Experiments on the Development and Growth of the Fry of the Salmon from the exclusion of the Ovum to the Age of Seven Months. By Mr JOHN SHAW, Drumlanrig, Dumfriesshire. Communicated by the Author.*

THERE are few subjects which have hitherto afforded more scope for speculative treatment than the natural history of the salmon. From its birth to its mature age its history is involved in a degree of obscurity which can only be removed by an accurate and long-continued series of experiments. The medium in which observations must necessarily be made, the migratory habits of the fish, and the proneness of scientific men to rear systems upon partial and insufficient data, rather than to acknowledge the want of that correct information upon which alone systems can securely rest, all tend to embarrass the question, and discourage the investigator. These are difficulties which alike beset the path of the learned and unlearned; but there is another difficulty which more particularly presses upon the latter, and that is, the scepticism with which his observations are generally regarded by scientific inquirers. This scepticism must obviously be met by increased industry and caution, and by an accumulation of evidence so conclusive as to overbalance the disadvantage of a defective scientific education. In the observations and experiments which form the subject of this paper, I have therefore endeavoured to proceed with that circumspection and exactness, necessary alike to convince the incredulous and to protect myself from the charge of crude observation.

It was objected to the former paper which I contributed to this Journal, that my observations being made upon ova taken from the bed of the Nith, there was not sufficient evidence that these were the ova of the salmon at all, the same streams being accessible to other fish. However well satisfied I myself might be of the accuracy of my observations, I felt that it was desirable to supply this link in the chain of evidence, and I have accordingly repeated my experiments from the moment when the ova are excluded, preserving the skins of the parent fish

* Read before the Royal Society of Edinburgh on 18th December 1837.

that no doubt may exist as to their offspring being the progeny of the true salmon. I have also at stated intervals preserved specimens of the young to exhibit their progress, and to vindicate the opinion advanced in my former paper, that the salmon fry do not migrate the same year they are hatched, but continue in the river for two years after their birth. I may at the same time state, that I still adhere to my former opinion that the parr is the young of the salmon, although the families of the salmon in my possession have not yet reached that age when their identity may be most distinctly determined.

Before proceeding to make the experiments about to be recorded, it was necessary to lay my experimental basins dry, not only for the purpose of removing the young salmon of last season's produce, but also to enable me to fit them up on such a principle as would exclude any possibility of confusion either from the overflowing of the ponds themselves, or from the flooding of the river Nith, on the banks of which they are situated. The plan on which these ponds are constructed is shewn in Plate III. Every precaution has been used not only to exclude error, but to place the young fry in circumstances as nearly resembling the state of nature as was consistent with their preservation.

The ponds, which are three in number, are two feet deep, and thickly embedded with gravel, while they are at the same time supplied with a small stream of spring-water in which the larvæ of insects abound. Pond No. 1 is 25 feet in length by 18 in breadth, and is fed by the stream which debouches into it at the fall F. Pond No. 2 is 22 feet in length by 18 in breadth, and is fed from pond No. 1 at G, where the communication is carefully grated with wire. Pond No. 3 is 50 feet in length by 30 in breadth, and is fed by the stream at F, having no communication with either of the other ponds. The waste water from pond No. 1 is conducted into pond No. 2 through a square wooden pipe covered at the mouth with a wire grating, the bars of which are about one-eighth of an inch apart. The waste water from pond No. 2 is conveyed under ground to the distance of 20 feet in a square wooden pipe grated in the same manner as the former. The waste water from pond No. 3 passes down a square wooden pipe 2 feet deep covered at the top with wire-gauze, and is conveyed under ground in a sma


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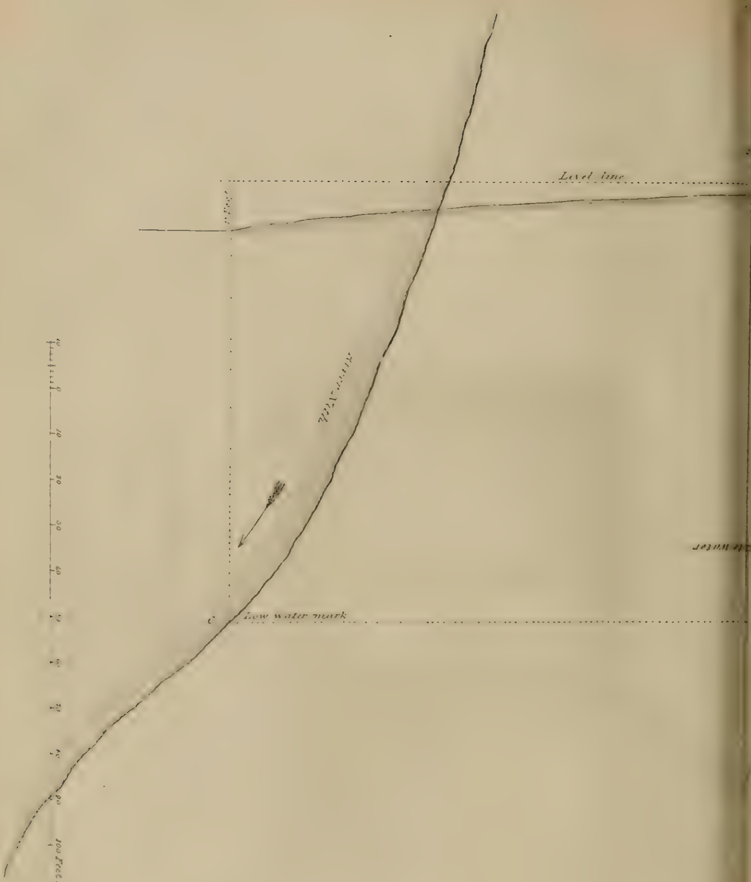
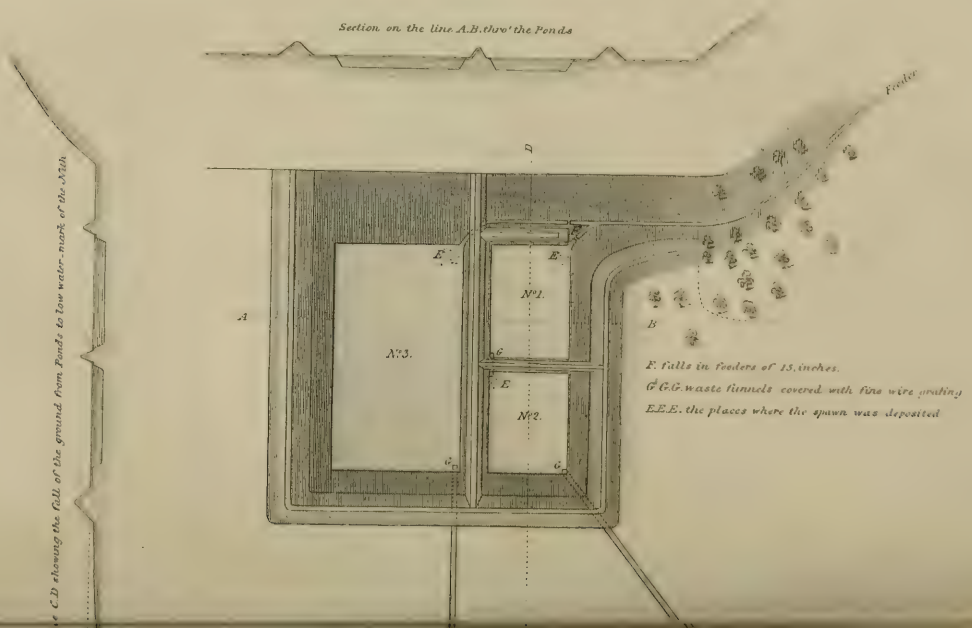


Level line
Low water mark
100 Feet.

TO ILLUSTRATE Mr SHAW'S EXPERIMENTS ON THE OVA OF THE SALMON.




NATURAL HISTORY

covered drain to the distance of 20 feet from the pond. The water of the whole is then left to find its way to the river.

To prevent any communication arising from an accidental overflow of the ponds themselves, I have raised embankments upon the intersecting walks of 2 feet in height, so that the several families of fish which the ponds contain can have no access, direct or indirect, to each other. Where the rivulet is divided for the purpose of supplying the several ponds, I have formed an artificial fall in each stream, of a construction to prevent the fish from ascending one stream and descending another. Finally, where the water discharges itself from the ponds, the channels are so secured by wire-grating that it is as impossible for the young fish to escape as for any other fish to have access to them. The whole occupies an area of nearly 80 feet square.

My experimental basins being prepared, my next object was to secure the fish, the progeny of which were to form the subject of experiment. With the view, therefore, of securing two salmon, male and female, while in the very act of propagating their species, I provided myself with an iron hoop 5 feet in diameter, on which I fixed a net of a pretty large mesh, so constructed as to form a bag 9 feet in length by 5 in width. I then attached the hoop and net to the end of a pole 9 feet long, thus forming a landing-net on a large scale. The weight of the net with its iron hoop being upwards of 7 lb., it instantly sunk to the bottom on being thrown into the water.

Being thus prepared with all the means of carrying my experiment into practice, I proceeded to the river Nith on the 4th January 1837, and readily discovered a pair of adult salmon engaged in depositing their spawn. They were in a situation easily accessible, the water being of such a depth as to admit of my net being employed with certain success. Before proceeding to take the fish, I formed a small trench in the shingle by the edge of the stream, through which I directed a small stream of water from the river 2 inches deep. At the end of this trench, I placed an earthenware basin of considerable size, for the purpose of ultimately receiving the ova. I then, at one and the same instant, enclosed both the fish in the hoop, allowing them to find their way into the bag of the net

by the aid of the stream. In capturing these fish, I considered myself fortunate in securing them by one cast of the net, for, in conducting the experiment of artificial impregnation, it appears to me to be very desirable that the male should be taken, with the female of his own selection, at the very moment when they are mutually engaged in propagating their species. To take a female from one part of the stream and a male from another, might not give the same chance of a successful issue to the experiment. Having drawn the fish ashore, I placed the female, while still alive, in the trench, and pressed from her body a quantity of the ova. I then placed the male in the same situation, pressing from his body a quantity of the milt, which, passing down the stream, thoroughly impregnated the ova. I then transferred the spawn to the basin, and deposited it in a stream connected with a pond previously formed for its reception, which, however, I have not considered it necessary to represent in the accompanying plan. The temperature of this stream was 39°, of the river from which the salmon were taken 33°, and of the atmosphere 36°. The skins of the parent salmon are now in my possession.

On examining the ova on the 23d of February (fifty days after impregnation), I found the embryo fish distinctly visible to the naked eye, and even exhibiting some symptoms of vitality by moving feebly in the egg. The temperature of the stream was at this time 36°, and of the atmosphere 38°. On the 28th of April (114 days after impregnation) I found the young salmon excluded from the egg, which was not the case when I visited them on the previous day. The temperature of the stream was then 44°. On its first exclusion, the little fish has a very peculiar aspect. The head is large in proportion to the body, the whole fish measuring $\frac{5}{8}$ths of an inch in length, and of a pale blue or peach-blossom colour. The bag, which at this early age is appended to the upper part of the belly, presents a very singular appearance. It is of a conical shape, the base being attached to the fish. It measures about $\frac{2}{8}$ths of an inch in length, is of a beautiful transparent red colour, very much resembling a light red currant, and is easily distinguished at the bottom of the water, even when the fish itself can with difficulty be observed. A slightly indented fin or fringe re-

sembling the tail of the tadpole extends from the dorsal and anal fins to the termination of the tail. The ova, which, for some time previous to being hatched, had been almost daily in my hand for inspection, did not appear to suffer at all from being handled. When I had occasion to inspect the ovum, I placed it in the hollow of my hand, covered with a few drops of water, where it frequently remained a considerable time without suffering any apparent injury. The embryo, however, while in this situation, shewed an increased degree of activity by repeatedly turning itself in the egg, an action probably produced by the increase of temperature arising from the warmth of the hand.

On the 24th of May (twenty-seven days after being hatched) the young fish had consumed the yolk, but in a few days afterwards the whole of this family, with the exception of one individual, was found dead at the bottom of the pond, a circumstance which has occurred more than once in the course of my experiments, arising, I apprehend, from a deposition of mud, the same result having been more than once produced, when the pond had not been sufficiently imbedded with gravel.

To shew the effect of increased temperature in hastening the development of the infant fish, I may relate an experiment which I made upon a few of the same ova, from which this family proceeded. On the 20th of April (106 days after impregnation) finding the ova alluded to unhatched, and the temperature of the stream being 41°, I took four of them and placed them in a tumbler of water, covering the bottom with fine gravel, in which I embedded the ova. I then suspended the tumbler from the top of my bed-room window, above which I placed a large earthen-ware jar, with a small spiggot inserted in its side, from which I easily directed a stream of pure spring water into the tumbler. The waste-water was carried out at the window along a wooden channel fitted up for the purpose. As there was no fire in the bed-room, and the window facing the north, the temperature did not range very high, 47° being the average, while the average temperature of the water in the tumbler was 45°. During the night, however, the temperature would be very considerably increased, and the consequence was, the young fish in the tumbler were hatched in thirty-six hours,

while those remaining in the stream did not hatch till the 28th of April, a difference of nearly seven days. At this stage the little fish are so very transparent, that their vital organs are distinctly visible, and when placed immediately under the eye of the observer they present a very interesting appearance. The pectoral fin is continually in rapid motion, even when the fish itself is otherwise in a state of perfect repose. They also begin to manifest an increasing desire to escape observation, a principle wisely implanted in them for their better security, during so feeble and helpless a stage. On the 24th of May (thirty-nine days after their birth) the fish in the tumbler were completely divested of the yolk, and the characteristic bars of the parr had become visible. At this time they measured nearly one inch in length and appeared to be in perfect health, but fearing that after the yolk was consumed, I should be unable to supply them with appropriate food, I returned them to the pond from which I had taken them on the 20th of April, where they perished with the rest of the family.

This last experiment proves, that by placing the ova under a temporary stream of water in the house, the development of the young may be materially accelerated, while it also shews that they may be kept alive for a considerable time afterwards; at all events, until the yolk, which I presume to be their sole support at this period, is totally consumed. I mention this fact, because it has been stated by a recent author on the subject, that their life in a state of confinement could not be prolonged beyond a period of ten days.

The next experiment, the circumstances of which I have to relate, has been attended with more success than those which I had previously made. The process of taking the adult fish, and all the circumstances attending the impregnation, were entirely similar in this case to that already narrated.

That the pedigree of the young fish may not be called in question, I have preserved the skins of the parents. The weight of the male when taken was 16 lb., and of the female 8 lb.

The spawn was impregnated and deposited in the stream immediately below the fall pond No. 1. E, on the 27th of January 1837; the temperature of the water in the stream being 40°, and that of the water in the river 36°. On the 21st

of March (54 days after impregnation) the embryo fish was visible to the naked eye. On the 7th of May (101 days after impregnation) the little fish had burst the shell, and were to be found amongst the shingle of the stream. The temperature of the water was at the time 43°, and of the atmosphere 45°. Fig. 1* is an accurate representation of the young fish ten days old, taken from the pond on the 16th of May. A considerable portion of the ovum is still attached to the abdomen. Fig. 2. is a specimen, forty-eight days old, taken from the pond on the 24th of June. Its symmetry is yet imperfectly developed. Fig. 3. represents the fish of two months' old, taken from the pond on the 7th of July. Its shape is now materially improved, and it presents in miniature the proportions of a mature fish. Fig. 4. is a specimen at the age of four

Fig. 1.

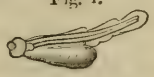


Fig. 2.

Fig. 3.

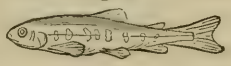


Fig. 4.

months, taken from the pond on the 7th of September. The characteristic marks of the parr are now distinctly visible. The fish has attained a fine symmetry, and the features of the parents may almost be discovered in their child. Fig. 5. is a

Fig. 5.

* In reference to these illustrations, it may be stated, that the drawings having been made from the specimens after they had been for a considerable time preserved in spirits, they do not possess all the plumpness and elegance of contour which distinguish the fish in their natural state. For all general purposes, however, I believe they will be found sufficiently exact.

specimen of six months' old, taken from the pond on the 7th of November. Its shape indicates a considerable accession of strength, and its approximation to the features of the parent fish becomes more striking. The gill-cover, on examination, will be found exactly similar in shape to the full-grown salmon. On comparing it with the parr in the river, of a corresponding age, no marked difference can be observed. The whole of this family, as well as another family in pond No. 3, are in a state of perfect health, and feed freely on small worms, gentles, &c., with which I have continued to supply them during the summer.* As nearly as I can judge, the number of the two families amounts to about 100. Pond No. 2. is occupied with another family of the salmon, also produced by artificial impregnation. The history of this family will form the subject of another paper, after I have had an opportunity of verifying the experiment by repetition.

On comparing the parr taken from the river at a corresponding period with those taken from the pond, I found that they were uniformly of a darker colour, arising no doubt from the fish in the ponds having been reared in pure spring-water, while the parr in the river have existed ever since their birth in water of a more impure quality. The surface of their bodies has, therefore, naturally acquired a duskier tinge, a result perfectly well known to all practical anglers who have angled in the various rivers in this country. The water of the pond, in consequence of being supplied from a spring at no considerable distance, is of a more equable temperature throughout the year than that of the river. The temperature of the former during the winter is seldom below 40°, or in the summer above 60°, while the temperature of the river, which is much more under the influence of the atmosphere, is more variable, and reaches to greater extremes both of heat and cold. I apprehend, however, that the mean temperature may not materially differ; and, while I freely admit that the difference may have

* The circumstances attending the development and growth of the family in Pond No. 3 so exactly correspond with those of the preceding family, that their history would only be a repetition of the former. I may, however, state, that the individuals in Pond No. 3 are considerably larger than those in Pond No. 1, the difference at the age of six months amounting to an inch.

some influence on the progressive growth of the fish by which they are respectively inhabited, I still believe the final result will prove almost the same.

Before concluding this paper, it may not be altogether out of place to detail the particulars of a few simple experiments made to elucidate a very extraordinary phenomenon connected with this fish, namely, the fact of its changing colour under certain circumstances.* In the course of my visits to the experimental pond, which were as frequent as other duties would permit, I had often observed, that, while the little fish remained stationary in any particular part of the pond, they were always found to be of a colour corresponding to the colour of the bottom, and when they removed to any other part of a different colour, that, after resting on it for a few minutes, they gradually assumed a corresponding hue. Wishing, therefore, to prove the fact of this assimilation by actual experiment, I procured two large earthenware basins, one nearly white inside, the other nearly black. I then placed a living fish in each, while at the same time I kept up a constant supply of fresh water in them. The fishes were of their natural colour when first placed in the basins; but they had not remained there more than four minutes till each had gradually assumed a colour nearly approaching to that of the respective basins in which they were placed. I next took the fish out of the white basin and placed it in the black one, and the fish which was in the black basin I placed in the white, and the results were uniformly the same,—the fishes changing according to the colour of the surface over which they were placed. I next placed both fishes in one basin, when the contrast for a short time was exceedingly striking. With the view of ascertaining what effect the light had in producing this extraordinary change, I next allowed the fish to remain in the white basin so long as effectually to acquire the light tint, when I excluded the light from them altogether by covering the basin with a thick mat, and on removing it a few minutes afterwards, I found the fish were

* Since these observations on the changing colour of the fish were put in types, my attention has been directed to an interesting paper on the same subject in reference to the minnow, stickleback, and perch, contributed by Dr Stark to the Number of this Journal for October 1830.

again changed to a dark colour, which gradually disappeared on exposure to the light. The change of colour is produced alike under a bright or cloudy sky. This singular phenomenon, with which I have only now become acquainted, adds another to the many beautiful provisions Nature has made for the safety and protection of her creatures. The cause, however, is a problem I make no pretensions to solve.

To recur to the subject of the salmon's growth, I trust I have now succeeded, by a process of demonstration the most exact that could be attained, in establishing the fact, that the *young salmon does not proceed to the sea the same year in which it is hatched.* Although I may not yet have succeeded in convincing naturalists of the identity of the parr and the young salmon, it may yet be conceded that my researches have not been altogether unproductive of benefit, either in a scientific or economic point of view, if I have corrected an erroneous opinion as to the growth of the latter, entertained both by the legislator and the naturalist. The belief that the salmon migrates the same year it is hatched, has created an indiscriminate slaughter of that fish, at an age when it especially requires the protection of the Legislature. There is no fish in our rivers that takes the fly more readily, and every little tyro who can cast his angle on the stream, can reckon pretty confidently on killing eight or ten dozen per day. Where a salmon river, therefore, runs through a populous country, the destruction of the fry from this cause alone is incalculably great. It is true the Legislature has made provision for protecting the young salmon for one month, viz. during the brief period it remains in the river after assuming the migratory dress, but for the two first years of its existence it is at present entirely unprotected.

Before concluding, I may advert to the perplexing circumstance of the apparent maturity of the sexual organs of the male, and the immaturity of those of the female parr. In my former paper in this Journal I have stated as follows:—

"That the female parr does not spawn is undeniable; and although the male parr of eighteen months old is to be found in the river, with the milt flowing from it in abundance, all the winter round till about the end of February, yet no instance has fallen under my observation of the roe in any female of the same age, or indeed of any age, having advanced to similar ma-

turity. The female parr may be found in the river in autumn, in nearly equal numbers to the male, but the roe found in it has not the most distant appearance of approaching to maturity. I have also taken it at times during the whole winter, when the weather was mild, and still the roe had no appearance of advancing; and even up to the period of their migration, it is to be found with the roe in the same immature state."

The apparent maturity of the male is a circumstance which cannot be reconciled with any of the existing theories regarding the parr; and it is also, I confess, a difficulty not easily reconciled with the opinion I entertain as to its being the young of the salmon. I trust that I shall not invalidate my statement of observed facts, if I venture to suggest a hypothesis upon which a speculative solution of the difficulty may be attempted. In the case of the hive-bee, we see a vast preponderance of males in the economy of the hive. The queen is productive to an extraordinary extent. She receives the conjugal embraces of all the males in the community, to enable her to perpetuate the race, and send forth infant colonies to compensate for the annual destruction of the species. The roe of the female salmon is prodigiously abundant; and when it is considered that she spawns in streams where the milt of the male may be often carried down without properly performing the function of impregnation; when it is considered, besides, that the male parr is found upon these streams with the milt flowing from him in abundance, have we not some ground for suspecting that the female salmon, like the queen-bee, has the aid of a plurality of males in propagating her species? I know it may be said, that these parr attend the female for a more exceptionable purpose, viz. that of devouring the ova which descend with the stream, and there is no doubt they do so to a very considerable extent; still, it is not beyond the bounds of possibility, that the gratification of two appetites may be subserved at the same time, and that they may be as instrumental in perpetuating their species as they obviously are in destroying it.

To conclude, I feel that my paper will be liable to many objections in a scientific point of view; but, as I make no pretension to scientific attainment, I am entitled to the indulgence of scientific men. I claim only to be considered a careful practical observer, and an honest inquirer after truth, possessing

facilities of observation peculiarly advantageous, and a disposition to take advantage of these facilities to advance the knowledge of this interesting subject. For a number of years I have resided in the immediate neighbourhood of some of the best spawning streams of the river Nith, and during the spawning season I have devoted more attention to the operations of the salmon than most men under any circumstances have an opportunity of doing. Finally, I may state, that I shall continue to take specimens of the young salmon from my ponds, at stated periods, until they assume their migratory dress, when I shall embody my observations in another paper on the subject.

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1. *On the Erratic Blocks of the Jura.* By M. Agassiz.—2. *On the Production of Crystals of Insoluble Substances by Artificial Means.* By M. Gaudin.—3. *On the Operation of the Earths in the process of Vegetation.*—4. *On the Algæ which communicated a Red Colour to the Waters of some Salt Marshes.* By M. F. Dunal.

1. *On the Erratic Blocks of the Jura.* By M. Agassiz.

Last year I spent several months in the neighbourhood of the Alps, for the purpose of studying the glaciers, and of examining the observations of MM. Venetz and Charpentier on the great *moraines*, which are found at distances more or less considerable from the existing glaciers; and I have convinced myself of the accuracy of the facts adduced by these observers.

I have not been less struck by the polished appearance presented by the rocks on which the glaciers have moved, an appearance which is still to be remarked in all the valleys, whose flanks are covered by ancient *moraines*, at whatever distance they may occur from the existing glaciers. Thus the flanks of the valley of the Rhone are entirely polished, even to the banks of the lake of Geneva, more than a day's journey from the glaciers, wherever the rock has been sufficiently hard to withstand the action of the weather. At the sight of this phenomenon, evidently produced by the glaciers which extended to the plains of Switzerland, and which, when they retired,