive decrease in the weight of the flesh, and (2.) the decrease of the remaining flesh of the body by 4.3 per cent. of its contents of albumen, we find, from a comparison with the composition of the ovarium, that *the loss of albumen from the side-muscle is sufficient to meet the entire consumption of albumen by the last four-fifths of the growing ovarium.*

In order to determine this matter more accurately, the weight of the side-muscle of two fish of average size† was ascertained, its substance analyzed, and the decrease of its albuminous matter compared with the increase of albumen in the ovarium.

Of these two fish the second may certainly be considered as an absolutely normal fish, weighing 8,930 grams. It had almost the average weight (8,926), and, measuring 878 millimeters, it had the average length of the group to which it would have been assigned according to Table IV, if it had been weighed and measured on the same day of the year 1878. This coincidence, though intended, had been reached only by an accident.

The head, vertebral column, the bones of the shoulder, and the ventral fins of this fish were prepared, and freed from all the portions of the side-muscle attached to them, whilst the other muscles were left. To this must be added the heart, liver, spleen, and kidneys (according to the determination of another and very similar fish). The surface of the skin, apart from that adhering to the head, tail, and fins, was care-

* The empty females had yielded their eggs a few days previous, for piscicultural purposes.

†For these and other experiments Mr. *Schneider-Wirz*, dealer in table luxuries, has very kindly furnished the fish during those seasons when Mr. Glaser only sold fish at wholesale.

fully measured on the split fish, by laying a thick sheet of paper over it and cutting this sheet so as to fit exactly. The skin, from a cross-cut of the body, measuring 8 or 9 centimeters in breadth, was prepared and weighed; and, by comparing the weight of a piece of paper of equal size with that of the large piece of paper mentioned before, the approximate weight of the entire skin was determined.

	Grams.
The weight of the fish was	89.30
Subtract the above mentioned portions (the blood which had run out being estimated at 47 grams, and the mature ovarium at 280 grams)	25.90
And there remains for the muscle	63.40

We will now endeavor to find whether the probable loss of substance which, according to our average figures, will be sustained by the muscle, is sufficient for building up the ovarium. The decrease of weight of the entire animal, with the exception of the loss of some intestinal fat and part of the liver, will almost exclusively be a decrease of muscle, as the skin does not show any visible layer of fat, and, as is well known, the head and fin muscles hardly decrease at all.

Table VI shows us a possible way of calculating the probable decrease in weight, at any rate till the 12th of October. From the 7th of August to the 12th of October its weight would probably decrease from 105.78 to 100 grams. The spawning season, however, does not commence till the middle of November, and the fish which we had before fore us (with an ovarium weighing 279.5 grams=3.13 per cent. of the entire weight of the body) would be classed among his cotemporaries which had been examined (see Table I), among the less advanced as to its sexual maturity, and would probably not have spawned till the end of November or the beginning of December. We may therefore, further calculate the decrease of weight on the basis of the last period till the 11th of November = 30 days, all the more as just as many fish after the 12th October, as before that date, have been used for calculating the final weight. Going on this supposition, 2.77 per cent. will yet have to be subtracted from 100, and the final weight sought will be to the weight of the 7th of August (8,930) as $\frac{97.23}{105.78}=\frac{91.92}{100}$. The probable loss of weight 8.08 per cent. of 8,930, would be 722 grams; the final weight at the spawning-period would be 8,930−722 = 8,208 grams. The probable weight of the ovarium will be 23 per cent. of this final weight (Group V, Table I), 1,888 grams.

The loss of weight of liver and intestines should also be taken into account:

	Liver.	Intestines.
Weight of these organs, August 7	*Grams.* 119	*Grams.* 125.5
This makes, calculated in per cent. of the final weight, November 11	1.46%	1.53%
From this subtract the average weight of the organ of mature female fish in November	1.06	0.70
Loss of weight of the body, in per cent	0.40%	0.83%

In building up the ovarium the following muscle substance has disappeared entirely:

(1.) Weight of the ovarium	1,880
(2.) Decrease of weight apart from liver and intestines (722—92)	630
Total	2710
With 16 per cent. albuminous matter	452.6
(3.) The remainder of the muscle (6,340—2,710) = 3,630 must, from 16.7 per cent. albumen, go down to 13.2 per cent. Loss 3.5 per cent of 3,630	127.1
Total loss of albumen	579.7

This *quantity of albumen* would very nearly correspond to the *nourishing matter* contained in 6 *pounds* (3,000 grams) of beef of medium quality.

Of its total quantity of nourishing albumen ($6{,}340 \times 16.7$) = 1,058.8 grams, the muscle has lost 54.74 per cent., or more than one-half; a result which will be interesting in many respects.

Of 100 parts muscle ("salmon-flesh," as understood by cooks) 43 per cent. have entirely disappeared; the remaining portion has sustained a loss of albumen, and has therefore lost 21 per cent.

Still greater is the relative loss of fat, whilst the loss of phosphoric acid is about equal to the loss of albumen.

From *this material* there had to be formed the ovarium, calculated at 1,880 grams, less that part of the ovarium already in existence (the contents of which, in firm substances, is almost equal to the mature ovarium) 280 grams, leaving 1,608 grams to be added to the ovarium.

Indeed, the demands made by the ovarium are very great! The clear, yellowish fluid, which forms by far its greater portion, is so concentrated that it dries very soon, and forms a sort of amber-like substance, which possesses such a strong refraction that the firm portions (little pellets and pieces floating about in it) look like holes (*vacuolen*).

Chemically considered, this fluid is nothing but "liquid caviar"—an intensely concentrated solution of a substance entirely analogous to the little yolk-disks of the sturgeon and other fish; it produces the reactions of albuminous bodies; by boiling it in alcohol about 20 per cent.

of a phosphoric fat (*Lecithin*) is produced, and by digesting it with artificial gastric juice, another phosphoric substance is obtained, viz, the *nuclein*, otherwise known to form the nucleus of the cells. This is of interest, in as far as both these substances, especially the last-mentioned one, are only found in the muscles in very small quantities. The formation of the liquid part of the egg can, therefore, not only be accomplished when muscle substance is taken from the flesh and is deposited in the egg, but the new combinations peculiar to the egg need to be produced from the albumen, the fat and the salts of the muscles containing phosphoric acid, by means of the most radical chemical changes.

I do not, at the present time, possess a sufficient number of albumen calculations from the ovarium, which would be useful in this connection. Taking from the figures at my command (which are probably somewhat too high) 30.0 per cent. of substance not soluble in boiling alcohol, ether, and water, I reach the following result:

Probable loss of the muscle	579.7
Probable amount of albumen consumed by the ovarium	482.4
Albumen left	97.3

to be used either as food, or for increasing the ovarium beyond its average size, or for spawning flesh containing more than 13.2 per cent. of albumen, not counting the loss sustained by the liver and the intestines.

The *other* fish to be examined was a decidedly lean one (we had purposely selected such an one). It was caught August 4, 1879, its length was 858 millimeters, and its weight 7,340 grams; therefore almost 700 grams less than the average weight of the division to which it belonged, according to its date (8,028). If in this case, where the conditions were less favorable, we could also succeed in showing a sufficient loss of substance, our proof would be doubly sure. The results obtained in the same manner as with the first fish are given in the following table in a tabulated form. As the development of the ovarium was farther advanced, I calculated the decrease of weight only to the 1st November.

TABLE VIII.—*Albumen balance-sheet—Growth of the ovarium at the expense of the muscle in a salmon caught near Basel, August 4, 1879.*

MUSCLE, *Dr.*					MUSCLE, *Cr.*		
Albumen.	Ovarium.					Albumen.	Albumen.
Grams.	*Grams.*		*Grams.*		*Grams.*	*Per ct.*	*Grams.*
		Weight of body August 4			7,340		
		Final weight, calculated for November 1: $\frac{7,340 \times 100}{107.84}$ =			6,806		
		Total probable loss of weight of body up to November 1			534		
		Liver of 108 grams = 1.58 per cent. of weight of body, November 1, less 1.06 average liver of the mature fish in per cent. of weight of body		0.42			

TABLE VIII.—*Albumen balance-sheet—Growth of the ovarium, &c.*—Continued.

MUSCLE, *Dr.*						MUSCLE, *Cr.*	
Albumen.	Ovarium.		Grams.		Grams.	Albumen. Per ct.	Albumen. Grams.
Grams.	*Grams.*	*Stomach, intestines, &c.* = 1.21 − 0.70 per cent. of weight of body		0.50			
		Loss of liver intestines in per cent. of weight of body		0.92	63		
		There remains, as share of the muscle, in decrease of weight of body			471	@17.3	81.4
	1,579	Probable weight of mature ovarium = 0.23 × 6,864.					
	430	Subtract from this: Ovarium in existence August 4.					
344.7	1,149	*Ovarium still to be formed,* @ 30 per cent. albumen (maximum).					
		Loss of muscle			1,149	@17.3	198.9
		Determination of the remainder of muscle November 1:					
		Weight of body August 4		*7,340			
		Subtract from this: Heads, fins, ovarian skin, various intestines + 30 cc. blood	2,400				
		Subtract from this: Reduced decrease in weight of body up to November 1	413				
		Subtract from this: Replaced by ovarium	1,149				
		Total amount subtracted from weight of body		3,962			
		There remains as remainder of muscle, November 1, with probable decrease of the albumen from 17.3 to 13.27 per cent.			3,378	@4.1	138.5
74.1	.....	Balance in favor of muscle.					
418.8		Total loss of muscle					418.8

In spite of the unfavorable selection of the fish used for the experiment, and an improbably high figure of the quantity of albumen in the ovarium, we also get in this case more than sufficient to cover the loss.

As regards the fat, the relative decrease of the quantity thereof can be approximately determined from the difference between the quantity of albumen and solid substance, under certain highly probable conditions. If this difference is made the basis of calculation in very lean fish, we shall get very near the absolute truth by either making this difference greater in proportion to the quantity of albumen, or by subtracting it from the total difference.

	Difference between the percentage of albumen and solid substance.	Calculated from the last difference (2.7) for ashes, &c.	Probable percentage of fat.
Average of two female March salmon (see Table V), one of them a Dutch fish	15.1	4.4	10.7
Average of female salmon during July and August (Table V)	9.3	4.1	5.2
Salmon of August 7, weight of body 8,930	13.0	4.0	9.0
Salmon of August 4, weight of body 7,340	9.3	4.1	5.2
Average of female salmon during November (Table V)	5.3	3.1	2.2
Average of two exceedingly emaciated female salmon, in whose flesh, even under the microscope, no trace of fat could be discovered	2.7	2.7	0.0

In the lean salmon (Table VIII) there is, therefore, the following quantity (approximated) of fat:

	Grams.	Decrease of percentage.		
Probable decrease in weight of body	413	at 9.3	=	38.4
Replaced by ovarium	1,149	at 9.3	=	106.9
Remainder of muscle, November 1	3,378	at 4.0	=	135.1
Probable total loss of fat				280.4
Subtract consumption of fat of 1,149 ovarium, at 9 per cent. (maximum).....				103.4
And there remains for self-consumption				177.0

We cannot form an opinion as to the use made of the excess of albumen and fat, or as to the formation of phosphoric fat from one source or the other, until we have reliable average figures showing the quantity of albumen contained in the ovarium.

There is no doubt that the muscle contains more than enough *phosphoric acid* to supply all necessary phosphorus for the ovarium, at 1.1 per cent. phosphoric acid in the fresh ovarium against 2, 3–2, 6 per cent. of the firm substance in the muscle.

By the agreement of all these figures with my hypotheses, I consider it proved *beyond a doubt* that our salmon of the beginning of August are identical with the November salmon, and that, with few exceptions, there is no addition to their number of more mature fish with more substance in their bodies.

The microscopical examination fully corroborates the opinion that the side-muscle is really the most important source from which the food of the fish is derived, and which aids in advancing sexual maturity. Even the winter and spring salmon (especially the thin ones) show more or less distinct rows of little drops of fat between the fine elementary fibrils of the considerably thicker muscle-fibers, such as are known as indications of so-called deterioration of the muscular tissue. About midsummer, the very time when the ovarium commences to grow more rapidly, the number of these drops of fat increases considerably, and even goes so far as to make some of the fibers quite opaque. The most prominent example of degeneration is in a separate thin muscle plate, which lies on the side of the body directly under the skin (the skin-muscle). There remain, however, almost *intact* and *free from fat*, all the other muscles, pectoral fin, neutral fin, dorsal fin, caudal fin, the muscles of the jaw and tongue, the upper and lower long muscle, and the tail muscles proper. Only the ventral fin showed in some places faint indications of degeneration.

With this, I find there agree the numerous figures obtained by me in weighing the fin-muscles, of which I will give, as a single example, the data relating to the pectoral fins.

TABLE X.—*Proportion of weight of the muscles of the pectoral fin (of one side) to the weight of body of female summer salmon and spawning salmon.*

	Weight of body—		Weight of muscles of the pectoral fin.	1,000 parts contain pectoral fin calculated on weight of body—	
	With ovarium.	Without ovarium.		With ovarium.	Without ovarium.
DUTCH FISH.					
May 31, 1879, ovarium 31	6,800	6,760	19.1	2,808	2,825
SALMON CAUGHT BETWEEN BASLE AND LAUFENBURG.					
July 1, 1879, ovarium 198	9,750	9,550	34.23	3,511	3,584
July 2, 1879, ovarium 300	9,700	9,400	32.41	3,341	3,448
July 9, 1879, ovarium 291	8,560	8,270	30.45	3,557	3,682
July 21, 1879, ovarium 341	10,270	9,930	35.30	3,437	3,555
July 28, 1879, ovarium 394	7,440	7,050	26.14	3,513	3,708
August 1, 1879, ovarium 802	11,130	10,330	32.72	2,940	3,167
August 4, 1879, ovarium 429	7,340	6,910	25.10	3,420	3,632
August 7, 1879, ovarium 270.5	8,930	8,650	30.03	3,363	3,472
August 25, 1879, ovarium 505	7,745	7,240	26.69	3,446	3,686
Average				3,392	3,548
November 3, 1879, ovarium 20.40	7,740	5,700	25.99	3,358	4,560
November 4, 1879, ovarium 18.18	9,020	7,800	34.30	3,565	4,397
November 8, 1879, ovarium 20.44	8,900	7,190	34.02	3,822	4,732
November 10, 1879, ovarium 20.44	7,650	5,610	24.85	3,248	4,429
November 15, 1879, ovarium 16.10	6,750	5,130	24.71	3,661	4,817
November 22, 1879, ovarium 85	7,510	7,420	33.11		4,462
November 22, 1879, 117.5	7,290	7,170	32.22		4,494
November 25	5,730		28.26		4,967
Average				3,531	4,607

It will be seen from Table X that the muscles of the pectoral fin maintain the same proportion to the weight of the body from summer till November, or even—corresponding to the decrease of weight of the fish—increase somewhat, thus furnishing proof that the ovarium takes the place of muscle-substance which has been used up.

The decrease of albumen in the fin-muscles is either very small or there is no decrease at all. The very muscles, therefore, which are most necessary to the fish for its motions, remain singularly free from emaciation, and are even built up at the expense of substances furnished by the muscle of the body. On the other hand, the fact that the fins remain the same—in spite of the increase of the ovarium—furnishes another convincing proof that the ovarium cannot be considered merely as an addition to the existing body, but is really a substitute for substance (belonging to the body) which has been lost.

All the above facts prove, with *absolute certainty*, that (with very few exceptions) all the *Rhine salmon caught between Basel and Laufenburg go through their entire sexual development, and the entire growth of the ovarium, at the expense of the body, whilst in the Rhine.*

As regards the *male* fish I have not such full and accurate calculations. The few given below will show, however, beyond a doubt, that from midsummer to October there is a very noticeable decrease of weight.

TABLE XI.—*Average change of weight of male Rhine salmon, from summer till autumn, 1878; two divisions of equal length, 79 fish in all.*

Number of division.	Length from nostril to root of tail.	Limits of dates between which the fish were caught.	Average date of group.	Average difference of time, days.	Number of fish in group.	Average length of group.	Average weight of body.	Difference of weight of group.	Proportion of weights, calculating the final weight at 100.	Daily decrease of weight.	
										In grams, +.	Calculating final weight at 1,000 grams.
I.	844–855	June 4 to July 18..	June 26	81.0	22	850.4	9723	632	106.95	7.80	0.858
		July 22 to Nov. 4..	Sept. 15		18	849.1	9091		100.00		
II.	863–874	June 1 to Aug. 10..	July 4	91.7	19	867.8	10657	673	106.74	7.34	0.735
		Sept. 5 to Nov. 4..	Oct. 4		20	868.1	9984		100.00		

The average decrease of weight of the male fish would be still more striking if there did not arrive in the Upper Rhine (late in summer) a good many male stragglers, not quite as emaciated, and which somewhat covered the decrease in older immigrants. But even in these fish a considerable decrease of albumen can be noticed in the muscle of the body. The flesh of two March salmon, caught near *Basel*, showed 17.9 and 19 per cent. of albumen, just like the female fish of the same period; a September salmon (caught September 19) which certainly belonged to a later batch of immigrants, and whose testicles were one-third formed, showed 16.6 per cent. albumen, and 25.7 per cent. dry substance. Three salmon of January, 1880, which had ejected their milt, showed (in their muscle) 13.0, 14.3, 13.3 per cent. albumen, respectively. The decrease might, therefore, well be compared with that of the female fish; possibly it was somewhat smaller. But, as the sexual glands need much less albumen for their growth than the ovaria, it seems that the male fish, corresponding to their greater animation and excitability, consume more albumen than the female fish.

The influence—just referred to—of these stragglers on the figures showing the degrees of emaciation makes itself felt with the female fish also, but at an earlier period. Whilst those groups which were composed of April and May salmon showed considerably greater average weights than summer salmon of the same length, there was almost a stand-still in the average weights from June till the end of July or the beginning of August; in some groups there was even a slight increase (seemingly accidental); but from that time on a constant and considerable increase was noticed. In fact there is among the salmon from these months—middle of July till beginning of August—a very distinct difference between the older salmon (older as to the time of their arrival) and those recently arrived, such as is not found among early spring salmon. These last-mentioned fish have dark red and the former pale red flesh; the latter have considerable, and the former very little fat; the duodenum of the latter is enveloped in fat, while that of the former shows but little fat. When the ovarium has reached one-fifth of its nature weight by far the larger mass of this fat has disappeared. This

difference is often, but not always, caused by the differences in the degree of development of the ovaria; for the July salmon, which contained the smallest quantity of fat (of all those examined by me July 9, 1877), had an ovarium which was only developed one-half of that of a very fat salmon of August 1.

This difference gradually vanishes from the beginning of August; the female September salmon, but still more the October salmon, are, apart from individual differences of bodily build, equally lean as to flesh and intestines.

To follow up these data, as regards the male fish, the measure of the length of nose, which, since September 1, 1878, was taken in fish of both sexes, is important. While in the female fish the average length of nose remains the same, an elongation of the jaw can be noticed in most male fish at an early date, and makes it possible to determine the sex (with the exception of a small percentage of doubtful individuals) as early as April and May.

Whilst in the male June salmon (length—exclusive of nose—800 to 910 centimeters) the length of the nose, in nine cases out of ten, varied between 5.4 and 6.4 per cent. of the weight of the body, and once in an exceptional case rose as high as 7.0 per cent., the same or very nearly the same minimum figures occur during the whole of July and August, although not very frequently, while the maximum figures become higher and more frequent. From September on, and all through October, both the minimum and the maximum figures increase, whilst the difference of the extremes decreases to some extent. But even in November there is a very considerable difference of length of nose in fully matured fish, whose size and shape are otherwise very nearly equal; and I am inclined to consider these differences as indications of different dates of arrival.

This will be the proper place to make use of the data relating to the *numerical proportion* between the two sexes, which I obtained from the weighing-lists I had kept without regard to individual differences. For 1879 I have made my calculations with the aid of the length of nose from June 1 whilst for 1878 I did not do this until July 1, at which time the sex may easily be determined, even without this aid. The average of both years shows as the average proportion of the sexes: 62.6 per cent. females, and 37.4 per cent. males.

TABLE XII.—*Numerical proportion of sexes among the Rhine salmon caught semi-monthly between Basel and Laufenburg.*

	1878.				1879.			
	Number of females.	Number of males.	Of 100 salmon there are—		Number of females.	Number of males.	Of 100 salmon there are—	
			Females.	Males.			Females.	Males.
July 1 to 15	97	44	68.8	31.2	4	23*	85.2	14.8
July 16 to 31	104	41	71.7	28.3	12	38	76.0	24.0
August 1 to 15	78	22	78.0	22.0	15	46	75.3	24.6
August 16 to 31	37	13	74.0	26.0	29	71	71.0	29.0
September 1 to 15	52	29	64.2	35.8	17	37	68.5	31.5
September 16 to 30	37	42	46.8	53.2	34	41	54.7	45.3
October 1 to 15	64	33	66.0	34.0	79	79	50.0	50.0
October 16 to 31	53	55	49.0	50.9	45	37	45.1	54.9
November 1 to 30	47	19	71.2	28.8	52	63	54.8	45.2
	569	298	65.6	34.4	311	460	59.5	40.5

From the above table a corresponding change will be observed in both years in the numerical proportion of the sexes. Till the end of August the female fish are in the majority; during September the males gradually increase so that the numbers become almost equal, and in October the relative proportions are about the same. As there is nothing in the quality of the fish, in their color, length of nose, and quality of the flesh, to point to such a late immigration in great masses; as the October figures show great irregularities, and as, moreover, the females are again more numerous in November, I consider it probable that the females during the last stage of the ovarian development keep much quieter than the males, and are therefore not caught as frequently. Mr. *Glaser* shares this view. It is not impossible, however, that a larger number of such males as have hitherto roamed about in the Central and Lower Rhine immigrate into our region at so late a period.

There are instances of direct immigration of fresh fish. In 1877 and 1879 I observed (as an entirely exceptional case, however) male fish which undoubtedly were late immigrants. They had the appearance of summer salmon; their skin showed red spots, but was not quite as thick and dark as that of summer salmon; the nose was short (5 to 6 per cent. of the length of the body, instead of 8 to 11), the hook was less developed; there was a considerable quantity of intestinal fat, and the flesh was still red. But these fish, of which I took note during the period, November to January, were *never (sexually) mature.* (Notices regarding the testicles of 4 fish, among them 2 by Prof. *His*, 1870).* The weights and the degrees of maturity, ascertained by microscopical observations, differed very much, and corresponded to the normal organs from August till the beginning of October. The question here was by

*Mr. *Glaser* remembers only two cases in 19 years where he succeeded in squeezing a little semen from such late-comers, during a late spawning season.

no means one of barrenness, but one of retarded formation of normal elements. These fish are, as a rule, called winter salmon, and fetch prices like these; but they must by no means be confounded with the *genuine winter salmon* described above, which do not spawn till November and December of the following year.

The observations which I made relative to these late-comers are, in my opinion, a certain proof that for the male fish the short migration-period from the sea to *Basel* does not suffice to complete the entire sexual development up to the point of maturity, much as the rate at which this development goes on may vary between individual fish. The probability, therefore, becomes still greater than would appear from what has been said above, that the entire spawning generation of one year consists of fish which have staid in the Rhine several months longer than the shortest period occupied by the migration from the sea.

Neither during the spawning season nor later have I seen female fish whose general appearance stamped them as fresh immigrants; it is a matter of doubt with me whether the very rare, full-ripe female fish which occurred in January 1879 and (in 1880) even as late as February 20 belong to this category. I had my suspicions regarding a very lean fish, of the middle of November, 1879, which had a clear skin, and an ovarium only weighing 16.5 per cent. of the weight of the body, and containing comparatively small eggs; all this, however, might have been caused by the unusually small quantity of flesh.

The different links of the long series of internal and external changes, by which the spring salmon is transformed into the spawning salmon, run, as a general rule, parallel, but not with mathematical accuracy. The gristle of the nose and chin begins to grow before there is any sign of development in the testicles; and before the testicles have reached one-eighth of their mature weight the skin often shows very distinct red spots. It would also frequently lead to mistakes if one were to determine—say in August or September—the stage of development of the sexual glands by the degree of development to which the hook formation has attained. On the one hand we see the influence of the different seasons of migration, and on the other hand we see the effort (notwithstanding this difference) to finish the sexual development for the same time of spawning. In short, the development of the sexual organs is not the direct cause of external influences, but is only indirectly connected with them.

Finally, I have to make brief mention of an internal organ which exhibits some very curious phenomena. The *spleen*, which is now generally considered as a gland forming blood, appears in the winter salmon as a tough, brown, insignificant organ, weighing about $\frac{1}{1000}$ to $\frac{1}{2000}$ of the weight of the body. In May a swelling is observed to commence in the female fish, in the shape of dark-red raised knots, which increase in size and number, and combine, till, about the end of June or sometime in July, the organ has reached 15 to 20 times of the

weight of the spleen, then at its smallest, and has become smooth, shining, dark-red, tender, and resembling coagulated blood. From that time on it shrivels again, and at the beginning of September is smaller than it ever was before, weighing now $\frac{1}{2000}$ to $\frac{1}{2800}$ of the entire weight of the body. In this condition it remains till the spawning season, and begins to increase shortly before the fish return to the sea. The volume of the spleen likewise changes in the male fish, but not in as regular a manner as in the female; it decreases and increases several times during the summer, until the largest size is reached, in the beginning of October (as much as $\frac{1}{120}$ of the weight of the body). During the spawning season it again decreases in size and weight.

This swelling is nothing else than a filling up with liquid blood. Under the microscope we see a net-work of beams, which, combined, form a sort of sponge. The outermost branches of the arteries open (as has been proved by injections) into the meshes of this sponge, and from this very same sponge the capillary vessels of the veins receive their supply. But these meshes may be either nearly empty or filled to repletion, according to the degree of contraction of the muscles of the arteries. This blood (as has been shown by comparing the coloring quality of the watery extract from the spleen with blood from the heart) is much richer in blood-particles than the circulating blood from the heart; the sponge acts upon the blood like an imperfect filter, partly retaining or keeping back the blood-particles, and at the same time, acts like a basin in the sea, in which the rapid current becomes slower, and drops its heavy accumulations. The whole mass of blood which is retained may, under different mechanical conditions, again join in the general circulation. As is shown by numerous comparisons between the veinous blood from the spleen and the blood from the heart, colorless blood-cells are formed in this stagnant blood, but, as it seems to me, not in such a degree as to thereby exhaust the significance of so remarkable an occurrence. Weighty reasons lead me to the opinion that such a temporary retaining of one-fourth to one-third of the entire quantity of blood, during certain phases of the sexual development, forms an important link in the chain of causes by which the great change in the internal economy of the entire body, described above, is introduced. This is not the place to enter more fully upon the discussion of this question. I only mention these curious phenomena of the spleen as further proof that the most radical changes in the formation of the salmon go on during its stay in fresh water.

STATISTICS RELATIVE TO THE MIGRATIONS OF THE RHINE SALMON.

The question of age.—At what age do the salmon, for the first time, migrate and spawn? Do they spawn every year or at greater intervals? Do they perhaps only spawn once in their life, and die soon after?

Such and similar questions have often been asked from a scientific and from a practical point of view; and I feel it my duty to examine

whether the facts at my disposal—especially the numerous measurements—will throw any light on these questions.

For this purpose I divided the salmon caught between *Basel* and *Laufenburg*, keeping the males separate from the females, and also separating the fish of 1878 from those of 1879 into groups of 20 millimeters difference, accepting as a constant their *length* (counting this with the males from the nostril, and with the females from the front part of the head, to the root of the tail), and from these groups constructed curves, the abscissas of which corresponded to the lengths of the fish, and the ordinates to the figures indicating the dates of occurrence of these lengths. The regularity of these curves* shows that they rest on a reliable basis, and at the same time proves the accuracy of the measurements.

The first thing to strike us, with both sexes, is, that certain sizes are either entirely or almost lacking. If any further proof were required that not a single salmon goes through its entire development while in the Rhine, this fact would furnish it. From the line indicating 0, or from a slight elevation above this line, the curves showing the periods of migration rise like finely-shaped mountains with a maximum height and slopes on both sides. With the males, three elevations may be recognized in both years, resembling each other. The first gives the small salmon, the so-called St. Jacob's salmon, weighing 1,500 to 3,000 grams. As will be seen from the Dutch market reports, these are mostly late immigrants, which do not occur on the price-lists until July and August, and which, though in comparatively small numbers, reach us in September or October. The height of this curve, therefore, does not furnish an exact standard for estimating the numerical proportion of the immigration of these young fish. The second elevation contains such sizes as are found with us in September and October, with an average weight of 3,800 to 6,600; the third elevation shows the fish for the same months, but with an average weight of 6,600 to 13,000. If we had more data we would probably be able to construct a fourth elevation. Before proceeding any further we give the statistics in tabulated form:

* These curves are not reproduced in the translation.—EDITOR.

TABLE XIII.—*Showing the relative frequency of the different sizes of Rhine salmon between Basel and Laufenburg.*

Males.

Limits of length (nostril to root of tail).	Number of males.			Weight (Sept. and Oct.).
	1878.	1879.	Total.	
Below 500	1	19	20	Supplemented by St. Jacob's salmon, from Wesel.
501-520	4	11	15	
521-540	2	16	18	
541-560	3	12	15	
561-580	.....	11	11	
581-600	.....	3	3	
601-620	1	.....	1	
				621-650.
621-640	1	6	7	Maximum 4,100
641-660	8	9	17	Minimum..... 3,200
661-680	14	13	27	Average.....**3,793**
				681-700.
681-700	**23**	**24**	**47**	Maximum 5,410
701-720	22	15	37	Minimum..... 3,900
721-740	14	15	29	Average.....**4,892**
				751-780.
741-760	11	8	19	Maximum 7,320
761-780	**11**	**5**	**16**	Minimum..... 5,620
				Average.....**6,601**
				781-810.
781-800	14	8	22	Maximum 9,450
801-820	24	23	47	Minimum..... 5,300
				Average.....**6,614**
				831-850.
821-840	38	36	74	Maximum 10,140
841-860	**53**	**27**	**80**	Minimum..... 7,350
861-880	52	25	77	Average..... **8,633**
881-900	23	17	40	
901-920	23	12	35	
				921-950.
921-940	10	3	13	Maximum 10,200

Females.

Limits of length (tip of nose to root of tail).	Number of females.			Weight (June and Aug.).
	1878.	1879.	Total.	
461-480	.....	.....	.....	
481-500	St. Jacob's salmon, from Wesel, Sept. and Oct.	2	.....	
501-520		2	.....	
521-540		2	.....	
541-560		5	.....	
561-580		3	.....	
581-600		3	.....	
601-620	.....	.....	.....	
621-640	.....	.....	.....	
641-660	.....	.....	.....	
				661-710.
661-680	3	1	4	Maximum 5,710
681-700	8	1	9	Minimum..... 3,350
701-720	13	8	21	Average.....**4,221**
721-740	15	15	30	
741-760	18	19	37	
761-780	22	14	36	
				781-800.
781-800	15	12	27	Maximum 7,870
801-820	34	18	52	Minimum..... 5,680
821-840	45	26	71	Average.....**6,687**
841-860	102	45	147	
861-880	138	61	199	
				881-900.
881-900	139	86	225	Maximum 11,560
901-920	106	69	175	Minimum..... 7,580
921-940	38	31	69	Average.....**9,549**
				941-960.
941-960	20	7	27	Maximum 12,400
961-980	9	4	13	Minimum..... 11,010
981-1,000	4	3	7	Average..... **11,533**
1,001-1,020	1	2	3	
1,021-1,040	.....	1	1	

941-960	1	3	4	Minimum....... 10,900	1041	....	2	2
961-980	2	4	6	Average...... **13,040**				
981-1,000	....	1	1			....	....	....
1,001-1,020	2	1	3					
1,021-1,040	1	....	1					
1,041-1,060	....	....	....					
1,061-1,103	2	....	2					
	728	418	....					

In examining the three elevations we are, first of all, struck by their very considerable breadth. This points either to very great individual differences of growth, especially in youth, or—which appears far more plausible—to an *unequal age of the fish* when they first immigrate. Persons who have raised trout will be better able to decide than I whether differences of 20 to 30 per cent. of length and 80 to 100 per cent. of weight occur in fish of equal age, or in younger fish of otherwise normal conditions of life. It is improbable that these differences are merely produced by differences of food, because (according to Mr. Glaser's and my own observations) the smaller St. Jacob's salmon appear to be well fed, to judge from their shape and the condition of their flesh.

Is it, moreover, merely accidental that both the starting points and the maxima of the first curve are at an exactly equal distance from the second as the second from the third, and, therefore, show *exactly the same increase in length?* As it can only be a question of whole years, either the vertebral column grows between the first and second period *exactly* two or three times quicker or slower than between the second and third, or (which seems to me more probable) the increase of length of the vertebral column takes place at the same periods, and to the same amounts; and this equal distance would then be an indication of equal differences of time between the three fresh-water periods.

The heights of the curves likewise deserve some attention. The small St. Jacob's salmon of the first curve are of no account in this calculation, as they do not come in our neighborhood. On the other hand, it is surprising that the third curve corresponds to twice as many fish as the second, whilst (by fishing and mortality) one would expect the older fish to be much less numerous than the younger ones. Is this caused by the greater ease with which they can escape from the net? In that case the St. Jacob's salmon must be still more rare. Do not these male fish of average size migrate to the Upper Rhine as frequently as the larger fish, or does only the smaller portion of the St. Jacob's salmon of one year which have returned to the sea again appear during the next season? and does the greater portion come a year later, and perhaps make their appearance in the Rhine for the first time? Nothing but further observations as to the relative frequency of the different sizes, made on the Lower Rhine, can solve this problem.

As regards the difference of time (always supposing that the *same* fish occur in two successive curves), it will not be proper to class all fish under one and the same category. As, for instance, the male fish of the spawning season 1878 (middle of November till middle of December) could hardly have again reached the Rhine before the beginning or middle of January, it is self evident that the exceedingly fat winter and spring salmon, with very short nose, which immigrate into Holland as early as November, 1878, to March, 1879, and reach Basel from January to May, must have skipped the spawning season of 1878. This possibly also applies to one or two later months. On the other hand, I

do not consider it impossible that among the later immigrants of 1879 there are many male fish which have still gone through the spawning period of 1878. This supposition would be the easiest explanation of the fact that—the length being equal—the winter and spring salmon are so much fatter and heavier than those among the August and September male fish (near Basel) which show indications of recent immigration in their color and nose, because the former have had more time to fatten in the sea. The same proportion would also apply to early and late salmon if the recent immigration of male fish from the spawning period 1878 would be placed in the year 1880. Supposing that the majority of the male salmon returns every year, there results a lowest possible *minimum age* for a male salmon begotten on the 1st December, 1874, and hatched on the 1st February, 1875, which participated in all three migrations, viz:

First migration (as young salmon) to the sea, spring of 1876 ..... About 1 year.

First spawning season (as St. Jacob's salmon), near Basel, partly in December, 1877, and partly in 1878. $2\frac{3}{4}$ to $3\frac{3}{4}$ years.

Second spawning season (as salmon proper), weighing $3\frac{1}{2}$ to $6\frac{1}{2}$ kilograms, December, 1878, and 1879 ..... $3\frac{3}{4}$ to $4\frac{3}{4}$ years.

Third spawning season (as salmon proper), weighing $6\frac{1}{2}$ to 13 kilograms, December, 1879, and 1880 ..... $4\frac{3}{4}$ to $5\frac{3}{4}$ years.

I must, however, consider it just as probable that every interval between the three last stages is one year longer; for I must confess that I cannot willingly accustom myself to think that so fine a fish as the salmon should be destined to starve throughout the greater portion of its adult stage, and should only eat with feverish voracity during short intervals between the starving periods, and yet grow during such periods at an enormous rate.

I think, moreover, that the influence of the feeding-process is rather overestimated, by supposing that, in $1\frac{1}{4}$ years, the small migrating salmon, weighing only 20 to 25 grams and measuring 7 to 9 centimeters,* should be transformed into the St. Jacob's salmon, which returns in June or July, and is seven times as long and 100 to 150 times as heavy, whilst the two-year old salmon of our waters which has remained with us, and which I occasionally observed, weighs about 80 to 100 grams.† We would, therefore, certainly have to allow $2\frac{1}{4}$ years for development from the small migrating salmon to the St. Jacob's salmon, and for the large St. Jacob's salmon probably one year more.

But why should we trouble ourselves with suppositions regarding a size which can be accurately determined according to our methods?

*As I did not have an opportunity to personally examine any specimens, I make use of an estimate by Mr. Glaser, which may have to be corrected.

†A very successful experiment was made to produce impregnation with the semen of such a salmon weighing about 100 grams. I have never seen mature females of this kind.

About 100 or 200 small salmon should be measured in the sea, and near the mouths of the Rhine, at a certain season of the year, if possible in one certain month (as the length does not always remain the same). These fish would certainly—as to their length—be classed among those the catching of which is forbidden by law; but the result would justify an exception; as the arrival of the great mass of the young fish is limited to a certain season of the year, the different migrations would show on the curves constructed from such measurements, like annual rings. So far all attempts to obtain such a determination of the age by the marking of young salmon have been in vain. But even supposing that fish thus marked are caught again, the result of the statistical method is much more valuable, because it alone can select from among the numerous exceptions and variations which doubtless occur in the conditions of life of these fish with absolute certainty, those *fundamental rules* on which everything depends.

From these and other reasons, to be considered later, I prefer to designate the time which elapses till the young salmon had been transformed from a small fish into the St. Jacob's salmon simply by t; and by introducing this unknown quantity to designate the following determination of the age of the fish as the more probable one in most cases in as far as fish which participate in all migrations are concerned:

Migration of the young salmon to the sea	1 year.
First spawning period of the St. Jacob's salmon:	
Small specimens	$1+t$ years.
Large specimens	$2+t$ years.
Second spawning period	$3+t$ and $4+t$ years.
Third spawning period	$5+t$ and $6+t$ years.

The curve indicating the sizes of the *females* is much easier to understand than that of the males. Here, likewise, three elevations may be noticed. Female salmon of the first migration are very rare near Basel, and the data had to be supplemented by measuring St. Jacob's salmon from *Wesel* (September 23 to October 13, 1879). Here the females are likewise in the minority; the *Wesel* salmon referred to (which were distinguished by the length of their nose) showed one-fourth females and three-fourths males.

The curves of the second and third immigration are very distinctly shown in the Basel salmon of both years. I am inclined to ascribe the considerable breadth of all three curves, just as with the male fish, first of all to differences of age in the first immigration which return at every succeeding migration, and to other differences of the intervals between the years of migration; and only in the second place to individual differences of growth. Attention should also be directed to the circumstance that the maxima of the three curves are not, as with the males, equidistant from each other, but that the proportion of the first distance to the second is as 10 or 11 to 7, or 3 to 2. Its proportion to the distance

between maximum I and II, with the males of 1879, is neither 1:1 nor 2:1, but nearer 3:2 than either of the two former proportions. This decidedly favors the supposition that, with most males, the interval between the first and second spawning period is two, and with most females three years; the interval between the second and third spawning period being two years. It is also probable that the age at which the first immigration takes place differs greatly.

With the females the numerical majority of the third immigration over the second, and—considering the small number of female St. Jacob's salmon—probably also over the first, is very marked:

	Number of fish of the—		To every 100 of the second curve the third curve contains—
	Second curve.	Third curve.	
1878	642	86	748.0
1879	353	64	552.0

In 1878 not less than 277 fish, or 38 per cent. of all the fish of that season, are found included in the narrow limits of length of 861 to 900 millimeters (average weight on the 12th October about 8.0 to 9.3 kilograms).

Is this only caused by the circumstance that the majority of these medium-sized fish do not go as far up the Rhine as Basel? My numerous measurements of Dutch salmon, taken at different seasons of the year during three years, do not seem to favor such a supposition. Although on two different occasions I found a small number of Dutch salmon measuring 700 and 800 millimeters, the large females were, next to the St. Jacob's salmon, decidedly in the majority. Mr. Glaser, whose experience as an old importer of Dutch salmon gives considerable weight to his opinion on this subject, is prepared to corroborate my view. Until we obtain more exact data regarding the salmon of the Lower Rhine, therefore, I consider it highly probable that many of the females of the third curve (measuring 800 to 960 millimeters in length) had only migrated once before, or even were now visiting *the Rhine for the first time*. Such fish will, of course, grow into the limits of the third curve at an earlier age, because they escaped the disturbing influence (to their growth) of one or both of the former migrations. What they gain thereby will not, however, be sufficient in many cases. Some of them stop at this intermediary stage, and thus the lack of a deep depression between Curves II and III (making it almost appear as if the sharp lines between the two main curves were obliterated by the interpolation of a third and smaller curve) is explained by the supposition of such an immigration which has been retarded one year. If these same fish immigrate once more, we shall find them in the right lower portion of Curve III.

I therefore consider it probable that the spawning period of the salmon of the second curve (length, without tail, 680 to 790 millimeters) is for the majority three and for the minority four years later, and with the salmon of the third curve (from 791 millimeters on), four, five, and six years later than the spawning period of the St. Jacob's salmon, to determine the age of which I feel utterly incompetent. On the other hand, it seems strange that everything comes to an abrupt close with this powerful third curve and its steep slopes. Females of exceptionally heavy weight, weighing more than 12 kilograms (during the spawning period), are very rare. I consider this as a proof of the truth of the assertion that the salmon fisheries certainly interfere with the keeping up of the species. I believe that but very few of those female salmon which have not gone through a spawning period as St. Jacob's salmon spawn three times during their lives. *The circumstance that most fish do not participate in every spawning period to which their age would entitle them is perhaps the only cause which has saved the salmon fisheries in the Rhine from complete decadence*, and which has kept the average weight of the Basel Rhine salmon at about 8 kilograms.

In reviewing this whole subject I feel compelled to warn people not to apply the experiences gained in other rivers to the Rhine salmon, and *vice versa*. Among many imported river salmon (with empty intestines) which I had occasion to observe in the course of many years, and which, according to Mr. Glaser's statement, came partly from the Oder and partly from the Elbe, the fish of the *second curve* were decidedly in the majority; and this could hardly have been brought about by the character of the orders for these fish. The Swedish salmon, on the other hand, were very much mixed, and among them I found more exceptionally large fish, weighing 16 to 21 kilograms, than among any other kind.

The habits of migration, therefore, seem to vary in the different rivers, perhaps according to the length of the route traveled and the extent of *distribution in the sea* within which certain kinds are found.

From what is known relative to the salmon fisheries of Scotland and Norway, the habits of life of the fish, even, seem to vary. Very probably the flesh does in all cases furnish building material for the ovarium, but doubtless in greatly varying degree.

WINTER SALMON.

After the curves, showing the length of the fish, have led us to the view that the conditions of migration of the Rhine salmon can show various exceptions from the general rule (supposing, of course, that any such rule can be laid down), we shall feel justified in using this circumstance in explanation of various striking phenomena. The appearance of the so-called winter salmon has always been considered as a mysterious problem in the biology of the salmon. These winter salmon immigrate from the sea simultaneously with the last spawning salmon, from September on, in small numbers (Dutch market reports), and from

October on in larger numbers, and are nearly every year caught in small numbers near Basel in November; they are fat fish, with red flesh, and fetch 2½ to 3 times as high a price as the spawning salmon. These fish, with their diminutive testicles and ovaria, have by many people been considered as a sort of barren variety of the salmon. But I have said before, that already during the first spring months, March and April (when the salmon increase in number), the ovaria increase arithmetically slow, but in a very considerable geometrical progression, until the large schools of summer salmon, which appear from May till July, show themselves as the undoubted candidates of the next spawning season. Soon, however, no former winter salmon can be distinguished from the summer salmon, at least not by any less development of the sexual organs.

If we observe these winter salmon closer—from November to March—we are first of all struck with the fact that, with few exceptions, they are very large fish, belonging as to length to the fish of maximum length, and to the second half of the third curve (length exceeding 860 millimeters). Also the Dutch fish—January and beginning of March—of which I have measurements, were, with few exceptions, within the same limits of size (861 to 970).* Among 99 Rhine salmon, the sex of most of which had not been determined (there being no decided difference of nose between males and females), from the months of January to March, 1878 to 1880, only five measured between 835 and 860 millimeters, whilst all the others measured more (as much as 975, and one even 990 millimeters); whilst during May and June, 1878 (just as in 1879), the salmon of the second curve came in large numbers, the St. Jacob's salmon making their appearance from July on.

By comparing nine winter salmon, which (by opening them) have been found to be females, and which are all of one and the same size, with the highest average weight (of a group) of the next division or group, comprising salmon of the same size, I found (although there are of course slight differences of shape) an excess of average weight over the summer salmon (June, July, and August) amounting to 990 grams, or 10 to 11 per cent.

That this cannot merely be ascribed to differences of "shape," but to an accumulation of reserve matter will be seen by a determination of the muscles of the pectoral fin of a *Basel* female salmon, made on the 5th April, which show these muscles to weigh 3.06 per cent. of the weight of the entire body (these same muscles in a Dutch salmon of March 18, weighing very nearly the same, viz, 3.03 per cent.), whilst otherwise the weight of these same muscles in eight *Basel* salmon (excepting, however, the strange fish caught August 1, 1879)† varied between 3.34 and

* As higher prices are paid in the Dutch markets for large salmon than for small salmon, while in the Basel market there is no such difference, no mercantile interests can here come into play.

† Could this fish (length 940 millimeters, entire weight 11,130, and weight of ovarium 808 grams) be an individual which was intended for a winter salmon, but which immigrated too late?

3.56 per cent. And still the great increase of the salmon fisheries in Holland during March and April, and near Basel from May to July, shows, without a doubt, that among the July and August salmon there must be many new immigrants, which is also indicated by the differences in the degree of maturity.

TABLE XIV.—*Female winter salmon from the Rhine, near Basel.*

Date.	Length (without tail).	Weight in grams.	Highest average weight of the corresponding group in table.	Differences in grams.
December 10, 1877	875	10, 200	9, 190	1, 010
January 30, 1878	878	11, 200	9, 190	2, 010
November 9, 1879	907	11, 210	10, 233	977
November 16, 1879	870	10, 140	9, 190	950
November 25, 1879	888	10, 880	9, 790	1, 090
March 13, 1880	885	10, 360	9, 790	570
March 20, 1880	884	9, 620	9, 190	430
March 20, 1880	897	10, 090	10, 044	46
April 5, 1880	885	10, 050	9, 190	1, 860
Average difference				994

In other words, the winter salmon and the early spring salmon are fish which, to begin with, have brought a larger *amount of fat* from the *sea* than the summer salmon. They need not, therefore, as *Barfurth* thinks, return to the sea, but their condition permits them to starve half a year longer. In view of these differences, the similarity (as to leanness) of the spawning salmon is very singular, as is (ignoring the rare late-comers) the relative constant difference between the amount of albumen and fat as compared with the greatly varying differences of the summer salmon. The lowest figures correspond to those fish which have already spawned, and which in consequence begin to grow lean very rapidly. I therefore agree with *Barfurth* that a certain degree of emaciation is, from causes regarding which we can as yet hardly venture a supposition, in both sexes a necessary, or at least profitable or favorable, condition of the complete development of the sexual organs, or of the act of copulation. And the different conditions of migration aim at reaching a comparatively normal spawning condition at the right time, and at the same time for all fish, no matter from what different points they have started in the race for life. The fat fish, therefore, as a general rule, immigrate earlier than the lean fish.

As the causes, to which the constantly recurring typical differences of natural phenomena may be traced, become simpler as the statistical data, which show them, become numerically larger, I consider *the different length of the fattening-period, viz, of the sojourn in the sea*, as the simplest cause of the varying quantity of fat found in the immigrating salmon.

The winter salmon are, in my opinion, therefore, fish which *have been in the sea for a longer period of time*, compared with the majority of their future companions in spawning, either—

(1.) By having skipped the entire spawning period by a period of more than one year; or,

(2.) By letting one more years intervene between two spawning periods. Possibly both cases occur.

The fish have thereby become longer than the majority of their future companions in spawning; they consequently belong to the right half of the third curve (showing size), but they have also become fatter, and therefore immigrate earlier, in order to reach their normal spawning condition. The gain in time which they have made is divided into an increasing and a decreasing phase, whereby they again reach the level of the rest.*

There may also be smaller fish, which go through the same course, because during the normal period they had an opportunity to fatten to an extraordinary degree. It is also possible that some fish which, as to age, correspond to the winter salmon,† on account of not having ready access to suitable food, join the later immigrants.

In reviewing this whole question one should not be led astray by differences of shape, which may occasion great differences of weight in fish whose length is the same. I would therefore recommend not only an analysis of the flesh of the body, but more especially the proportion of the muscles of the pectoral fins to the weight of the body, as a standard by which to measure the amount of reserve substance contained in the body.

It will also appear from the above remarks that it would be a mistake to determine the emaciation by two series of data showing the weights of fish at any two periods differing about two months. The influence of great masses of salmon coming in July would disarrange the curve still more, if the new immigrants were not somewhat leaner to begin with. We therefore (possibly) owe the plausible result, in part at least, to the fact that various mistakes neutralize each other. Not till the middle or end of July, when from other causes I must consider the immigration of females into our waters as almost finished, can I pay closer attention to the figures indicating emaciation; in my opinion it is only from that time that the actual change of substance (*Stoffwechsel*) commences.

I have finally to direct attention to a sort of counterpart of the fat winter salmon. In reviewing the six groups (or divisions) of female salmon, each containing fish of equal length, considerable variations

* Some exceptionally lean spring salmon had fallen off very much owing to an invasion of leeches; they had gatherings in various parts of the body, and the rays of the fins had begun to fester. Not every lean spring salmon can, therefore, be adduced as proof against the truth of my view.

† Only those muscles which form the bones of the extremities extend to the basis of the rays of the fins.

must be looked upon as perfectly natural, but in some groups (not till July, however) some individuals attract attention by their exceptionally small weight, whilst there is no difference of length. Such fish, (some of which I myself have seen) occur only in isolated instances, one or two being found in a group, and they differ from the next smallest by 500 to 1,000 grams. We evidently have here extremes not produced by natural causes, but by some extraordinary cause. I have sometimes thought that these fish are possibly the counterparts of the winter salmon—impatient fish, which, after their return to the sea, do not skip the spawning period, but which immigrate as early as the summer of the same year, though their quantity of substance is as yet incomplete. Against this, however, speaks the very small weight of the pectoral fins (3.26 per cent. of the body) in a November salmon which I examined. If, moreover, we take those fish from all groups which differ very considerably from the average weight, and place them in groups, each varying from the other by 100 grams, we find no tendency whatever in these figures to form an independent curve; they are and remain scattered and disconnected figures. I therefore consider it probable, at least for the present, that these are pathological cases—fish which, during an invasion of leeches (much feared in early summer, especially when the water is low), or owing to some disease, have lost some of their substance. Supposing this to be the case, I have excluded these scattered figures from the calculation of the averages. Their number is very small (about 15 among 470).

The emaciation of the Rhine salmon in fresh water, which is really the main point of our entire investigation, has now been viewed by us from two standpoints, viz, as self-consumption, in its relation to the length of the starving condition, and as a yielding of substance for the building up of the ovarium. Both these processes require albumen and fat; both draw albumen and fat from the muscle of the trunk, which in March salmon, and even in winter (December) salmon, shows distinct traces of fatty degeneration. But whilst the self-consumption uses much fat, but very little albumen, as is shown conclusively by a comparison of the spring salmon with the midsummer salmon, the growing demand of the ovarium for substance makes considerable inroads on the albumen of the muscle of the trunk in a progression which is not quite regular, and has the same effect as a wasting disease, no matter whether there is much fat or not. Where, therefore, are we to look for the analogy, and where for the difference of these two processes?

The solution of this problem is, in my opinion, found in the condition of the muscles of the fins and of the head, regarding which I have numerous data, showing weights and quantities of albumen; these muscles but rarely share in the fatty degeneration, and they decrease but little, if any, in weight and albumen. What can be the cause? That it cannot be a so-called "morphological cause" (which, to me, is an entirely vague idea, though some other people may be able to fathom it) is

clearly shown by the circumstance that the muscles of the ventral fins, which most assuredly are not homologous with the muscles of the trunk, form an exception to the rule. The muscles of the ventral fins degenerate in a moderate degree; and, though they show a marked decrease of albumen, it is by no means as striking as that of the muscles of the trunk.

At first sight one would feel inclined to think of the nerves on which the condition of the muscles depends to a large degree. But in vain have I sought for degenerated nervous fibers; and, moreover, how can it be possible that primitive bundles, some of which are greatly and others but little or not at all degenerated, should be found close together, as—considering the very small number of nerve-fibers entering from the spinal marrow—large masses of muscle are supplied by branches of a primitive fiber?

It therefore seems necessary to turn in another direction for the desired explanation. In soaking portions of different muscles of a salmon (which have been carefully weighed), such as those of the pectoral, ventral, dorsal, and anal fins, and those of the tail and the tongue, in equal quantities of water, we find—as the result of numberless experiments—that, *without exception*, the muscle of the trunk produces the extract having *the least color of blood*. Next to it comes the ventral fin, whilst the reddest extract, often possessing a threefold coloring power, is producedfrom the pectoral fin.* The same result is obtained with sea salmon, whose trunk muscle shows no signs of degeneration. It is the expression of the varying wealth of blood-vessels, which is also noticed in preparing fish.

As the fish in question is a starving fish, the blood cannot be considered as a food-giving liquid, but can only come into play in as far as it is of importance for breathing.

Here the accepted axioms of physiology leave us in the lurch. Whenever it was reported that the organs of a famishing animal decreased in varying degrees, these were principally supposed to be differences in the self-consumption of the organs. In view of this, the grand effort of the Rhine salmon—the building-up of its ovarium from the muscle of the trunk, will hardly be considered by any one as an isolated biological curiosity. Essentially analogous occurrences probably take place a thousand times under circumstances which are far more difficult to understand. In my opinion the experience which we have gathered with regard to the Rhine salmon is destined to extend our knowledge of the dependence of the life of the cells on external causes, by adding another fundamental principle, in which, possibly, one of the most important laws of nature as to the formation of portions of the animal body may lie concealed.

There is a period in the life of the cells of active animal tissue in

*The muscle of the skin cannot be considered in this connection, because its fibers contain the coloring matter of blood.

which this tissue decreases in quantity, not only by self-disintegration, but by protoplasm (organized albumen), being transformed to not organized, soluble albumen, which is absorbed by the juices of the body ('liquidation').

The same tissue may to-morrow absorb, under different circumstances, the same substances which it has given up to day, and grow at their expense.

The conditions of *the giving up of albumen* are *insufficient breathing*, insufficient in proportion to the energy displayed in the dividing processes (*Spaltungs-vorgänge*), and, more than anything else, an insufficient supply of oxygen; this supply must not, however, go below a certain minimum for any length of time.* If this is not the case, the decrease continues until the equilibrium has again been restored between the demand of the decreased quantity of tissue and the conditions of breathing.

The conditions of growth and absorption of substances are, amongst the rest, an ample supply of oxygen and the proper evacuation of the products of disintegration.

The substance which is formed is, besides salts containing phosphoric acid, principally albumen, for I have never found *pepton* either in the muscle of the trunk or in the blood of the summer or autumn salmon; whilst I have found in the serum of the blood more globuline than could in any way be supposed to come from the colorless blood-particles. This albumen may play the same part in the organism as the albumen contained in food which is absorbed by the intestines. Wherever the conditions favor disintegration it becomes disintegrated, and wherever the conditions favor new formation it forms new tissue.

The former (disintegration) is more frequent in male salmon, especially late in summer and in autumn, when the products of disintegration (protamine, guanine, sarkine) gather in considerable quantities in the seminal ducts.

The latter (formation), *i. e.*, the economical use of albumen from the muscle of the trunk for building a new organ, is more frequent in female salmon, as their absolutely necessary consumption of albumen is very small.

We, therefore, have here "stock-albumen," as Voit terms it, containing substances which became disintegrated, if there are no organs which quickly absorb them and draw them away from the current of juices. I have always favored the distinction which Voit makes in this respect. It only became open to objection when, more through Voit's pupils than through himself, they became unnecessarily mixed with rude mechanical hypothesis, relative to the "current of juices rushing through the cells," &c. Whenever this "stock-albumen" becomes rapidly disintegrated

*The insufficient evacuation of carbonic acid or of other products may possibly be one of the principal causes of sudden death. Tissues with strongly alkaline reaction, such as the immature testicles of the Rhine salmon, can at certain periods stand an extraordinary loss of blood, which continues for some time as a normal phenomenon.

we cannot tell whether this process takes place in the liver or in the colorless blood-particles. It is not at all necessary that the bulk of it should circulate through the blood, if only it is capable, when required, of being rapidly absorbed by the blood, like the "glycogen" of the liver or the fat of the fatty tissue. However this may be, there is in the body, independent of nutrition, a certain quantity of albumen which, owing to the locality where it is found, becomes quickly disintegrated, unless there are organs which rapidly assimilate and, so to speak, save it. Similar in its course to nutrition is the "liquidation" of a large organ containing plenty of albumen, if this process can be carried on in such a manner as not to affect the vegetative functions of the heart, nerves, and breathing apparatus.

In the salmon, therefore, it is not only the growing sexual glands which derive advantage from "liquidation" of the muscle of the trunk, but even the gristle of the nose grows, large wounds become cicatrized and all the muscles of the fins which are necessary for moderate motion and proper steering decrease hardly at all; they seem to live on substances from the muscle of the trunk. In short, apart from the muscle of the trunk, the fish lives like an animal which is scantily fed. The cause of this is that it has in its body genuine "stock-albumen."

And still we cannot speak of it as of a "reserve substance," for there is in the muscle of the trunk hardly any intermediate tissue. It is the excitable and contractile fibril of the muscle which, from its protoplasm, supplies substance. It is not a falling to pieces of entire elements of tissue and an absorption of their broken remnants, but the fibers of the muscle remain alive. With the exception of a few places (the convex portion of the tail-part of the vertebral column) I have, even in cases where degeneration had far advanced, never found entirely empty muscle fibers. Nor have I ever found in large sea-salmon—even when, by the length of their nose, or by the ovarium, they showed traces of having recently passed through a spawning period—any signs of the new formation of entire muscle fibers. Perhaps not a single fibril is completely assimilated with the muscle of the trunk.

I do not think it has been proved beyond a doubt that the fatty degeneration and the "liquidation" of an organ always go together, even if, according to the weight of the fins, this seems to be the case with the Rhine salmon.

We may well ask here: What is the principal cause which, when the starving period commences, compels the muscle of the trunk to act as a feeder?

I am here reminded of the technical rule laid down by physiologists, that frogs should be fed on meat if the circulation through their various organs was to be clearly demonstrated. What is the faint pulse of sick people, accompanied by serious disturbances of the process of nutrition, but an indication that, insufficiently elastic, owing to the tension of the vessels, but little blood flows into the heart before every pulsation, and

is expelled by contraction, so that the entire quantity of blood requires a longer time to pass through the heart?

I am, therefore, of opinion that when the starving period commences, circulation first of all becomes less energetic, and continues in this course until in some organ or other, owing to insufficient respiration of the tissues, a state of "liquidation" is produced. As soon as vital organs are attacked in this way, death takes place. But if there is a solid organ which does not contain many vessels, but is rich in albumen, and may, comparatively speaking, be easily spared, it serves as a feeder, first of all to the vegetative central organs, and in the second place to the rest of the body, thus making it possible to maintain life. Besides the innate energy of the dividing processes, which is dependent on the temperature, conditions like the ones described above are, in my opinion, mainly instrumental in imparting to animals the greatly varying ability to stand hunger.

Such nutrition, however, must never reach a degree which would again render the energy of circulation normal, for in that case the state of "liquidation" would come to an end, and the food-supplying source would cease.

We thus find in the spring salmon, and more especially interpersed with the thin muscle fibers, rows of fine grains of fat, until in the early part of summer the growth of the ovarium in geometrical progression leads to a positive monthly consumption of substance, the demands of which, in addition to the self-consumption proper, become very urgent. If indications do not deceive, the swelling of the spleen, the extension of its arteries, the filling up of its net-work with blood, are powerful aids in causing the pressure of the blood to sink further, of increasing the state of "liquidation," and extending it to a constantly-growing number of muscle fibers, even such as are in a relatively favorable position with regard to the blood-vessels. At the time, therefore, when the monthly growth of the ovarium has risen from the thousandths to the hundredths per cent. of the weight of the body—from the middle of June till the end of July—we notice that the filling up with grains of fat becomes more intense, some of the fibers becoming almost opaque; and we see those black, shining, jelly-like spleen, resembling large clots of blood, which cause a decreased circulation of blood, less abundant in blood particles.

Meanwhile the ovarium is growing steadily, and the capillary nets of the follicle, numbering 10,000 to 20,000, begin to make such an abundant collateral blood-channel that its influence on the pressure of the blood renders the spleen superfluous. We thus see the spleen gradually diminish again, beginning in August, and remain at its minimum size from September till the spawning period. The ovarium, owing to its changing quantity of blood, is now able to regulate the intensity of the process of "liquidation." This seeming change of the phenomena, however, has this rule in common, that, in some way or other, the pressure of blood

sinks till the consumption of matter and the loss of matter are equalized, still leaving something for self-consumption.

Sometimes, however, circulation sinks very low, like fish which in spring have been entirely sucked out by leeches. Some salmon show shortly before and during the spawning period small and large ulcers, with limber undermined bands and adhesive yellow scabs, at the bottom of which muscles and bones are laid bare. Such ulcers are not only, as in former times, found back of the lower jaw (where they may have been caused by constant rubbing against rocks or stones), but more particularly at the basis of the rays of the fins, at the tail, and sometimes on the operculum. Sometimes an entire ray becomes gangrened and falls off. In other parts of the body, especially on the jaws, there may be seen raised, yellow, opaque spots, void of blood, which are probably the forerunners of the ulcers. Fish in this condition are positively sick, and the epithelium, gradually tearing to shreds, indicating a disturbance of its process of nutrition, may well be compared to the tongue of a patient who is very low with a fever. The flesh of the trunk is entirely opaque, whitish, and full of little grains of fat. Even the heart, which has long remained intact, shows in many cases numberless fibers filled with little grains of fat, and to the naked eye shows a brownish color, whilst the inner layers of its flesh are quite tender.

What a different appearance is presented by fish which have passed the spawning period ten days, or, better still, some weeks (empty female fish, caught at the end of December or in January; but also one specimen from Mr. Glaser's fish-boxes, which certainly had lost its eggs not longer than ten days ago). The skin is again bluish, clear, and shining; the ulcers have become cicatrized or are healing; the flesh is transparent, entirely or nearly free from grains of fat; even the fibers of the heart are beginning to be purified, and in the intestines there is no trace of food. The ovarium contains more or less eggs, which, imbedded in a serous and occasionally somewhat suppurated secretion of the follicle skin, shrivel in the most manifest manner, and become absorbed. It is, therefore, a sort of nutrition, as it were—a little pocket-money for the return voyage. The greatest importance, however, I am inclined to ascribe to the pale, shriveled-up follicle skins. The collateral blood-channels of the ovarium have become closed (by contraction of the vessels). The salmon resembles a patient who, after *Esmarch's* bandage has been placed on his leg, has had that limb amputated. Its blood circulates within narrower limits, therefore with a higher pressure, and supplies a smaller quantity of substance than ever before with oxygen; the circulation again satisfies all demands upon it, and the muscle of the trunk again becomes normal. But the difference of color of the extracts with water, between the greatly reduced muscle of the trunk and the muscles of the fins which have remained intact, has become alarmingly small. Vital organs are now attacked, and what little nutritive matter is furnished by the ovarium is partly consumed by the

convalescent muscle of the trunk. To all appearances hunger, in its most threatening aspect, does not make itself felt *till this time*, and compels the fish to enter upon its return trip. These late travelers, on their return to the sea, often show little knots in the spleen again, sometimes even considerable swellings. We know now what this means; some organic albumen has to be "liquidated."

Mr. Glaser is inclined to consider the period of this return journey as very short (shorter than I have estimated it), because these fish, in their haste, dash against the sand-banks near *Ste in*, and there run aground, which at other times does not occur. We must also remember that nearly the same weight of fin-muscles has to move a much smaller mass of body, and, what is also in its favor, *down* the stream.

As regards the male fish, the spleen, owing to their greater self-consumption, seems to be drawn upon as early as May and June, when not much weight can be attached to the increase of the testicles. During the summer, and up to September, there are many changes; we sometimes find small, and at other times average-sized spleen, with various intermediate sizes, as it seems to me, in some way corresponding to the varying quantity of blood in the sexual glands; but my investigations of this matter are not far enough advanced to lay down any certain rule regarding it. It seems somewhat singular, especially when we compare with it the striking regularity of this change from small to large spleen in the female fish; which regularity remains the same, no matter whether some of the female fish are more belated than others. Could varying conditions of sexual excitement have an influence on the consumption of matter? One thing, however, is certain: in October, generally early in the month, we find as a rule large (and the largest) spleen. All the maximum weights (as high as 0.86 per cent. of the weight of the body, or sixteen times the smallest weight observed in males) belong to this period. During the spawning period the weight of the spleen again decreases gradually.

The maturing of the sexual gland of the male fish does not require as large quantities of albumen and fat as the ovarium of the females, but as far as my experience goes,* the sexual gland needs all the more phosphoric acid salts to form the various substances of the semen which contain phosphorus. Taking the weight of the mature testicles as 5 per cent. of the weight of the body, with 25 per cent. dry substance of 11.3 per cent. phosphoric acid,† we find that the growing testicles must take away from the blood 0.141 per cent. phosphoric acid; a larger quantity than is contained in one-half of the mature ovarium of a female fish of equal size. Why should not the hunger for phosphorus with the male fish produce similar effects as the hunger for albumen with the female?

* *Die spermatozoen einiger Wirbelthiere* (The spermatozoa of some vertebrates), in the Transactions of the Basel Society of Natural History, vol. vi, part 1, p. 147.

† The same work.

This demand can only be met by the "liquidation" of muscle-substance containing phosphorus.

The falling off and the degeneration of the heart of the females described above I have also occasionally noticed in males, but not nearly as frequently. The purification of the skin, however, and especially the disappearance of the little grains of fat from the muscle of the trunk, I have often met with in a more or less advanced stage. One of the fish made an exception from the rule (as has been mentioned before), and had taken food. Though to a less extent, similar conditions may have to be taken into account, as with the females. I am inclined to lay considerable weight, as regards the improvement of the respiration of the tissue, on the reaction and consequent *decrease in the consumption of oxygen and substance*, which certainly follows the strong excitement of the spawning period.* The low temperature of the months of December and January, following close upon the spawning period, may also do its share of the work. It may safely be asserted, moreover, that when the season of extraordinary excitement is over, the blood-vessels of these lean fish have to supply only about two-thirds or even only one-half the original quantity of muscle, and that the demand and supply of oxygen have become nearly equalized.

The proof of the "*liquidation*" *of organs* and the description of the conditions under which this process takes place, which have been furnished by the investigations relative to the Rhine salmon, will, I think, very soon bear fruit on a more extended physiological and pathological field. Many interesting facts are scattered all through the literature of the salmon, but they were disjointed, and there seemed to be no proper connection between them, because the important element of "*liquidation*" was wanting; and because whenever there was a question of the dissolution of dead elements of tissue, the positive *loss of matter* by an organ was erroneously considered identical with a *change of matter*. I will here only remind the reader of the intensification of the disintegration of albumen by phosphorus, as shown by *J. Bauer*,† which fact has been corroborated by the investigations of *O. Fränkel*.‡ *Bauer* attempts an explanation by speaking in a somewhat vague manner of "an equilibrium between organs and juices." *Fränkel* quotes an attempt at an explanation by *L. Traube*, which very correctly lays stress on the difference in

*An observation made by Mr. Glaser, about 15 years ago, shows how high the passions of these fish run during the spawning period. He had placed a trap containing a male fish in the Rhine, directly above Basel, near to a spawning female salmon. A male salmon of medium size, prompted by jealousy, made violent attacks on the fish in the trap, and was caught, the iron prongs piercing his body. But as the trap was old and did not work very well, he succeeded in getting loose. He returned three times, however, and tore himself loose as many times, until a new trap was set, in which he was finally caught, his whole body being torn and bleeding from twenty wounds.

†*Zeitschrift für Biologie*, vii, viii.

‡*Virchow's Archiv.*, lxvii.

the disintegration of living and dead albumen, but only supposes that there is an increased mortification of elements of tissue. How much easier can these and other phenomena be explained, as soon as we know for certain that it is not a question of life or death, but only one of disturbance of the equilibrium of normal conditions of life; and as soon as we take into consideration the circumstance that even organs like the obliquely-striped fibers of the muscle, without losing their excitability, and without—so to speak—making much stir, throw enormous quantities of albumen into the juices delivering them to disintegrating processes, under conditions which can at any time be fulfilled through the system of the vascular nerves? Is it certain that the few milligrams of phosphorus really produce the well-known and extensive fatty degeneration by exercising a direct influence on every fiber and cell of a mass of muscles and glands weighing many kilograms? May not this influence be exercised by means of the system of vascular nerves, and by a radical disturbance of the circulation? And, finally, we should seriously inquire if this same anomaly in the distribution of the blood—caused by a feverish process and in a nervous way affecting the retention of heat in the body—does not also produce the state of liquidation of the muscles, the consequent intensified disintegration of the albumen, the diminished desire for food, and the consumption, which no feeding can check.

These hints will sufficiently explain why I have made the conditions of life of the Rhine salmon the subject of exhaustive investigations. We are here confronted with the strongest and most effectual tendency to starvation known to physiology; owing to the supremacy exercised by the mass of *one* organ over all the rest, we are favored with a clear view of the internal economy of the substances of the animal body, such as we shall rarely find in any of the other animals which are generally made the subjects of such experiments. To find such objects as will aid in solving the different dark problems of life is, in my opinion, the proper aim of comparative biology.