ample caught at St. Andrews was a mass consisting of a number of herrings, "small" whitings, and haddocks.

EXPLANATION OF PLATE XIII.

Fig. 1. Mature ovum of *Callionymus lyra*, L., somewhat darkly shaded, and slightly altered (from keeping) inferiorly. Magnified.
Fig. 2. Honeycomb-like arrangement of the surface of the same. More highly magnified.
Fig. 3. Immature egg of the same from the ovary. Magnified.
Fig. 4. Section of an immature ovum in the ovary. The areolated superficial layer of the zona radiata presents a confused appearance externally, from collapse in mounting.
Fig. 5. Young example of *Staurocephalus Siberti*, n. sp. The eyes are absent in this example. Enlarged.
Fig. 6. Dental apparatus of the foregoing. × 90 diam.
Fig. 7. Dorsal bristle of the same. × 350 diam.
Fig. 8. Ventral bristle. × 350 diam.
Fig. 9. Stem of *Tubularia indivisa* with crustacean nests (*a*,*a*) and filamentous processes (*b*, *b*) attached to the chitinous periderm. About natural size.
Fig. 10. Structures resembling ova attached to a fragment of willow. Slightly enlarged.

XLVIII.—*On the Nest and Development of* Gastrosteus spinachia *at the St. Andrews Marine Laboratory.* By Edward E. Prince.

[Plate XIV.]

A communication to the Biological Section of the British Association at its recent meeting embodied certain observations made during the past summer at the St. Andrews Marine Laboratory, and of this the present paper is an amplification. *Gastrosteus spinachia*, amongst the smaller Teleosteans occurring upon our coasts, is a very common though a highly interesting form. Various authors, Kupfer, Ransom, Möbius, and others, have treated of this or the allied freshwater species; but the notices of the nidification, development, &c. of the marine form are very fragmentary and incomplete.

During the summer of 1885 a large number of the nests of the fifteen-spined stickleback have been examined in the St. Andrews laboratory; the process of building has been watched and the early stages of development studied.

Towards the latter end of April and during the months of May and June these nests may be found in sheltered rock-pools, between tide-limits, and generally some distance from low-water mark, so that, as Dr. Day observes, "they may be left uncovered for two or three hours at a time."* They

* Hist. of Brit. Fishes, p. 248.

occur most frequently amongst sea-weeds fringing tidal pools, and of such marginal weeds they are constructed. Prof. Möbius states * that the nests vary from 2 to 3 inches (5 to 8 centims.) in diameter; but these dimensions are often exceeded, the size being very variable and depending on (1) the character of the materials employed, and (2) the number of fishes depositing their ova in a particular nest. It is remarkable that the eggs of more than one female may be deposited in a single nest. This actually took place in the tanks of the laboratory—a female taking possession of an old nest, which contained advanced ova, and upon completing oviposition in the lower part of the nest, the male immediately surrounded that portion with binding threads. That the number of ova in one nest is often greater than a single female produces has been noticed by many observers; and Couch, struck by their disproportionate bulk, said that it was "only to be explained by the well-known fact that the ova of fishes generally obtain an increase of bulk by the absorption of water after exclusion"†; but the enlargement of non-pelagic eggs with dense capsules is not sufficient to account for the phenomenon in question, and the explanation is to be found in the plurality of females resorting to a particular nest. The male fish, which is the nest-builder, often selects a growing mass of Fucus-fronds, projecting 8 or 10 inches from the rock, and having a diameter of 5 or 6 inches in the widest part (Pl. XIV. fig. 5). A bunch of more minute Algæ, e. g. *Ceramium*, *Corallina*, &c., may be chosen, and the nest assumes a less cylindrical and more spherical form, measuring from 3 to 5 inches in diameter. In the former case little labour is required in building, the male merely binding the fronds by delicate circumscribing threads, which pass round transversely to the long axis of the mass (Pl. XIV. fig. 5, *a*, *a*). In the latter case, in which softer and less coarse materials are used, much labour is involved, the growing tuft forming merely the basis upon which the gathered fragments of Algæ, *Ulva*, *Corallina officinalis*, Hydrozoa, &c. are woven; this heterogeneous collection of dead fragments being intermingled with the fronds of the living plant and secured by tenacious threads, so that a somewhat compact mass is formed (Pl. XIV. fig. 5). The nest is pendulous and, being firmly anchored, is swayed about by the movements of the tide. So compactly are the materials interwoven that it is often difficult to tear them asunder, though they are always so disposed as to leave interspaces which are enlarged into more capacious chambers by the

* *Vide* Note in Aug. part (1885) of this Journal, p. 153.

† Couch, Hist. of Fishes of Brit. Islands, vol. iii. p. 182.

motions of the fish, the snout being introduced and worked about until pocket-like cavities are formed, or the creature, as often happens, passes and repasses through the cavities with similar results. The thread-like material which binds the nest is a remarkable product. It is secreted by the male, is colourless, tenacious, of the consistency of mucilage when freshly extruded, and exhibits a delicate blue opalescence which disappears in two or three days, leaving the threads of a transparent grey or dirty-white colour. According to Möbius it is nitrogenous, as is shown by treating with acids and alkalies, and evidently a form of mucin peculiarly modified. Like normal mucin it is gelatinous and viscid in water, turning white like tallow on immersion in spirit. Carmine stains it deeply.

On examining the male at the breeding-season, the kidneys are seen to be considerably swollen, the enlargement being especially noticeable posteriorly (fig. 1 A). Sections of the kidneys reveal an altered condition of the sinuous tubules (fig. 1 A, *b*), the conical epithelial cells of which are swollen at their free ends and indefinite in outline. The nucleus of each cell is slightly displaced and occupies a more terminal position than in the normal condition. These epithelial cells are active in secreting the material used in constructing the nest. They perform the function, indeed, of cell-glands, and their secretion is carried by the uriniferous tubes to the outer ventral border of each kidney, where a large duct passes longitudinally. In cross section the ureters (Pl. XIV. fig. 1 A, *a*, *a*) are oval, and their capacity is very great at this time, the walls being of dense fibrous tissue lined with pavement epithelium. Both ureters emerge from the renal mass near the posterior end and, descending in a forward direction, become applied to the wall of the so-called urinary bladder, which at this point is somewhat attenuated, and, passing anteriorly, they open obliquely from without inwards into the bladder. This structure, it is unnecessary to say, is not morphologically connected with the urinary receptacle of higher Vertebrates, the lengthened course of the ureters, of which it is simply a dilated common portion, being due to its extraordinary development in the male stickleback. In a fish $5\frac{1}{4}$ inches in length it is about an inch long, and at its widest part $\frac{1}{5}$ inch in diameter. Situated on the right side of the abdominal cavity, immediately below the swim-bladder in the post-hepatic region, it has the form of a capacious pyriform sac, ending blindly anteriorly, and diminishing in circumference as it passes backwards (Pl. XIV. fig. 6, *a*). Before terminating posteriorly it describes a double curve,

crossing over the intestine from the right to the left side (Pl. XIV. fig. 6, *b*), and after a short parallel course passing on the ventral side of the intestine to the right side again (Pl. XIV. fig. 6, *c*), debouching behind the genital pore (Pl. XIV. fig. 6, *d*) into a urinogenital sinus, forming the posterior portion of a cloacal depression (Pl. XIV. fig. 6, *e*), into which also the anus opens (Pl. XIV. fig. 6, *f*). The wall of the bladder consists of two layers, an internal epithelium (Pl. XIV. fig. 1 B, *a*), which is readily detached, and a dense external connective layer (Pl. XIV. fig. 1 B, *b*), which thins out as the bladder enlarges anteriorly. Traces of an intermediate muscular layer appear posteriorly where the walls are extraordinarily thickened. The descending ureters (Pl. XIV. fig. 1 B, *c c*) approach opposite sides of the bladder, that on the left proceeding obliquely below the common duct of the *vasa deferentia*, and passing forward and merging in the walls of the bladder on the left side. This union is shown in the same transverse section which shows the union of the *vas deferens* of the left testis with that of the right. The course of the right ureter is shorter and more direct, as the bladder lies on that side of the abdominal cavity at this point. It coalesces with the right wall of the bladder precisely opposite the left ureter. As the bladder descends to cross the intestine inferiorly it twists, so that the left ureter is brought to the ventral side and the right ureter ascends to the dorsal side of the cervix of the bladder. Both return to the lateral position as the bladder crosses the intestine. The intestine now curves to the right, and the relations of the ureters become reversed, the right being below and the left rising to the dorsal side of the bladder. They increase rapidly in capacity, showing in cross section an extremely elliptical cavity, and as the bladder enlarges they pass obliquely into its chamber, their walls being continuous with the external layer of the bladder. Along this tortuous course the viscid secretion of the renal tubules reaches the bladder, where it is stored up. When first formed the secretion is simply a plastic jelly; but a fibrillar structure appears to rapidly develop in it. Indeed this appearance is assumed while the secretion is contained in the ureters. The epithelial cells of the urinary canals exert so actively the secreting function that the bladder becomes much distended by the accumulating mucus, and at length it flows slowly to the urinary aperture, where it emerges as a tenacious elastic thread which readily adheres to any external object on contact. It can hardly be doubted that this secretion can be extruded at pleasure, the walls of the bladder assisted by the abdominal

parietes being sufficient to effect this; but it is produced so abundantly that it also often appears to ooze out involuntarily. Male fishes may often be seen with a glistening, pendulous, conoid mass hanging from the urinary aperture, and increasing in size until it becomes detached. Such flask-shaped masses of mucus occur frequently in tanks where these fishes are confined and no opportunity is afforded for nest-building. When, however, an appropriate mass of sea-weeds has been selected by the male, the fish has merely to approach closely, so that the protruding mucus may adhere to a projecting frond, and by passing and repassing round the mass the weaving operation is accomplished *. Occasionally a rapid ejaculatory movement is observed, and it is interesting to note that the threads are not carelessly superposed, except when necessary for increasing the density of the nest, but are crossed at an angle by the varying movements of the fish, so that rhomboidal spaces are enclosed and a regular reticulum is thus produced (Pl. XIV. fig. 5).

Often the tightly-drawn thread snaps asunder, though its tenacity is extreme; the fibres then curl up and form a terminal pellet, many of which occur on the surface of the nest. As before remarked, the mucus is not merely a semi-solid plasm, but assumes a funicular character while in the ureters. If one of the cords binding a nest together be examined it will be found to consist of several strands, the cord itself measuring from ·0046 inch to ·0051 inch in diameter, and the constituent threads from ·0008 inch to ·00092 inch. These smaller threads again consist of fine homogeneous filaments, which adhere in parallel order. The parallel arrangement of the ultimate fibrils is very striking and quite characteristic (Pl. XIV. fig. 4).

On the completion of the nest the female deposits the ova in the various chambers (Pl. XIV. fig. 5, *b b*). The ovum is disproportionately large, viz. ·085 inch in diameter, rarely spheroidal, the form being generally an ellipsoid. The capsule does not harden for several hours, its soft tenacious nature, assisted by the ovarian fluid, causing the ova to adhere strongly together. Indeed, after being separated, these ova, when brought into contact again within a few hours, immediately cling firmly to each other. As just

* The interesting behaviour of the male fish at this time has been described by many observers. His solicitude for the safety of the ova, and especially for the young when hatched, is very remarkable: *vide* Ransom, this journal, vol. xvi. 1865, p. 449; also G. J. Romanes, 'Animal Intelligence,' pp. 243–245.

observed, this tenacity is increased by the fluid secreted by the ovary, which slowly hardens when exposed to sea-water, and the ova are bound strongly in irregular masses. They cannot be separated save by exerting some force, and distinct facets or scars upon the capsule mark the points of attachment to neighbouring ova. Small spaces are left between adjacent ova, and the mass thus possesses a porous or spongy character, a feature of great consequence, to which attention was first drawn by Prof. M'Intosh in the June part of this journal. In describing the ova of *Cottus bubalis* Dr. M'Intosh said, "All adhered firmly together, yet leaving a series of cavities, so that the whole mass, as in *Cyclopterus*, imbibes and retains water, a provision of importance in the case of eggs deposited near low-water mark" *. When newly extruded the ova exhibit a delicate pale-green hue, which, however, soon gives place to the characteristic translucent amber tint. The capsule is hyaline, very dense, and resistent, the thickness being ·0013 inch, and it is separable into lamellæ. In microscopic section from twenty-five to thirty strata can be distinguished, and upon roughly tearing the capsule the successive lamellæ are readily seen (Pl. XIV. fig. 2). The capsule is minutely punctured, the pits being arranged in parallel rows (Pl. XIV. fig. 2). The micropyle is very distinct, and exhibits the usual funnel-like form, bold striæ radiating from the external aperture and giving it a stellate outline when viewed from above. A large mass of pale yellow oil-globules are aggregated at the vegetative pole and maintain usually a position in the segment opposite the germinal pole. About two hours after fertilization the protoplasmic cap is formed, and cleavage proceeds in the usual manner, the 16-cell stage being completed about the twelfth hour. The morula is reached at the thirtieth hour, and the periblast is then boldly marked, though no nuclei are apparent. In cross section the usual triangular form of the periblast is seen. The disk occupies the under side of the deutoplasmic globe; but if the ovum be shifted so that the disk becomes uppermost, it occasionally remains in that position, or, as is usual, regains its normal position slowly, and apparently with difficulty, the oil-globules having little power to "right" the disk. Delicate filaments, often very numerous, connect the mass of globules with the under surface of the disk. Similar pseudopodial threads were noted in *Tinca* by E. van Beneden, and in *Gastrosteus aculeatus* and *G. pungitius* by Ransom.

* Ann. & Mag. Nat. Hist. June 1885, p. 433.

The course of development is very slow as compared with pelagic ova. It was not until the fourth day that nuclei became visible in the periblast, and the corneous layer differentiated from the "lower layer" cells. On the sixth day the marginal rim is defined and the embryonic scutum indicated, the embryonic thickening being also apparent about noon on that day, by which time the blastoderm invests barely one third of the yelk. By the eighth day two thirds of the yelk-surface are enveloped, and the blastoderm is somewhat depressed. The portion of the yelk-surface not yet invested is dotted (with some approach to regularity) with nuclei. Round each nucleus, which is multinucleolate, protoplasm gathers and sends out radiating pseudopodia. Large cells also occur and refringent particles are abundant. Meanwhile the cephalic portion of the embryo is increasing in thickness, so that the keel prominently projects on the ventral blastodermic surface; the optic vesicles are rudely indicated, and the neurochord is differentiated, growing down as the notochord appears; and before the close of the eighth day the mesoblastic plates are well defined. The blastoderm, external to the embryo, assumes a striking appearance, as clear vesicles can be discerned scattered numerously over it. These nuclei, possibly periblastic, have a rounded outline and exhibit several nucleoli. Epiboly continues during these changes, and on the twelfth day the closure of the blastopore is effected. Many of the nuclei just noted now approach each other and coalesce. Segmentation of the embryonic trunk proceeds rapidly, and on this day twelve protovertebræ are marked off. On the following day (the thirteenth) four more are segmented, the primitive optic vesicles are pushed in, and the lenses developed; the otocysts also appear; the nasal pits are distinguishable and the cranial divisions are rudely marked. By the fourteenth day the embryo has appreciably lengthened; Kupfer's vesicle (which appears just before the closure of the blastopore, and attains its maximum shortly after) still persists, though reduced in size; the cranial region is greatly advanced, an enteric strand of cells is being aggregated in the mid-ventral region, and nineteen protovertebræ can be counted. A pectoral swelling is visible, indicating the growing heart. This organ rapidly develops, and by the seventeenth day assumes its characteristic campanulate shape. By the dehiscence of the yelk and the splanchnic mesoblast of the embryo a chamber is formed round the heart. At this time the caudal end of the young becomes free, the embryonic fin passing as a median membrane along the dorsum round the termination of the tail, along the ventral ridge, to the anal

area. The eyes, in which the lenses are now fully formed, are faintly pigmented with black. Nuclei still persist over the blastoderm, probably periblastic, but they are much reduced in number. Before the close of the seventeenth day the heart pulsates, though slowly and irregularly; more rapidly, however, on the eighteenth, though no hæmal fluid is as yet visible.

On the nineteenth day a distinct circulation is active. The formation of circulatory channels on the yelk-surface is very readily seen, and coincides with Ryder's description of the embryo of *Apeltes* *. The venous end of the heart, as in all Teleosteans, is applied to the yelk-surface, and by an excavation in the latter a capacious sinus is formed, in which corpuscles are seen vibrating to and fro, with the cardiac pulsations, before a circulation has commenced. Whether these primitive corpuscles originate in the periblast was not determined; but it certainly is the case that periblast-cells are detached and pass with the hæmal fluid into the heart when the circulation is established. This accords with Ryder's contention (in common with Hoffman, C. Vogt, and others) that the blood is a derivative from the periblast.

The vascular trunks, ramifying over the vitellus, appear to be simple lacunæ hollowed out of the yelk-cortex. In addition to the circulation of the embryonic trunk proper, the subnotochordal, arterial, and the cardinal (venous) trunks (which extend no further than the root of the tail at this stage), there are a subintestinal vein, breaking up apparently in the liver, and two large vitelline vessels. Of the last-named, one emerges behind the heart and the other in the region of the hind gut, the alimentary canal as yet ending blindly. These two capacious vitelline trunks unite in the distal portion of the yelk and return by a common large vein, which is joined by numerous lesser trunks, until it reaches the pectoral region, where it pours its volume into the sinus communicating with the heart.

A complex network of blood-vessels, or, rather, of sinuous lacunæ, covers the deutoplasmic globe, and the early approach of the hatching stage is indicated. On the nineteenth day, indeed, the embryo is very restless, the tail being spasmodically flexed and straightened, and vigorous side-to-side movements are executed. The pigment of the eyes is more dense, though the trunk is comparatively free from pigment, a few non-stellate black spots merely occurring on the dorsum. The development of the liver and alimentary canal agrees with

* U.S. Fish Comm. Report, 1882, p. 543.

that of Teleosteans in general. The swim-bladder can be made out immediately beneath the notochord; but no anal or urinogenital structures can be clearly distinguished. By the twentieth day the heart has lost its simple tubular structure, and, as a thin-walled sac, is flexed upon itself; and on the twenty-first day the circulation is in vigorous action, a great volume of corpuscles surging through the yelk-trunks.

It is not proposed to make reference to the serial microscopic sections of embryos which were prepared during these observations, as space will not permit, and the preparations have not yet been completely worked out in the laboratory. It must suffice in this brief survey of the early stages of *Gastrosteus spinachia* to note that the embryos emerge at various dates from the twenty-fifth to the fortieth days after fertilization—this variation in series of ova deposited at the same date being due to their unequal rate of development, the more central ova being longer, and the external ova being more rapid in reaching maturity. The newly-hatched young are soon richly supplied with pigment, bright yellow spots being scattered over the surface of the trunk, especially the dorsum, and elaborate stellate black pigment-spots occurring on the dorsal and lateral regions. They are very vigorous and active, contrasting greatly with the frail embryos of our common food-fishes, whose ova are pelagic.

It may be noted that the temperature of the water in the tanks during these observations varied from 41° F. in May to 50° or 51° F. early in June. The unique situation of the St. Andrews Marine Laboratory and its natural conditions being unusually favourable for the development of the ova of marine fishes, the phenomena observed in the progress of *Gastrosteus spinachia* may be taken as almost normal.

P.S.—It is remarkable that, whereas in the freshwater sticklebacks the male during the breeding-season assumes brilliant colours, the pectoral and ventral region being of a bright scarlet tint, in the marine species no such distinguishing marks appear. Both sexes exhibit a similar marking. The male alone appears to construct the nest, and though female fishes, distended with eggs, often hover near during the building process, none were observed at St. Andrews to take any part in the work. The statement published by Heincke * that the male and female fishes build the nest is probably incorrect and due to the similarity of the hues of both sexes.

* 'Illustrirte Naturgeschichte d. Thiere' (Leipzig, 1882), p. 400.

EXPLANATION OF PLATE XIV.

Fig. 1. Transverse section (male *Gastrosteus sp.*) of renal mass, urinary bladder &c. *in situ*, × 150 diam. A, kidneys (coalesced portion) : *a*, *a*, right and left ureters passing longitudinally along outer ventral borders of kidneys ; *b*, urinary tubules, nuclei of epithelial cells indicated. B, urinary bladder, behind the cervix : *a*, epithelium ; *b*, fibrous layer ; *c*, *c*, right and left ureters (on opposite sides of bladder) ; *d*, contained thread-like secretion from kidneys ; C, intestine ; D, D′, testes.

Fig. 2. Fragment of hyaline capsule of ovum, showing the rows of pits and lamellæ, × 300.

Fig. 3. Ditto, in transverse section, showing numerous lamellæ, × 350.

Fig. 4. Portion of mucous secretion, showing funicular structure, × 350.

Fig. 5. Sketch of nest (diagrammatic), one third nat. size, the pockets containing ova exposed. *a*, *a*, transversely-arranged intersecting threads ; *b*, *b*, masses of ova contained in the interspaces of nest.

Fig. 6. Dissection of male, showing viscera of posterior portion of abdominal cavity, about nat. size. *a*, enlarged urinary bladder ; *b*, left flexure of ditto (cervix) ; *c*, right flexure of ditto (near posterior termination) ; *d*, genital pore ; *e*, cloacal depression ; *f*, anus ; *g*, urinary aperture ; *h*, alimentary canal ; *i*, *i*, right and left testes ; *j*, *j*, kidneys ; *j* 1, ureters ; *k*, swim-bladder.

XLIX.—*On the Genus* Fistulipora, *M'Coy, with Descriptions of several Species.*

By H. Alleyne Nicholson, M.D., D.Sc., Regius Professor of Natural History in the University of Aberdeen, and Arthur H. Foord, F.G.S., late of the Geological Survey of Canada.

[Plates XV.–XVIII.]

Introduction.

In the course of our study of various species of *Fistulipora* a most interesting and suggestive structural feature has come under our observation. This consists of a very peculiar modification of the walls of the autopores*, which gives them quite a distinct *facies*, and as it appears to have an important bearing upon the question of the zoological affinities of the genus (and consequently upon that of the Monticuliporidæ in general) we shall describe it as minutely as possible.

* We avail ourselves of this opportunity to offer a few words of explanation to the reader with reference to this and other terms we have found it expedient to introduce in substitution for the older ones hitherto in use. The principal tubes in *Fistulipora* and other genera of the Monticuliporidæ have been called "large corallites," or simply "corallites;" the tubes or tubuli filling the interspaces among these received the name of "interstitial tubes;" while the minute tubuli situated at the angles of