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On Some Variations of Cardium edule Apparently Correlated to the Conditions of Life

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VII. *On some Variations of* Cardium edule *apparently Correlated to the Conditions of Life.*

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[Plate 26.]

Introduction.

The following paper forms part of an investigation of the relation between the variations of animals and the conditions under which they live. It appears to me necessary that any investigation of this problem should be begun by the examination of cases in which difference in environment is known to exist, and that variations should then be sought for among the forms of life subjected to these conditions. If by this examination any variations can be shown to occur regularly with the change of conditions, or in any way in proportion to their intensity, it is so far evidence that there is a relation of cause and effect between them.

By thus first approaching the question from the point of view of the conditions, many difficulties are obviated which occur in any attempt which begins by ascertaining the variations in the animal, in the hope of afterwards finding an environmental change to which they may be traced. Such attempts to trace back variations to some environmental cause have often been made, and have, in general, been unsuccessful. In the case of species which have varied in isolated situations not apparently differing from each other, the failure to find points of environmental difference has been held to be evidence that the variations in question did not arise from such causes at all. This appears likely, and is probably true of the variations in question; but it must be borne in mind that the fact that no palpable difference can be found between the conditions in the several localities is no proof that they do not exist. While these differences in condition are usually evasive and hard to detect, it is best to begin to investigate their relation to variations in animals by selecting cases in which the change in conditions is unequivocal, and proceed from this starting point to seek for correlated variation in the forms of life subjected to them.

It appears that a particularly favourable opportunity for investigating this question is offered by the fauna of isolated lakes of various composition and of different degrees of salinity, and the following observations were made in accordance with this view. They are chiefly interesting owing to the great scarcity of any systematic observations of the relations between variation and the condition of life and to the rare occurrence of opportunities for investigating them.

While it has been held by some persons that the conditions of life are without definite effect in producing variations in animals, others, on the contrary, regard their production as an obvious consequence. The result of my investigations is to show that the whole relation between variation and conditions is much more complicated than it would be in accordance with either of these views; and that, while one animal may be profoundly and uniformly modified in every case by a certain change of conditions, yet these same changes produce no palpable effect on an allied animal of a different sort. For example, particulars will be given of the constant modification of *Cardium edule* consequent upon the drying up of the lakes in which they were, while *Dreissena polymorpha* and *Hydrobia ulvæ* do not appear to have been affected. It may be here remarked that the general variability of a form, as *Dreissena polymorpha*, does not appear to predispose it to assume a new form for a given change of condition.

In view of the fact that definite variations have been shown to be produced in *Cardium edule* by change in the composition of the water, it next becomes desirable to know to what extent these changes would be maintained if the conditions were altered back again to their original state. Upon this point I have no evidence; but that the animals would, if they lived and propagated, ultimately regain their former structure appears probable; for, since it can be shown that certain variations are constantly produced by water of certain constitution, it practically follows that the maintenance of these variations depends also on the same cause. It would, however, be of the greatest interest to ascertain the length of time and the number of generations necessary to effect these changes.

The specimens forming the subject of this paper were collected in the district of the Aral Sea and in Egypt.

In 1886 and 1887 I made a journey to some of the lakes of Western Central Asia, for the purpose of making observations on their fauna. As the waters of these lakes are of very various composition, being salt, alkaline, bitter, or fresh in differing degrees, I looked forward to an opportunity of investigating the question whether these diverse environmental conditions produce any correlated changes in the structure of the animals which are exposed to them. The collections made with this object consist chiefly of Crustacea, of which an account will be published hereafter.

In the course of the journey thus undertaken, I visited the northern shores of the Aral Sea and the sandy region called Ḳara-Ḳum, over a part of which, at least, the Aral Sea formerly extended, as is shown by the quantities of shells of the Aral Sea Cockle which are strewn on it. The area from which the Aral Sea has thus receded is not a level tract, but contains three considerable depressions, called respectively Shumish Kul, Jaksi Klich, and Jaman Klich. When the level of the sea was changed these three depressions remained, for a time, as isolated lakes, each containing a separate sample of the fauna of the sea living in it. The lakes gradually dried up, becoming salter and salter; and it is the object of the present paper to investigate the changes which befell the animals inhabiting them during this process.

General Account of the Desiccation of the Aral Sea.

Before entering into a detailed account of these lakes, it may be well to describe briefly the present conditions of the Aral Sea itself, of which they once formed a part. As is well known, the Aral Sea is a closed basin, receiving the waters of two rivers only, the Syr Darya and the Amu Darya. In this respect, it resembles the Caspian Sea, which receives the Volga, Ural, and Emba rivers. It is universally supposed that these two seas were united at a comparatively recent period. The evidence for this belief is the statement that banks of shells of species now living in the Caspian Sea are found on the land lying between them. As the level of the Caspian Sea is now 84 feet below that of the Black Sea, and the level of the Aral Sea is 128 feet above that of the Black Sea, if it be supposed that the respective levels of the beds of these two seas were formerly the same as they are now, it follows that the Caspian Sea must, at the time of its connection with the Aral Sea, have been more than 200 feet deeper than it now is. On the other hand, the change in the levels of the two seas may have been due to subsidence of the bottom of the one, elevation of the other, or both. It is further supposed by many that the conjoined Aralo-Caspian Sea had a northward extension, probably on the east of the Ural range, thus connecting with the Arctic Ocean. One reason for this belief, amongst others, is the presence of a Seal in the Caspian Sea whose affinities are rather with *Phoca vitulina* of the Arctic Ocean than with *P. fœtida* of the Mediterranean. It has also been supposed that this Aralo-Caspian Sea had an eastward extension as far as Lake Balkhash. The reason for this view is not easy to suggest, as none of the typical Aral fauna occur in Balkhash, nor are any deposits of Aralian shells found between the two waters. It may be added that Balkhash is bounded, both north and west, by very considerable hills, the Koi Djarlegan, &c.

Moreover, apart from the question as to the extent of the hypothetical Aralo-Caspian Sea, it has been suggested that the Aral Sea, at all events, has retired in recent times from some considerable area, and is continuing to recede thus. This statement, which occurs in several text-books, would appear to be only partially supported by the facts which came within my own observations. In the summer and autumn of 1886, I visited the whole north shore of the Aral Sea lying between Gulf Peroffsky and the mouth of the Syr Darya. From Togusken to Sary Cheganak the shore is formed by high cliffs composed of horizontal beds of Eocene formation, containing fossils. Of these I collected some 130 species, which have been examined by Mr. T. Roberts, of St.

John's College, and Mr. Keeping, who state them to be of about the age of the London Clay and of the Bracklesham beds of England. In some places these cliffs rise from the water's edge, and in others recede from it, opening up considerable valleys which slope gradually down to the shore. In places where the cliffs do not abut on to the water there is generally a sandy beach, but occasionally, as at Ḳuḳturnaḳ, there is a steep bank of large shingle and pebbles. The shores of the Sary Cheganaḳ (Yellow Gulf), which forms the northern limit of the Aral Sea, are low lying and sandy. These sands extend northward and eastward for about 150 miles, constituting the Ḳara Ḳum (Black Sand). The southern edge of the Ḳara Ḳum is thus the northern shore of the Aral Sea, and it is generally assumed that it was covered by those waters at a comparatively recent period.

The waters of the Aral Sea oscillate greatly under the pressure of the wind, and this effect is especially seen when the wind is from the south for some days. The water is then driven in some hundreds of feet over the almost horizontal beach of the Sary Cheganaḳ.

The Mollusca which have been recorded as occurring in the Aral Sea are *Cardium edule, Adacna vitrea, Dreissena polymorpha, Neritina fluviatilis, Hydrobia ulvæ.* In addition to these I found *Hydrobia spica* in large quantities (this species is already known from the Caspian Sea) and also *Neritina* (? n. sp.).

The *Cardium* occurs in great numbers on all parts of the shore which I visited, and when the wind falls and the sea retires the shore is left covered with stranded Cockles. The highest limit to which the flood thus induced ever reaches is in this way more or less clearly shown by the fresh shells and other *débris* left behind. Above the level of this fresh deposit the ground is always strewn with old shells, indicating the area covered in past times by the water. The coast of the south-west shore of the peninsula Ḳuḳturnaḳ is covered entirely with Cockle shells, extending in a band nearly a mile wide. With the exception of those points in which the cliff rises from the water's edge, there is always a tract of shore on which shells are found. On the hypothesis that the Aral Sea formerly had a much greater depth than at present, it would be expected that shells would be thus found in position for a considerable height above the present level, but this is not the case. On the contrary, where the shores are more or less steep the shells are found in great quantities up to a certain level, about 15 feet above the water, and above this level they are never found. In places where the land slopes very gradually to the water level the horizontal extent of the shell-covered tract is very great, being as much as 15 miles in some places; but whenever the ground rises suddenly so as to reach a greater height than about 15 feet above the Aral Sea level no more shells are found. The fact that the shells cease abruptly at a definite horizon is true both in sandy parts of the coast and on the clayey tracts, and it is equally true of those deposits of shells which occur in the bottom of valleys opening to the sea which are now altogether dry, but which were formerly filled by the sea. Some of these deposits of shells reach inland four or five miles (*e.g.*, Meregen Sai), but always without any marked rising of the ground; where any elevation occurs the level at which the shells cease is always definite and striking.

The absence of shells above a definite level seems to suggest that the sea has never in recent times extended over parts above that level. There is nothing to suggest that any Aral Sea deposits, higher than this line of demarcation, have been denuded. For, had denudation been the cause of the absence of Aral shells above this line, it would be expected that the shells would *gradually* disappear on a line travelling up from the sea, and that they would disappear at different levels in different places, which is not the case. If, therefore, the Aral Sea did ever extend over a greater tract of country than that which would be covered by it if it rose about 15 feet above its present level, it can only be supposed that such a condition occurred in the remote past, and not that it has gradually diminished to its present size from a much greater extent, as has been often suggested. Moreover, if the Aral Sea had recently retired from a greatly extended area, it must have covered the Ḳara Ḳum entirely, extending to Lake Tschalkar, which is marked on the Russian maps as a lake about 40 miles long and 25 miles broad, forming the termination of the great valleys of the Irghiz and Turgai streams. In the belief that such a connection might have formerly existed between Lake Tschalkar and the Sea of Aral, I travelled down the Irghiz river as far as the lake. I found it to be a vast sheet of salt mud, which becomes dry in summer in most places. The joint stream of the Irghiz and Turgai never reaches the main part of the lake, becoming lost in reedy morasses of nearly fresh water at the western end. The lake was so dry that my camels crossed the west end of it in the beginning of August. Its northern shore is bounded by a range of hills which rise about 600 to 800 feet from the lake. Their southern front, which faces towards the lake, is nearly vertical, and is cut in places by ravines. These hills are composed of horizontal beds containing Eocene fossils, similar to those which were found in the hills on the north-west of the Aral Sea. Above these beds was a deposit of horizontally stratified sand about 80 feet thick.

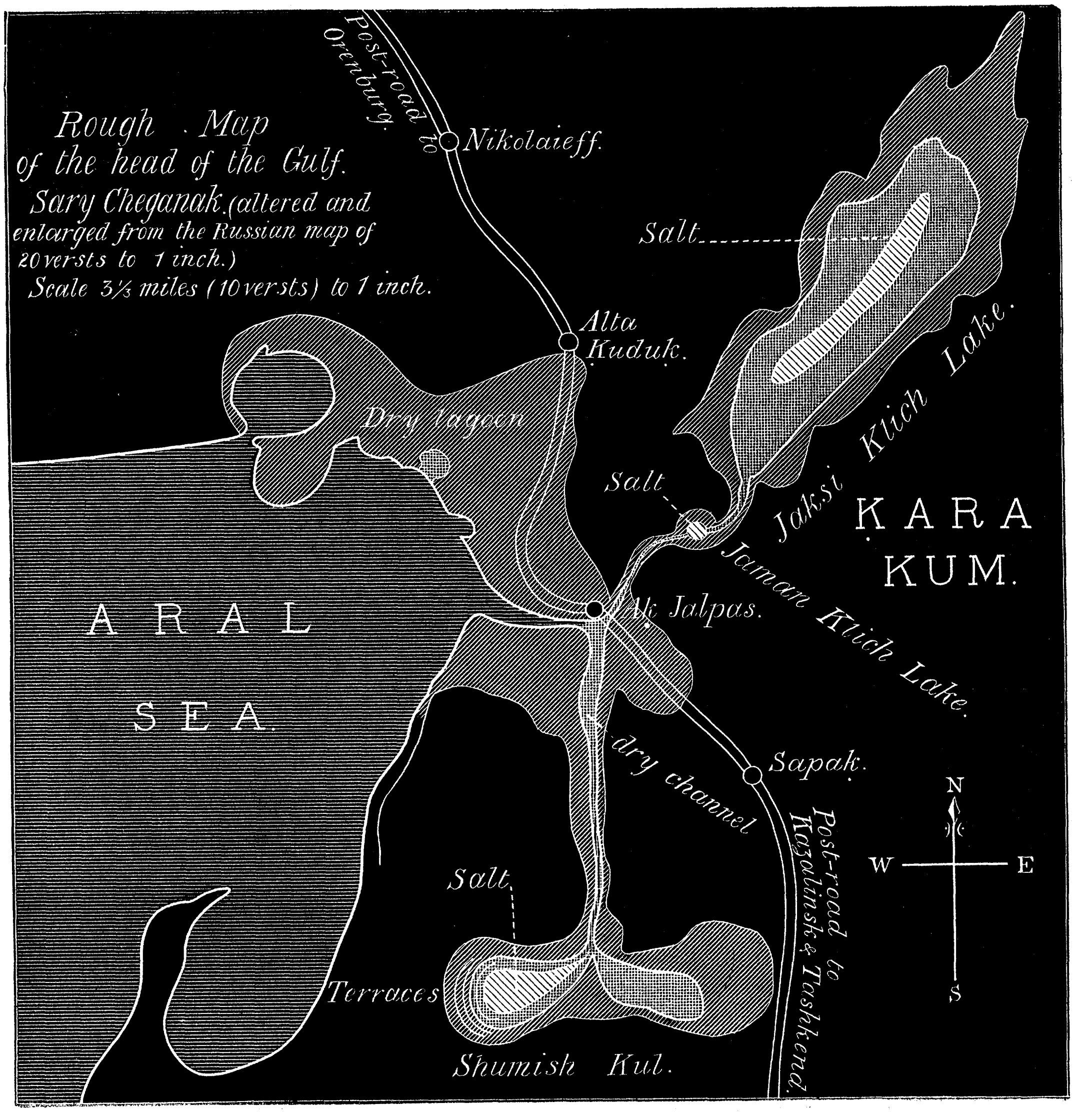
In no case, either in the ravines, or among the hills, or on the shores of the lake, or in the *dêbris* thrown up at the mouths of the wells, were any shells found other than those of the fossiliferous beds. There was no trace of the previous presence of the Aral Sea. The ground did not differ in any way from considerable low-lying tracts near the Aral Sea, which remain covered with Cockles; and, had the sea recently been in Lake Tschalkar, these shells could not have failed to be found in quantity. Also in the Ḳara Ḳum, excepting the above-mentioned low-lying tracts, the ground is without Cockles, but on descending to these depressions the deposit of shells is suddenly reached. This is true in the case of the north end of the depression, Jaksi Klich, which, though 15 miles from the Aral Sea, was formerly joined with it by a channel, and equally true of the steepest parts of the bank, as, for example, where the southern slopes of Togusken rise almost vertically from the water's edge. I have also every reason to believe that those parts of the Ḳara Ḳum which I did not visit are also without Aral shells. I made particular and independent inquiry from many of the Kirghiz who live in various parts of the Ḳara Ḳum, showing them Cockle shells (*Aigulaḳ*), and asking if they knew any localities where they were found. They all said that they had seen them at Jaksi Klich, Jaman Klich, and Shumish Kul, which are in the depressed regions, but they had never seen them in any other locality. I made special inquiry with regard to Aris Kul, which is marked on the maps as a considerable depression lying to the east of the Ḳara Ḳum, and I was told by several persons, independently, that no such shells were found there. For these reasons, it seems that, though the Aral Sea has retired within recent times from such an area as would be covered by it if its level were about 15 feet higher than it now is, yet it cannot be shown that it has continuously receded from an area much larger than this. If it ever extended over the Ḳara Ḳum northwards to Tschalkar, this must have been in the remote past, and its disappearance from the definite shell-covered area must have been a comparatively recent event, not continuous with its disappearance from the larger and vaguely defined region which it is supposed to have covered in later Tertiary times.

Special Account of the Basins Jaksi Klich, Jaman Klich, and Shumish Kul.

The region where the greatest exposure has taken place is situated to the north and east of the Sary Cheganak. Here the sandy coast slopes very gradually to the sea, and at the post-station Alta Ḳuduḳ, for example, the shell-covered region is about 3–4 miles wide. But at Aḳ Jalpas there is a dry channel running up from the bay, which divides into two branches, the one running east and north, and the other running south. The latter has a course of about six miles; near Aḳ Jalpas it is about half a mile wide, and is covered with mud, which is impassable after rain. Further south the channel narrows, and in some of the deeper holes in it there is always a little very salt water. This channel runs in a depression between the hills Aḳ Jar and Bultuḳ, and then opens out into a great depression, lying east and west, for a distance of about 8 miles. This place is known to the natives as Shumish Kul. (It is marked on the Russian maps as "Khan Sultan." This name is not known on the spot, though the mountain at the east end of the lake is called Khan Turt.)

The appearance of this lake is very striking. The north and west shores are formed by bare hills, with a few bushes and coarse grass at their base. Thence to the bottom of the lake is a tract of undulating sand, bearing scanty vegetation. Below the sand a stretch of baked mud is exposed, surrounding the pan of salt which fills the lowest part of the lake. The salt lies in large contorted sheets, overlaying each other like frozen waves of muddy ice. On the eastern and southern shores, which shelve away gradually to more distant hills, are great flats of salt mud covered with *Salicornia*, &c.

The biological interest of this place lies in the fact that upon the steep western shore are marked very definite terraces, showing the position of the water at different periods during the progress of the gradual drying up of the lake. On each of these terraces Cockle shells are found in great quantities, having been left there when the water was at the level of the terrace. A series of specimens, therefore, taken from each terrace from above downwards, gives examples of the shells as they were at each stage during the progressive desiccation of the lake. On several of the terraces the shells are paired shells, with the ligaments more or less preserved, placed upon their



oral surfaces, just as they were when alive, being kept in position by a crust of sand cemented with oxide of iron. Unfortunately, there is no reliable means of estimating the time which elapsed during the process of drying up. The intervals of time, however, between the formation of the successive terraces were sufficiently long to enable the shells to acquire definite characters, especially of colour and texture, which made it easy to distinguish shells of any one terrace from those of the one above or below it.

The principal terraces are seven in number, but, before describing in detail the condition of the shells on them, it may be well to give a general account of the changes which were produced in correlation to the diminished size of the lake. The principal changes are as as follows :—

(1.) *Diminution in the Thickness of the Shells,* which is first apparent in the shells of the third terrace. It proceeds to such an extent that the shells of the lowest terrace are almost horny and semi-transparent.

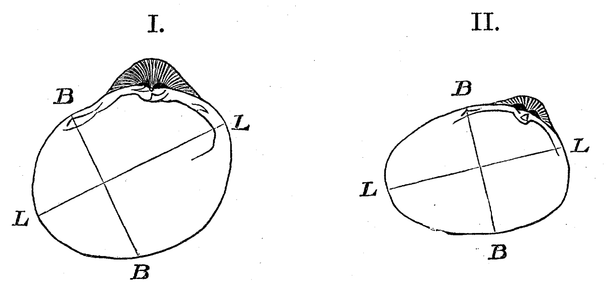
(2.) *The Size of the Beak is Greatly Reduced.*—In the shells of the upper terraces the beak encloses, so to speak, a separate chamber, while in those of the lower terraces it hardly forms a projection on the outside of the shell.

(3.) *The Shells become Highly Coloured.*—This change and (1) occur almost uniformly. The shells of each terrace are very nearly alike in texture, thickness, and degree of coloration.

(4.) *The Grooves between the Ribs appear on the Inside of the Shell as Ridges with Rectangular Faces.*—This change first affects only the ribs behind the 8th or 10th, but on the lowest terraces all the ribs are so affected.

(5.) On the lowest terrace *the shells diminish greatly in absolute size.*

(6.) *The Length of the Shells in proportion to their Breadth Increases.*—I use the term "length" to mean the greatest antero-posterior dimension, and the term "breadth" to mean the dorso-ventral measurement at right angles to the length, passing in right valves across the point of the posterior tooth, and in left valves across the depression into which the posterior tooth of the right valve fits.



Diagrams showing the directions in which the length and breadth of the shells are measured :—
I. A shell from the shore of the Aral Sea.
II. A shell from Jaksi Klich (inner deposit) L, L, length; B, B, breadth.

It must be remembered that, though the tooth is a fixed point in the morphology of the shell, there is no defined point on the ventral margin which can be determined in each shell for comparison with other shells. Hence, I am aware that the points selected for these measurements are arbitrary, and that they are not taken in absolutely homologous places in every shell. Nevertheless, they are very nearly so, and on the whole they are more satisfactory than any others. The object of these measurements is to obtain an arithmetical conception of the difference in the proportion of length to breadth which is apparent to the eye. This difference in appearance is almost all due to a change in the proportion which the greatest length bears to the greatest breadth at right angles to it. The measurements, owing to the irregularities of the shell, were made accurate to half a millimetre, and I believe that any difference due to variation in the selection of the exactly comparable morphological point on the ventral edge of the shell would be found to be within this limit of error. I am also aware that conchologists use the term length for the shorter of these two measurements; but, as this appears confusing to the general reader, it seems better in a paper of more general biological interest to use the terms in their ordinary sense. In comparing these shells of the upper terraces with those of the lower, it will be found that the greatest length is greater in proportion to the greatest width than it is in those shells which have been exposed to salter water.

I have made tables which are intended to show this change in the proportions of the shells in a tabular form. The Tables bring out three points:—

(*a.*) That the change in proportions does not occur in all the shells, nor to an equal degree in those in which it is found. Thereby it differs from the changes which occur in the texture and colouring. A few shells may be found in any terrace at Shumish Kul which do not differ materially in shape from normal shells. In the case of Jaksi Klich, however, almost all the shells are affected.

(*b.*) The second point noticeable in the occurrence of this variation is that it is far more marked in shells of greater absolute size (that is, presumably, of greater age) than in smaller and younger ones. This fact is brought out in the second column of the Tables.

(*c.*) The third fact which appears on comparing the averages is that the lengthening of the shells occurred slightly in the shells of the second terrace; increasingly in those of the third and fourth; reaching a point in the fifth terrace which is practically not afterwards exceeded in shells found as much as 30 feet lower, though the changes in texture, &c., had greatly progressed in these latter. Evidence will be given, moreover, which tends to show that this lengthening of the shells is more probably due to some other consequence of the diminished size of the lake than to the increase in saltness; for example, to its increasing shallowness and consequent high average temperature in summer. Examples will be given of Cockles from lagoons both of the Aral Sea and in Egypt, which, while differing entirely from those of these salt lakes in general appearance, are yet like them in the proportion of length to breadth. The whole question will be fully considered after the specimens have been described. The shells on the several terraces may now be described in detail.

First Terrace.—The shells on the first terrace were, no doubt, living at the time when the Aral Sea was connected with this series of lakes and, perhaps, also for a short period after its separation from them. They lie at the foot of the hills coming down to the lake, and, though mostly covered with earth, it was possible to get plenty of them, especially among the *débris* thrown out by burrowing animals. They are, for the most part, smallish shells, being chiefly 19 mm. to 24 mm. in length. They are thick shells, pale in colour, having from 18 to 22 ribs, the region behind the 11th to 14th ribs being purplish in colour.

No paired shells were found at this level. In 30 shells, all between 21 mm. and 16 mm. in length, the average ratio of length to breadth is 1 : 0·799 ; that is to say, that the average breadth of a shell 20 mm. long would be 15·98 mm.

The Second Terrace.—This is a flat about 50 paces across. Upon it are two well marked ridges of shells, the lowest of which is about 10 feet below the level of the first terrace. These ridges were obviously formed by the casting-up of shells on the beach during gales, as may be seen on the shore of the Aral Sea in many places (Meregen Sai, &c.). They contain no paired shells with ligaments, such as are found lower down in places where the bottom of the lake has been exposed and not afterwards disturbed.

Shells on this terrace were found of the maximum length of 26 mm. They have from 18 to 21 ribs, the region behind the 11th to 16th being purplish in colour. In 20 shells taken from the lower of the two ridges of shells on this terrace the average ratio of length to breadth is 1 : 0·770 in shells between 26 mm. and 20 mm. in length, and 1 : 0·782 in shells between 21 mm. and 16 mm. in length ; that is to say, that among shells similar in size to those of the first terrace the average breadth of a shell 20 mm. long would be 15·64 mm. The shells do not differ materially in consistency from those of the first terrace (*vide* Table of Comparative Weights) ; they are, however, slightly more highly coloured.

The Third Terrace consists of a strip of small sand-hills about 180 yards wide. The division between it and the region which I have called the fourth terrace is not sharply defined, but is indicated by a ring of old tamarisks. Such rings of tamarisks occur round many of the salt lakes of this steppe, and always show that the water stood at a definite level below them for a sufficiently long period to influence the vegetation. Some of the lakes in the Turgai district were surrounded by several concentric rings of tamarisks, showing several distinct periods in the progressive drying up of the water. This ring of tamarisks stands at a level about 20 feet below that of the ridge of shells which marked the lower limit of the second terrace. Amongst the bases of these sand-hills are many Cockles *in situ*, with their ligaments preserved, indicating that this part of the shore remains as it was when it formed part of the bottom of the lake. The shells on this terrace differ from those of the second terrace, being thinner, and showing that appearance of grooving on the inside of the shell which was referred to above (4). In shells of this terrace the grooving is not much marked in the case of ribs anterior to about the 11th. The number of ribs and distribution of colour are as they were in the last terrace.

In 30 shells between 22 mm. and 18 mm. long the average ratio of length to breadth was 1 : 0·751 ; that is to say, that the average breadth of a shell 20 mm. long would be 15·02 mm.

The Fourth Terrace is like the last, in that it is a stretch of shelving sand about

100 yards across, falling about 10 feet in level. On it also are many paired shells *in situ*. These shells differ considerably from those of the third terrace, being much thinner and more highly coloured (*vide* Table of Weights). The grooving on the inside of the shells is generally well marked in all behind the 7th rib.

There are generally only about 17 to 19 well marked ribs, the remainder being slightly indicated on the purple posterior surface of the shell. Most of the shell is purple behind about the 11th rib, and the whole shell is suffused with pinkish-purple (see Plate 26, fig. 4).

In 30 shells whose lengths vary between 26 mm. and 18 mm., the average ratio of length to breadth is 1 : 0·730, and, taking 30 shells from 16 mm. to 21 mm. long, this average ratio is 1 : 0·735 ; that is to say, that the average breadth of a shell 20 mm. long would be 14·7 mm. The beaks are reduced in size.

The Fifth Terrace is a similar stretch of sand ; it is 200 yards wide, falling nearly 20 feet, and upon it are very many paired shells placed on their oral faces, like the others. These shells are much thinner than those of the fourth terrace. They have 15 to 17 well marked ribs, and almost the whole shell is purple in colour in some specimens, but in others the first 3 ribs remain yellowish. The ribbing on the inside of the shell is generally apparent behind the 4th or 5th rib. The beaks are still further reduced in size.

In 30 shells between 27·5 mm. and 21 mm. in length the average ratio of length to breadth is 1 : 0·731 ; and in 30 shells between 21 mm. and 16 mm. long this average ratio is 1 : 0·743 ; that is to say, that the average breadth of a shell 20 mm. long is 14·8 mm., not materially differing from those of the last terrace. This terrace ends with the shelving sand. Below it are mud flats, the upper part of which is covered with heaps of muddy sand, cemented together with salt, forming the *Sixth Terrace*. The shells upon it, however, do not differ materially from those of the last, except, perhaps, in being rather thinner.

Below it is the lowest level at which shells are found (*Seventh Terrace*). This level is 8 to 10 feet below that of the fifth terrace, and distant from it about 200 yards. Upon this lowest level are several (five) concentric ridges, composed of shells washed up and partially cemented together with oxide of iron. The shells of which these ridges are made are like those of the fifth and sixth terraces. On the flat mud between these ridges, especially between the fourth and fifth, are great numbers of small paired shells placed on their oral faces. These shells are those of the last Cockles which lived in the lake before it was dried up. At this time the water must have been very salt indeed, as the salt bed itself is about 5 to 6 feet lower and 300 yards distant.

The shells are very small. The largest paired shell found in this place was 21 mm. long. They have 14 to 15 distinct ribs, are very thin, and of an almost uniform purple colour. The grooves between the ribs are all marked on the inside of the shell as ridges with flat sides. The beaks project very little from the general curve of the shell.

The average ratio of length to breadth in 30 shells the lengths of which were between 16 and 21 mm. is 1 : 0·725 ; that is to say, the average breadth of a shell 20 mm. long is 14·50 mm., as compared with 15·98 mm. in the case of the shells of the highest level.

Dreissena polymorpha.—At one side of the lake on the level of the third terrace were found many shells of this form, which did not differ from those of the Aral Sea. The same is true of *Hydrobia ulvæ*, which was found in fair quantities on most of the terraces.

Jaksi Klich.

This is the largest, superficially, of the three dry lakes containing Cockles. Its length is about 10 miles, and its breadth 3 miles. It differs from Shumish Kul in being comparatively shallow. While the former must have been nearly 60 feet deep at the time of the separation from the Aral Sea, the basin of Jaksi Klich cannot have been more than 15 to 20 feet deep. There is not in it a distinct series of terraces, as at Shumish Kul, but the shells occur in two chief deposits, the one marking the original high level of the water, and the other forming a band round the salt which now fills the bottom of the lake. Moreover, owing to the fact that the shells of the outermost deposit are almost all single valves, and not paired shells *in situ*, as at Shumish Kul, a good deal of mixing has become possible amongst them, which was, no doubt, facilitated by the shallowness of the lake ; as the banks are so flat that at the time when the lake was low it may have happened that under a strong wind the water was driven upon the shore even as high as its original level. Hence it results that the upper deposit of shells at Jaksi Klich is more mixed in character than the deposits hitherto described. I will first describe the condition of the shells found at the bottom of the lake. They occur there in enormous numbers, being for the most part washed up into banks. A certain number of paired shells occurs between the ridges. Their texture is uniformly thin and papery, and they are very highly coloured, thus resembling the shells of the lower terraces of Shumish Kul, especially those of the sixth terrace. Their length is very great, and this feature is found in almost every individual shell. While they thus resemble in many respects the shells from the salter levels of Shumish Kul, they yet have several features peculiar to themselves, especially the enormously greater degree to which they are elongated ; also, though their colour resembles the Shumish Kul shells in being much brighter than that of ordinary Aral Sea Cockles, it has a character of its own, which would make it impossible to mistake a shell from either locality.

As will be seen in the Tables, the average ratio of length to breadth in 30 shells varying in length between 30 mm. and 25·5 mm. is 1 : 0·660 ; and in 30 shells varying in length from 25·5 mm. to 19 mm. is 1 : 0·682. It will be seen, therefore, that the increased proportional length is greater in these shells than in any others that were obtained.

The size of the beaks is reduced, just as in the case of the Shumish Kul shells. The shells of the outermost deposit at Jaksi Klich are, as stated above, rather mixed in character. I found, however, one locality towards the southern end of the lake where the bank was comparatively steep, and from this place I obtained a fairly uniform sample. These shells are thin as compared with Cockles of the Aral Sea, but thicker than those of the lower deposit of Jaksi Klich. From the latter they differ also in not being highly coloured and in having the beaks fairly developed, though diminished relatively to those of normal Aral shells. As will be shown hereafter, they very closely resemble those shells which were found on the shore of the lagoon Abu Kir, in Egypt; the length of these shells is as great in proportion to their breadth as it is in those of the fourth or fifth terrace at Shumish Kul. The average ratio of length to breadth in 30 shells varying in length between 22 mm. and 17 mm. is 1 : 0·740; that is to say, that the average breadth of a shell 20 mm. long is 14·8 mm.

Many examples of *Hydrobia ulvæ* were found amongst these modified shells, but they do not differ from those of the Aral Sea.

In attempting to realise the conditions under which the Cockles lived in Jaksi Klich before the separation of this series of lakes from the Aral Sea, the fact of its situation must be borne in mind. It was a large lagoon, ten miles long and three miles broad, very shallow, and connected with the main body of the Aral Sea only by a narrow and shallow channel at Aḳ Jalpas. Hence the conditions of life in it, in a climate which undergoes the greatest extremes of heat and cold, must have been always very different from those prevailing in Shumish Kul, which had a considerable depth, and so must have maintained a much more constant temperature.

Before, therefore, the communication between the lakes and the Aral Sea was interrupted it is clear that the water of Jaksi Klich must have been sometimes very hot, and, from the consequent evaporation, it was probably in summer much salter than the nearest parts of the Aral Sea. In view then of the obvious correlation between the effects of the diminution in size of Shumish Kul and the increase in the proportional length and thinness, &c., of the shells found there, it appears reasonable to ascribe these appearances in the shells of the outer deposit at Jaksi Klich to similar causes, and these must of necessity have existed, consequent upon the peculiar situation and shallowness of the basin.

All these appearances, as has been shown, became greatly intensified in those shells which lived in it during the period after the separation from the Aral Sea.

Besides the shells in these two deposits, there were found at Jaksi Klich a few shells of an entirely different character. These were very large and very thick shells, generally occurring in pairs, more or less buried in the sand, though without ligaments. The length of these shells was about 30 to 35 mm.; they almost all show the feature of great proportional length and large beaks, and were always found in groups of ten or twelve, lying between the outer and inner deposits. These shells are all much worn. I shall allude to these shells as "great shells." Similar shells will be shown to have occurred at Jaman Klich, on the sand flats between Jaman Klich and Shumish Kul, in a small dry lagoon lately separated from the Aral Sea, and in the old deposits at Abu Kir (Mandara, Plate 26, fig. 12). Taken in connection with these cases of the occurrence of such shells, I think that there can be little doubt that shells of this type are connected with life in shallow lagoons opening out from a sea. All the five localities in which they were found were of this kind, and none were ever found by me anywhere else. On the shores of the Aral Sea and at Shumish Kul none occurred.

Jaman Klich.

This is the smallest of the three dry lakes. It was little more than a large pool formed by a widening and deepening of the channel which connected Jaksi Klich with the Aral Sea. At the time when it was full of water its diameter was about half a mile, and its depth 15 to 20 feet. The bottom of the lake is covered by a sheet of salt about 300 yards across. The shells upon the upper part of its shore do not differ materially from those of the Aral Sea, being thick shells with large beaks and little colour. Their proportional length is rather greater than that of the Aral Sea shells. There is little or no ribbing on their inner surfaces.

The shells at the bottom of Jaman Klich are thin, highly-coloured shells, with much ribbing on the inside and beaks greatly reduced in size. They are greatly elongated, though less so than the shells of Jaksi Klich. The average ratio of length to breadth in 30 shells varying in length between 24 mm. and 16 mm. is 1 : 0·726, being practically the same average ratio as that in the shells at the bottom of Shumish Kul.

Amonst these shells were great quantities of *Dreissena polymorpha*, which, though, as always, very variable in shape, did not differ in any uniform manner from those of the Aral Sea.

At the bottom of Jaman Klich is a considerable number of "great shells." They are like those of Jaksi Klich and are much worn.

On the flat between these two lakes and Shumish Kul are many shells strewn. They are, in all respects, like those of the upper deposits at Jaman Klich, and in no way remarkable. There are amongst them a few "great shells," but no thin or highly coloured ones, which occur only in the three lake beds.

Cockles of the Aral Sea.

In the Aral Sea itself, the Cockles are of very uniform character. They are fairly thick shells (see Table of Weights). The anterior 10 to 11 ribs are generally white, and the remaining 6 or 8 bluish or brown.

There are no "great shells" among them, nor any thin and highly coloured ones.

The average ratio of length to breadth in 30 shells of the Aral Sea varying in length between 22 and 18·5 mm. is 1 : 0·761.

The beaks in every case are large and well developed.

On the west shore of the Sary Cheganaḳ, near Alta Ḳuduḳ, is a small dry lagoon, which had once communicated with the Aral Sea. It was about half a mile wide and had been about 2 to 3 feet deep. In it were many Cockle shells; nearly all of these were "great shells," the remainder being shells of the ordinary Aral type.

This completes the description of the Cockles of the district of the Aral Sea. It has been shown that in each locality a particular type prevails, which varies hardly at all as regards texture and colour, and that, though the individuals of each type vary considerably in shape, yet that there is a distinct preponderance of long shells among those which have been exposed to the conditions incidental to the drying up of the lakes in which they were living; and that, in the case of each of three lakes, the changes undergone by the shells have been similar, though different in degree.

I will now describe the shells found in the lagoons near Alexandria, and then compare them with those of the Aral Sea district.

The Cockles of Lake Mareotis and Lake Abu Kir.

At the present time (1888)* Lake Abu Kir is a shallow salt lake, having an area of about 20 square miles and a depth of about 1 to 2 feet at most. In April, 1888, its specific gravity was 1·05. No living shells were found in it but its shores were covered with great quantities of uniformly small, thin, highly coloured shells (see Plate 26, fig. 10). These shells are elongated in the same way as those of Jaman Klich, which they closely resemble.

The average ratio of length to breadth in 30 of these shells varying in length from 24 mm. to 19·5 mm. is 1 : 0·738. (For average weight see Table of Weights).

These shells are plainly those of the Cockles which last lived in the lagoon of Abu Kir, and it may be supposed that they lived in it under conditions not very different from those now prevailing. It is difficult to assign with certainty any cause for their extinction, but this may perhaps have been due to an unusually dry season following on a low Nile.

The lagoons of Abu Kir and of Mareotis are separated from the sea by a narrow bank, partly of limestone and partly of sand; and from the presence of marine shells in the lagoons it is clear that they formerly communicated with the sea. The Cockles, therefore, of these lagoons are the descendants of those of the Mediterranean.

There is some reason for supposing that they passed through another condition between that of the Mediterranean type and that found on the shores at Abu Kir; for at Mandara and at other points on the shore of the Lake Abu Kir, where cuttings have been made, deposits of great quantities of shells almost invariably occur at a varying depth below the surface.

* Abu Kir was pumped out in May, 1888.

These shells are nearly all of the very large and thick type spoken of above (*vide* p. 309) as "great shells." From the great abundance of shells of this type in the deposits below the present bed of Abu Kir, it seems clear that they were numerous in the locality for a long period. As they are entirely absent among the shells now lying on the shores of the lake (namely, those which were the last inhabitants), I would suggest that these "great shells" perhaps lived there in the period when the sea communicated with the lake. This becomes still more probable in connection with the fact of the occurrence of similar shells at Jaksi Klich, Jaman Klich, and on the flats between them and Shumish Kul, for at the time when these localities were under water and connected with the Aral Sea the conditions in them could not have been very different from those prevailing in the lagoon of Abu Kir when it was open to the Mediterranean. The shells, then, of Abu Kir are of two kinds :—

(1.) Shells of animals lately extinct, which lived in a lagoon of water having a specific gravity of about 1·05 ; these shells show the same variations from the "normal" type as those of the Aral district living under similar circumstances.

(2.) "Great shells" occurring in a more or less definite bed below the level of the present lagoon, the origin of which is uncertain, but which were probably living when the lagoon was open to the sea.

Mareotis and the Fresh-water Lakes at Ramleh.

The Lake Mareotis is now divided by an embankment into an eastern and western part, which differ from each other entirely.

The western lake is full of red brine-water, and beneath the water is a permanent crust of salt.

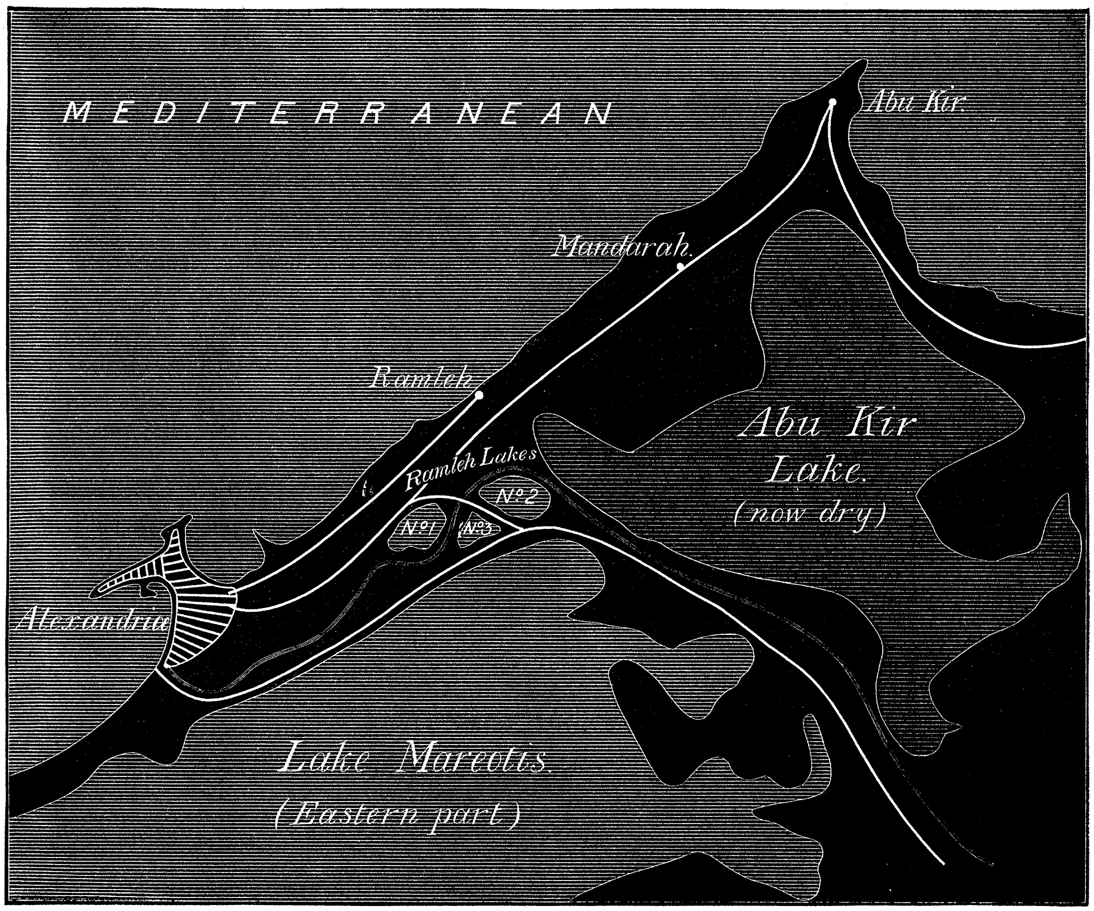
I did not succeed in finding any shells on the shore of this portion, though, no doubt, Cockles lived in it before the changes were made which have led to its present condition.

The eastern lake contained about 1 to 3 feet of water in most places in April, 1888. A very small stream of sea water runs into it near Meks. At the time of my visit its density was about that of the Mediterranean, but it, no doubt, varies greatly with the time of year and the state of the Nile. The lake, which lies 8 feet below the surface of the Mediterranean, is stated to have been nearly dry at the end of the last century, but in the course of military operations in 1801 it was again opened to the sea by the English. Possibly, then, the shells now found on its shore are the descendants of those then admitted from the Mediterranean. Another opening was lately made from the sea, but has been nearly closed, the small stream of water from the sea mentioned above being due to this opening.

At high Nile the level of the lake rises, owing to the infiltration of fresh water, and probably it is brackish at this season. From these considerations and from the many vicissitudes that the lake has undergone, it is clear that nothing can be stated with certainty as to the conditions which have prevailed in it for any length of time, beyond the fact that it has always been a large shallow lagoon, and that a large quantity of fresh water from the Nile has been poured into it every year.

I did not find any live Cockles in it, and am disposed to believe that they are extinct in it, having probably died in consequence of some of the sudden changes which have befallen the lake.

The shells found on the banks of Mareotis are, like those of Abu Kir, of two kinds :—



Rough map of Lake Mareotis, together with Abu Kir and the three Ramleh lakes.

(1.) Old shells, for the most part very large and not greatly differing from the "great shells" of Abu Kir. These occur especially on the cliffs near the road running beside the lake on its south-west shore. The shells here occur at a level several feet above that of the lake. These shells are much worn, and may be regarded as being in a semi-fossil state. They are possibly shells which lived in the lagoon when it was open to the sea.

(2.) Shells found in great numbers on the shores of the lagoon. These are nearly all paired valves with their ligaments. They are all of a most definite type (*vide*

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Plate 26, fig. 11) being moderately thin shells, having generally the anterior 6 to 10 ribs yellowish-white in colour, and the posterior 7 to 12 bluish or chocolate coloured; the inside of the shells is much ribbed; the posterior part is generally chocolate colour, and sometimes the whole interior of the shell is so coloured. Many of the shells have bands of dark colour running transversely to the ribs. The shells are nearly all elongated. The average ratio of length to breadth in 30 shells varying in length between 27 mm. and 20 mm. is 1 : 0·680; as in other samples, the elongation is more marked in large shells than in small ones.

The beaks are rather variable, but in most shells they are low.

The peculiarities in colour of these shells are so definite that they could not possibly be mistaken for the shells of Cockles from any other locality.

Amongst these modern shells are a few of the old semi-fossil shells mentioned above, which, however, are so different from them, being bleached and worn, that they may be at once distinguished.

Ramleh Lake No. 1.

By the formation of the Mahmudiyeh Canal, which was begun in 1819, a small piece of water was separated from the great Lake Mareotis, in the neighbourhood of Sidi Gaber station.

This lake is about a mile in greatest diameter, and its water is at the present time fresh, receiving much waste water from the irrigations, and is, perhaps 10 to 12 feet deep in the middle, though shallow at the sides. The bottom at the sides is sand, and in the middle is mud. Great quantities of Cockle shells lie on the bottom of the lake, but I found no live animals, and believe that they are extinct. These shells have a definite character, being thick and coarse in texture, with 14 to 16 anterior ribs, white, and from 3 to 5 posterior ribs, chocolate colour. The region of the anterior ribs (6 to 10) is generally not ribbed on the inside of the shell. The insides of the shells have a peculiar white colour. The shells are very long in proportion to their breadth, and most of them have one or more deeply marked lines of growth. The beaks are high and large. Amongst the smaller shells found here are some few which are extraordinarily thick.

Ramleh Lakes Nos. 2 *and* 3.

By the construction of the railway from Alexandria to Cairo, 1855, a second part of Mareotis has been cut off by an embankment, and the lake thus formed was again divided into two by the embankment recently made to connect the Cairo railway with the Ramleh line. In this way two lakes have been formed, an eastern (No. 2) and a western (No. 3). Both of these are fresh, receiving the water from irrigations. In the western lake I found no Cockles at all, either dead or living, though the water is crowded with Prawns (*Palæmon*, sp. ?).

In the eastern lake (No. 2) were great numbers of living Cockles. In texture these shells resemble those of Ramleh Lake No. 1, though the tendency to ribbing on the inside was not so much marked, being generally slightly present behind the 10th to 12th rib. The colour of the outside of the shells is yellowish-white almost all over, but on the inside the region of the posterior 3 to 6 ribs is chocolate colour, but the rest of the inside of the shells has the same bright white colour as in Ramleh Lake No. 1. The proportion of length to breadth is very great in these shells. In 30 shells varying in length between 29 mm. and 16·5 mm. the average ratio of length to breadth is 1 : 0·657, and in 30 shells varying in length between 21 mm. and 17 mm. this average ratio is 1 : 0·665. It is a remarkable fact that in the case of these shells the increased proportional length is almost as much marked among the small shells as it is amongst the large ones, and, as may be seen in Table VI. (a), this feature is present fairly uniformly in nearly all the individuals.

Another character of these fresh-water shells is the frequent occurrence of specimens with the free ventral margins of the shell bent inwards, as shown in Plate 26, fig. 13.

Recapitulation (*Mareotis and Ramleh Lakes*).

The shells found in the Mareotis and Ramleh district were of four kinds: (1) ancient shells, like the ancient shells of Abu Kir; (2) shells lately extinct (?) in Mareotis itself. Though the conditions under which these animals lived cannot be positively stated, it is nevertheless clear that they lived in shallow water, and that this water received in winter a great volume of fresh water from the Nile, being then probably brackish, while it is likely that in summer it was rather salter than the sea.

The shells having lived under these conjectural conditions have definite characters, being long, thin, highly coloured shells.

From them are descended independently (3) the Cockles of Ramleh Lake No. 1, and also (4) the Cockles of Ramleh Lake No. 2. Both (3) and (4) have been living in more or less completely fresh water for some time, and, on comparing them with (2), they will be found to differ from them similarly, and to resemble each other in most respects. They are both fairly thick and coarse, and the high colour of the Mareotis shells is much reduced in (3), and still more so in (4).

The feature of great proportional length remains in both.

As was found in the case of the various samples of Aral shells, the samples of each locality are distinct and easily recognisable, but, excepting a slight difference in colour, (3) and (4) are very nearly alike. A few specimens among (2) resemble in colour those of (3), but they are quite different in texture.

Conclusion.

The importance of these observations lies in the fact that, by examining and comparing the shells, an opportunity is given of observing the origin of a set of structural variations in correlation to, and perhaps in consequence of, environmental changes which are to some extent ascertained. The first point which is to be noticed is that the shells of each sample, whether it be from a separate lake or only from a particular terrace, are more like to each other than to the shells of one of the other lakes, or to those of another terrace in the same lake as at Shumish Kul, where the shells of each terrace have a distinct appearance and character of their own, and may easily be known from the shells of higher or lower terraces.

The next feature of importance is the fact that, in the four independent cases—Shumish Kul, Jaksi Klich, Jaman Klich, and the Egyptian lagoon Abu Kir*—the shells which have lived under similar conditions, *i.e.*, in very salt water, have become like each other, having the characters of thinness, high colour, small beaks, ribbing on the inside, and great relative length. In view of these four instances of similar variations occurring under similar conditions, it seems almost certain that these conditions are in some way the cause of the variations. Similarly, in the case of the two groups of Cockles from Mareotis which have been isolated and exposed to fresh water in separate lakes, the result has been to produce a form of shell in both cases which is practically the same. Cases of this kind, in which it is possible to observe the appearance and progress of a variation through successive generations in the same place, are so rare that it has seemed worth while to describe these shells in detail. The mode of occurrence of the shells in terraces at Shumish Kul provides an almost unique opportunity for beholding the gradual succession of these changes. If, then, it is admitted that the structural changes in the shells are to be regarded as the consequence of the environmental changes in the water of the lake, the question arises to what extent these structural changes follow directly on the changed circumstances, and how far they may not be due to the natural selection of a different type as the fittest to live in the altered state.

Now, while the cases given above do not give a definite answer to this question, they nevertheless contribute something towards it. The chief qualities which appear in the shells which have been exposed to the increased saltness are comparative thinness, high colour, and increased length, together with diminished beaks. If, then, it is supposed that shells having these qualities were being gradually chosen by natural selection as the fittest for the new conditions, it would be expected that in each

* Amongst the shells in the Cambridge University Museum collected by MacAndrew are a few Cockles from a lagoon at Tunis, which show the same features. Though, in the absence of further information as to the locality from which they were brought, nothing can be positively stated, yet it is likely that they afford another instance of a similar variation occurring under similar conditions.

terrace these several attributes would be found in varying degree among the individual shells—that some would be thick and some thin, some long and some short, &c.; on the other hand, if the new qualities were the result of the new conditions, then it would be anticipated that the shells of each terrace would be all nearly similar in texture and shape. The more uniformly any of the new variations are found among the individuals, the more probable is it that they are due to the direct action of environmental change rather than to natural selection; but a new quality, which is found in the several individuals to a greatly varying degree, cannot be held to be shown to be the direct result of the conditions, even though it be found to be increasingly more marked on the average in successive generations as the conditions to which it is supposed to be due become more intense. Now the variations formed among these shells are of two kinds. The variation in proportional length, though becoming more and more marked in the shells which have been exposed to salter water, is not found in all the individuals (*vide* Tables); on the other hand, the variations in the quality, texture, and colour of the shell are found developed to nearly the same degree among all the individuals of successive terraces. Hence it may be fairly supposed, in the case of these latter variations, that they are really due to direct environmental change. The same also is true of the shells from the fresh-water localities, the texture and colour of which are practically uniform, while a good deal of variation is found in the shape, though the general prevalence of the long type is clear. In view of the manifest connection between variation in the texture, &c., of the shells and the conditions in the lake, it would be interesting to know more clearly the mode of action of these conditions in producing those effects, but as to this it is difficult to make a conjecture. No doubt they are the result of changes in the nutrition of the animals, but more than this does not seem clear. It can scarcely be supposed that the thinness of the shells was due to a deficiency of lime in solution in the water, since this would rather increase in relative amount with the evaporation. Moreover, the shells from the two fresh-water lakes at Ramleh are fairly thick. Neither can the deficiency in the amount of the shells be due to general starvation, since there is no diminution in absolute size at Shumish Kul, except in the case of the shells of the lowest level, which do appear generally ill-nourished; while, at Jaksi Klich, those shells which have become thin and papery from the desiccation of the lake are, on the whole, absolutely larger than an average sample of shells from the Aral Sea.

It may here be remarked that the striking similarity between the shells which had been exposed to very salt water at Abu Kir and those of the salt lakes of the Aral region has features of special interest, since not only have the similar conditions prevailed in producing two forms closely resembling each other, but this has been achieved, though the animals subjected to the influence were at first unlike and had had a very different history. For even supposing that the Cockles in the Aral Sea were originally derived from those of the Mediterranean, which is uncertain, yet the

Aral shells have been living for ages in water containing less than a third of the salt contained in Mediterranean water, and the Aral Cockle is quite sufficiently different from that of the Mediterranean to constitute a well marked variety. So that, while the Cockles originally isolated in Abu Kir came directly from the Mediterranean, the ancestors of those which were subjected to increased saltness at Jaksi Klich, &c., had been living in brackish water in the Aral Sea for an indefinite number of generations, *yet the resulting forms in both cases are closely alike.*

It is not well to press conclusions of this kind too far, and it may be that unfavourable conditions of some kind quite other than increased saltness may result in producing similar variations. All that can be stated with certainty is that shells exposed to increasingly salt water do change in a particular way, and that they do so with great regularity and uniformity. In the same way it has been shown that the influence of fresh water does not lead to the production of a peculiar type of shell. In the case of the variation consisting in increased proportion as to length, it is especially probable that the cause lies in the general unfavourableness of the conditions. It was shown to be present both in those shells which had been exposed to salt water and in a still greater degree among those which had been living in fresh water. It is not rare to find occasionally shells of Cockles from the English coast of similar shape. Nevertheless, the regularity of the presence of this feature among the shells from these abnormal situations is so great as to make it certain that this phenomenon is in some manner due to the conditions. Instances in which it is possible to actually trace the occurrence of variations are so rare that no apology is required for having given so much attention to details which would be otherwise unimportant. In the cases here given it has not only been possible to observe the variations, but also to obtain the actual ancestors of the varying offspring, for comparison, and in the case of the shells of Shumish Kul an opportunity is given of doing this at several successive stages.

I wish to express my thanks to many persons who have assisted me in the course of my investigations and especially to Sir ROBERT MORIER, G.C.B., British Ambassador at St. Petersburgh, who obtained permission for me to travel in Central Asia; to M. SEMENOW, Vice-President of the Imperial Geographical Society, and to M. MAXIMOVITCH of the Botanic Garden, for much valuable information and advice; also to C. A. COOKSON, Esq., C.B., British Consul at Alexandria. Moreover, though this page may never reach them, I cannot let this opportunity pass without expressing my gratitude for the courtesy and hospitality which I everywhere met with at the hands of the Kirghiz people.

Tables Showing Variations in the Average Ratio of Length to Breadth in Shells from Different Localities.

Explanation.—In the first column of these Tables the actual measurements of the lengths and breadths of each shell are given in millimetres. The second column is constructed from the first. It shows the number of shells of each length which compose the sample of 30, and also shows the average breadth of shells having the same length. The third column is constructed from the second by dividing the average breadths in each case by the length. The final average ratio is obtained from the third column by multiplying these quantities by the number of shells from which they were derived, adding together these products and dividing the sum by 30.

[In the column in which the breadths are given the figures in brackets show the number of shells having the same breadth.]

Table I.—The Aral Sea.

Measurements of shells in millimetres.		Average breadth of shells having the same length.			Ratio of length to breadth.
Length.	Breadth.	Length.	Average breadth.	Number of shells.	
22	17·5, 17(4)	22	17·1	5	1 : 0·77
21·5	16	21·5	16	1	·74
21	16(4)	21	16	4	·75
20·5	16	20·5	16	1	·76
20	16·5, 16(4), 15·5(3), 15(4), 14	20	15·4	13	·77
19·5	15·5, 15, 14	19·5	15	1	·76
18·5	14, 13	19	14·8	3	·76
		18·5	13·5	2	·72

Average ratio of length to breadth in 30 shells varying in length between 22 mm. and 18·5 mm. is 1 : 0·761.

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Table II.—Shumish Kul.

The First (Highest) Terrace.

Measurements of shells in millimetres.		Average breadth of shells having the same length.			Ratio of length to breadth.
Length.	Breadth.	Length.	Average breadth.	Number of shells.	
21	17, 16	21	16·5	2	1 : 0·77
20·5	16(2)	20·5	16	2	·78
20	16(5), 15·5, 15(2)	20	15·6	8	·78
19	15·5(2), 15(4)	19	15·1	6	·79
18·5	15·5, 15, 14·5, 14	18·5	14·7	4	·79
18	15(3), 14·5(2), 14(2)	18	14 5	7	·80
17·5	14·5, 14	17·5	14·2	2	·81
17	14(5), 13·5, 13	17	13·7	7	·81
16·5	14	16·5	14	1	·84
16	13	16	13	1	·81

Average ratio of length to breadth in 30 shells varying in length between 21 mm. and 16 mm. is 1 : 0·799.

The Second Terrace.

(*a.*) Shells Varying in Length between 21 mm. and 16 mm.

Measurements of shells in millimetres.		Average breadth of shells having the same length.			Ratio of length to breadth.
Length.	Breadth.	Length.	Average breadth.	Number of shells.	
21	17(2), 16(2)	21	16·5	4	1 : 0·78
20·5	16	20·5	16	1	·78
20	16(2), 15·5, 15(3)	20	15·4	6	·77
19·5	16, 15·5, 15	19·5	15·5	3	·79
19	16, 15·5(3), 15, 14	19	15·2	6	·80
18·5	14	18·5	14	1	·76
18	15(2), 14·5, 14(3)	18	14·4	6	·80
17·5	14	17·5	14	1	·80
17	14	17	14	1	·82
		16	13	1	·31

Average ratio of length to breadth in 30 shells varying in length between 21 mm. and 16 mm. is 1 : 0·782.

(*b.*) SHELLS Varying in Length between 26 mm. and 20 mm.

Measurements of shells in millimetres.		Average breadth of shells having the same length.			Ratio of length to breadth.
Length.	Breadth.	Length.	Average breadth.	Number of shells.	
26	20	26	20	1	1 : 0·76
25	19(2), 18·5	25	18·8	3	·75
24·5	19	24·5	19	1	·77
24	19, 18(2)	24	18·3	3	·77
23	17(2)	23	17	2	·73
22	18(4), 17·5(2), 17(2)	22	17·5	8	·79
21	17, 16	21	16·5	2	·78
20·5	16	20·5	16	1	·78
20	16, 15·5, 15(2)	20	15·3	4	·76
19·5	15·5, 15	19·5	15·2	2	·75
19	15·5(2), 15	19	15·3	3	·80

Average ratio of length to breadth in 30 shells varying in length between 26 mm. and 20 mm. is 1 : 0·770.

The Third Terrace.

Measurements of shells in millimetres.		Average breadth of shells having the same length.			Ratio of length to breadth.
Length.	Breadth.	Length.	Average breadth.	Number of shells.	
22	17, 16(4)	22	16·2	5	1 : 0·73
21·5	16·5, 16(4), 15	21·5	15·9	6	·74
21	16·5, 16(3), 15	21	15·9	5	·75
20	16(2), 15(3)	20	15·4	5	·77
19·5	15	19·5	15	1	·76
19	15(2), 14·5, 14(2)	19	14·5	5	·76
18	14·5, 14, 13	18	13·8	3	·76

Average ratio of length to breadth in 30 shells varying in length between 22 mm. and 16 mm. is 1 : 0·751.

The Fourth Terrace.

(*a.*) Shells Varying in Length between 21 mm. and 16 mm.

Measurements of shells in millimetres.		Average breadth of shells having the same length.			Ratio of length to breadth.
Length.	Breadth.	Length.	Average breadth.	Number of shells.	
21	16·5, 16, 15·5, 15(2)	21	15·4	5	1 : 0·73
20·5	16·5, 16, 15(2)	20·5	15·6	4	·76
20	16, 15, 14·5, 14(3)	20	14·5	6	·72
19·5	15, 14(2)	19·5	14·3	3	·73
19	14, 13·5, 13	19	13·5	3	·71
18·5	13	18·5	13	1	·70
18	14, 13	18	13·5	2	·74
17·5	14, 13	17·5	13·5	2	·77
17	13	17	13	1	·76
16	12·5, 12, 11·5	16	12	3	·75

Average ratio of length to breadth in 30 shells varying in length between 16 mm. and 21 mm. is 1 : 0·735.

(*b.*) Shells Varying in Length between 26 mm. and 18 mm.

Measurements of shells in millimetres.		Average breadth of shells having the same length.			Ratio of length to breadth.
Length.	Breadth.	Length.	Average breadth.	Number of shells.	
26	19	26	19	1	1 : 0·73
25	18	25	18	1	·71
23	18, 17·5, 16	23	17·1	3	·74
22·5	17	22·5	17	1	·75
21	16·5, 16, 15·5, 15(2)	21	15·4	5	·73
20·5	16·5, 16, 15(2)	20·5	15·6	4	·76
20	16, 15, 14·5, 14(3)	20	14·5	6	·72
19·5	15, 14(2)	19·5	14·3	3	·73
19	14, 13·5, 13	19	13·5	3	·71
18·5	13	18·5	13	1	·70
18	14, 13	18	13·5	2	·74

Average ratio of length to breadth in 30 shells varying in length between 26 mm. and 18 mm. is 1 : 0·730.

The Fifth Terrace.

(*a.*) Shells Varying in Length between 21 mm. and 16 mm.

Measurements of shells in millimetres.		Average breadth of shells having the same length.			Ratio of length to breadth.
Length.	Breadth.	Length.	Average breadth.	Number of Shells.	
21	17, 16·5, 16(2), 15·5	21	16·2	5	1 : 0·77
20·5	15	20·5	15	1	·73
20	15·5, 14	20	14·7	2	·73
19·5	14·5, 14	19·5	14·2	2	·73
19	15, 14(4), 13·5, 13	19	13·9	7	·73
18	14(2), 13·5	18	13·8	3	·73
17·5	13·5, 13	17·5	13·2	2	·75
17	13·5, 13(2), 12·5	17	13	4	·76
16	13, 12·5, 12(2)	16	12·3	4	·77

Average ratio of length to breadth in 30 shells varying in length between 21 mm. and 16 mm. is 1 : 0·743.

(*b.*) Shells Varying in Length between 27·5 mm. and 21 mm.

Measurements of shells in millimetres.		Average breadth of shells having the same length.			Ratio of length to breadth.
Length.	Breadth.	Length.	Average breadth.	Number of shells.	
27·5	19	27·5	19·5	1	1 : 0·70
26	20, 19, 18	26	19	3	·73
25·5	17	25·5	17	1	·67
25	19·5, 19, 18·5, 18, 17·5	25	18·5	5	·74
24	19(2), 18·5, 18, 17·5	24	18·4	5	·75
23	17, 16·5(2), 16(2)	23	16·4	5	·71
22·5	17(2), 15·5	22·5	16·5	3	·73
22	17·5, 17, 16·5, 15	22	16·5	4	·75
21·5	16	21·5	16	1	·74
21	17, 16	21	16·5	2	·73

Average ratio of length to breadth in 30 shells varying in length between 27·5 mm. and 21 mm. is 1 : 0·731.

The Seventh Terrace.

SHELLS Varying in Length between 21 mm. and 16 mm.

Measurements of shells in millimetres.		Average breadth of shells having the same length.			Ratio of length to breadth.
Length.	Breadth.	Length.	Average breadth.	Number of shells.	
21	15	21	15	1	1 : 0·71
20·5	15	20·5	15	1	·73
20	15(3), 14·5, 14(3)	20	14·5	1	·72
19·5	13·5	19·5	13·5	1	·69
19	14·5, 14(2), 13	19	13·8	4	·72
18·5	13	18·5	13	1	·70
18	14(2), 13·5(2), 12	18	13·4	5	·74
17·5	13, 12	17·5	12·5	2	·71
17	13(2), 12(4)	17	12·3	6	·72
16	13, 12	16	12·5	2	·78

Average ratio of length to breadth in 30 shells varying in length between 21 mm. and 16 mm. is 1 : 0·725.

TABLE III.—Jaksi Klich.

Shells of the Outer Deposits Varying in Length between 22 mm. and 17 mm.

Measurements of shells in millimetres.		Average breadth of shells having the same length.			Ratio of length to breadth.
Length.	Breadth.	Length.	Average breadth.	Number of shells.	
22	16(3)	22	16	3	1 : 0·72
21	16(3), 15·5, 15(3)	21	15·7	7	·74
20	15(7), 14·5, 14	20	14·8	9	·74
19·5	14(2)	19·5	14	2	·71
19	15, 14	19	14·5	2	·76
18·5	14(2)	18·5	14	2	·75
18	14, 13(2)	18	13·3	3	·73
17·5	13·5	17·5	13·5	1	·77
17	14	17	14	1	·82

Average ratio of length to breadth in 30 shells varying in length between 22 mm. and 17 mm. is 1 : 0·740.

Shells of the Inner Deposit.

(*a.*) SHELLS Varying in Length between 25·5 mm. and 19 mm.

Measurements of shells in millimetres.		Average breadth of shells having the same length.			Ratio of length to breadth.
Length.	Breadth.	Length.	Average breadth.	Number of shells.	
25·5	17·5, 17	25·5	17·2	2	1 : 0·73
25	17·5, 17, 16·5	25	17	3	·68
24·5	16(2)	24·5	16	2	·65
24	17, 16(2)	24	16·3	3	·67
23·5	16(2)	23·5	16	2	·68
23	15·5(2), 14·5	23	15·1	3	·65
22·5	16, 15·5, 15	22·5	15·5	3	·68
22	16(2), 15(4)	22	15·3	6	·69
21·5	15·5, 15(2)	21·5	15·1	3	·70
21	14·5	21	14·5	1	·69
20	13	20	13	1	·65
19	14	19	14	1	·73

Average ratio of length to breadth in 30 shells varying in length between 25·5 mm. and 19 mm. is 1 : 0·682.

(*b.*) SHELLS Varying in Length between 30 mm. and 25·5 mm.

Measurements of shells in millimetres.		Average breadth of shells having the same length.			Ratio of length to breadth.
Length.	Breadth.	Length.	Average breadth.	Number of shells.	
30	20	30	20	1	1 : 0·66
29	20	29	20	1	·69
28	19, 17·5	28	18·2	2	·65
27·5	19·5, 19, 18	27·5	17·5	3	·63
27	19(3), 18(2), 17·5	27	18·4	6	·68
26·5	18(2), 17·5, 17	26·5	17·6	4	·67
26	18(3), 17 5, 17(3)	26	17·5	7	·67
25·5	18, 17·5(2), 17(3)	25·5	17·3	6	·67

Average ratio of length to breadth in 30 shells varying in length between 30 mm. and 25·5 mm. is 1 : 0·660.

TABLE IV.—Shells from the Bottom of Jaman Klich.

Measurements of shells in millimetres.		Average breadth of shells having the same length.			Ratio of length to breadth.
Length.	Breadth.	Length.	Average breadth.	Number of shells.	
24	17, 16·5	24	16·7	2	1 : 0·69
23	17, 16	23	16·5	2	·71
22	16(3)	22	16	3	·72
21·5	15·5	21·5	15·5	1	·72
21	15(2)	21	15	2	·71
20·5	15	20·5	15	1	·73
20	14(2)	20	14	2	·70
19	14·5, 14(2), 13·5(2)	19	13·9	5	·73
18·5	14(4), 13	18·5	13·8	5	·75
18	13·5, 13	18	13·2	2	·73
17·5	14, 13	17·5	13·5	2	·77
17	13, 12	17	12·5	2	·73
16	11·5	16	11·5	1	·71

Average ratio of length to breadth in 30 shells varying in length between 24 mm. and 16 mm. is 1 : 0·726.

TABLE V.—Shells from the Shore of Mareotis.

Shells Varying in Length between 27 mm. and 20 mm.

Measurements of shells in millimetres.		Average breadth of shells having the same length.			Ratio of length to breadth.
Length.	Breadth.	Length.	Average breadth.	Number of shells.	
27	19, 18	27	18·5	2	1 : 0·68
26	18	26	18	1	·69
25	18(2), 17·5, 17, 16(2)	25	17	6	·68
24·5	17	24·5	17	1	·69
24	16·5	24	16·5	1	·68
23	16(2), 15·5(2), 15(2)	23	15·5	6	·67
22·5	16(2), 15·5	22·5	15·8	3	·70
22	15·5, 15	22	15·2	2	·69
21·5	15	21·5	15	1	·67
21	15, 14(4)	21	14·2	5	·70
20	14(2)	20	14	2	

Average ratio of length to breadth in 30 shells varying in length between 27 mm. and 20 mm. is 1 : 0·680.

TABLE VI.—Ramleh Fresh-water Lake No. 2.

(*a.*) *Shells Varying in Length between* 21 *mm. and* 17 *mm.*

Measurements of shells in millimetres.		Average breadth of shells having the same length.			Ratio of length to breadth.
Length.	Breadth.	Length.	Average breadth.	Number of shells.	
21	15, 14, 13·5	21	14·1	3	1 : 0·67
20	14, 13(3), 12·5	20	13·1	5	·65
19·5	13(2)	19·5	13	2	·66
19	13·5, 13(4), 12·5(3), 12(2)	19	12·7	10	·66
18	13(3), 12·5, 12, 11·5(2)	18	12·3	7	·68
17·5	12(2)	17·5	12	2	·68
17	11·5	17	11·5	1	·67

Average ratio of length to breadth in 30 shells varying in length between 21 mm. and 17 mm. is 1 : 0·665.

(*b.*) *Shells Varying in Length between* 29 *mm. and* 16·5 *mm.*

Measurements of shells in millimetres.		Average breadth of shells having the same length.			Ratio of length to breadth.
Length.	Breadth.	Length.	Average breadth.	Number of shells.	
29	17	29	17	1	1 : 0·58
28	19, 18	28	18·5	2	·66
27·5	18·5, 18(2), 17	27·5	17·7	4	·64
26	19, 18·5, 17, 16·5	26	17·7	4	·68
25	17·5, 16	25	16·7	2	·67
24	17(2), 16·5, 15·5, 15	24	16·2	5	·67
23·5	15·5	23·5	15·5	1	·65
23	15, 14	23	14·5	2	·63
22	15·5	22	15·5	1	·70
21·5	15, 14	21·5	14·5	2	·67
20·5	13	20·5	13	1	·65
20	14, 12	20	13	2	·63
19·5	13	19·5	13	1	·66
19	12	19	12	1	·62
16·5	11·5	16·5	11·5	1	·69

Average ratio of length to breadth in 30 shells varying in length between 29 mm. and 16·5 mm. is 1 : 0·657.

TABLE VII.—Shells from the Shore of Abu Kir.

Measurements of shells in millimetres.		Average breadth of shells having the same length.			Ratio of length to breadth.
Length.	Breadth.	Length.	Average breadth.	Number of shells.	
24	17·5, 17	24	17·2	2	1 : 0·71
23	17, 16, 15·5	23	16	3	·69
22·5	17·5, 16·5, 15·5	22·5	16·5	3	·73
22	16, 15·5, 15	22	15·3	3	·69
21·5	15(5), 14	21·5	14·8	6	·68
21	16, 15·5, 15(2)	21	15·3	4	·72
20·5	15	20·5	15	1	·74
20	14·5, 14(5)	20	14	6	·70
19·5	14·5, 14	19	14·2	2	·75

Average ratio of length to breadth in 30 shells varying in length between 24 mm. and 19·5 mm. is 1 : 0·738.

TABLE VIII.

This Table gives the results of the previous Tables. The extremes of length of the shells measured for these averages are given in millimetres, and the average breadths are given in terms of the length, which is taken as 1.

Locality.	Level.	Smaller samples.		Larger samples.	
		Extremes of length.	Average breadth.	Extremes of length.	Average breadth.
Shore of Aral Sea	. .	22 –18·5	0·761		
Shumish Kul	First terrace . .	21 –17	0·799		
" "	Second terrace .	21 –17	0·782	26–19	0·770
" "	Third terrace. .	22 –18	0·751		
" "	Fourth terrace .	21 –16	0·735	26–18	0·730
" "	Fifth terrace . .	21 –16	0·743	27–21	0·731
" "	Seventh terrace .	21 –16	0·725		
Jaksi Klich	Upper deposit .	22 –17	0·740		
" "	Lower deposit .	25·5–19	0·682	30–25·5	0·660
Jaman Klich	Lower deposit .	24 –16	0·726		
Shore of Mareotis	. .	. .	. .	27–20	0·680
Ramleh Lake No. 2 (fresh-water).	. .	21 –17	0·665	29–16·5	0·657
Shore of Abu Kir	. .	24 –19·5	0·738		

Table Showing the Comparative Weights of Shells of Similar Size.

For the purpose of this Table twenty shells were chosen from each sample to be compared, as nearly alike in length as was possible.

The first column gives the name of the locality, the second the level, the third shows the extremes of length in millimetres of the shells selected, the fourth column gives the sum of the lengths of the twenty shells, and the fifth column gives the total weight.

Locality.	Level.	Extremes of length in millimetres.	Average length of 20 specimens.	Total weight in grammes of 20 specimens.
Shore of Aral Sea	. .	21–17	19·2	13·3
Shumish Kul	First terrace	21–17	19·1	14·1
,, ,,	Second terrace	21–17	19·4	14·5
,, ,,	Fourth terrace	21–17	19·2	6·5
,, ,,	Fifth terrace	21–17	18·9	6·1
,, ,,	Seventh terrace	21–17	19·7	4·6
Shore of Abu Kir	. .	21–17	19·0	6·4
Jaksi Klich	Upper deposit	23–19	20·4	7·8
,, ,,	Lower deposit	23–19	20·4	5·5
Jaman Klich	Lower deposit	21–17	19·2	5·1
Ancient shells exposed at Mandara	. .	26–21	23·4	24·2
Shore of Mareotis	. .	25–22	23·8	12·0
Ramleh Lake No. 1 (fresh-water)	. .	25–20	21·4	18·3
Ramleh Lake No. 2 (fresh-water)	. .	26–23	24·1	23·6

Explanation of Plate 26.

Figs. 1–7 represent shells of *Cardium edule* from the successive terraces at Shumish Kul.

Fig. 1. Right valve from the first (*i.e.*, the highest) terrace.
Fig. 2. Right valve from the second terrace.
Fig. 3. Left valve from the third terrace.
Fig. 4. Right valve from the fourth terrace.
Fig. 5. Right valve from the fifth terrace.
Fig. 6. Right valve from the sixth terrace.
Fig. 7*a*. Left valve from the seventh terrace, seen from the outside.
Fig. 7*b*. The same shell as fig. 7*a*, seen from the inside, showing the grooves.
Fig. 7*c*. Dorsal view of an individual from the seventh terrace, showing the reduced size of the beaks.

Fig. 8. Right valve from the lower deposit at Jaksi Klich.
Fig. 9. Right valve from the lower deposit at Jaman Klich.
Fig. 10. Left valve from the edge of the great lagoon at Abu Kir.
Fig. 11. Left valve from the western shore of Lake Mareotis.
Fig. 12. Left valve from the deposit of sub-fossil shells at Mandara.
Fig. 13. *Cardium edule* from the fresh-water lake at Ramleh (referred to in the text as Ramleh Lake No. 2), seen from its oral end.

All the figures were drawn by the Cambridge Scientific Instrument Company. They show the natural size of the shells and their colours as they appear when *wet*.

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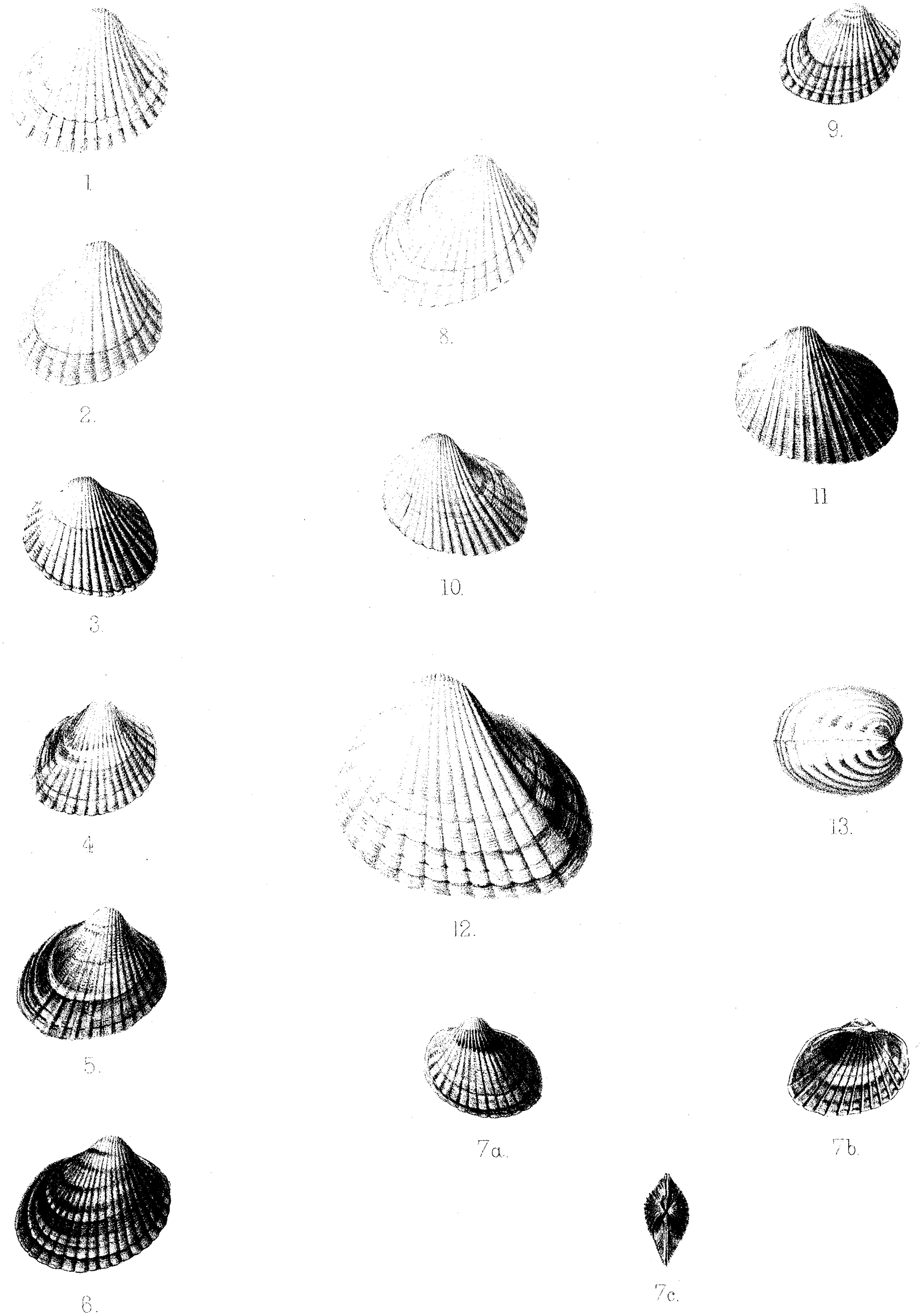

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