creasing amounts of lactic acid in milk not carefully handled might check the multiplication of *B. abortus*. The results showed that lactic acid added to the milk to bring the acidity to 0.4 per cent had no effect upon the multiplication of these organisms in the cream layer.

Bacillus abortus is characteristically an organism infecting cream. Since glycerine has been shown to be one of a very few food substances which it can utilize, and inasmuch as growth takes place slowly, with no apparent effect in litmus milk from which the cream has been removed, but is abundant in the cream layer of whole milk, with the production of acid, the facts suggest that the butter fat is broken down to obtain the glycerine and that the fatty acids thus liberated increase the acidity of the milk. Chemical determinations will be made to prove or disprove this theory, and the results will be included in a detailed report of the various bacteria occurring in the udder.

ZOOLOGY.—*On certain aspects of the bathymetrical distribution of the recent crinoids.* Austin H. Clark, National Museum.[1]

In bridging the gap which lies between the conclusions deduced from the facts gathered through the study of palæontology—which gives us a more or less detached series of instantaneous flat views of local littoral conditions covering an immense period of time—and the conclusions deduced from the facts accumulated through the study of marine zoölogy—which permits a prolonged examination of a single stereoscopic view—the two prime requisites are: (1) to discover some means of adding geographical and bathymetrical perspective to each of the palæontological pictures, and (2) to discover some means of calculating geological time based upon the internal characters of the recent animal groups without reference to their fossil representatives.

The comparison between recent marine types and their fossil representatives, while yielding results of the greatest value, is open to two objections: (1) it necessarily takes no account of the ability of many types to persist in specially restricted localities where they stand little or no chance of preservation, yet where

[1] Published with the permission of the Secretary of the Smithsonian Institution.

there is possible an unbroken organic continuity extending through long periods of geological time, as in the case of the elasipod holothurians, certain anemonies, and many annelids, known only from the Cambrian and from the recent seas; and (2) it fails to emphasize the significance of the gradual differentiation in the conditions of marine life as a result of which many organisms, originally living together under the same œcological surroundings, have during geological time travelled gradually, and increasingly, diverging paths, so that now they have become widely separated from their original companions, like the phyllopod crustaceans, certain marine worms, and the elasipod holothurians, all of which lived side by side in the Cambrian seas.

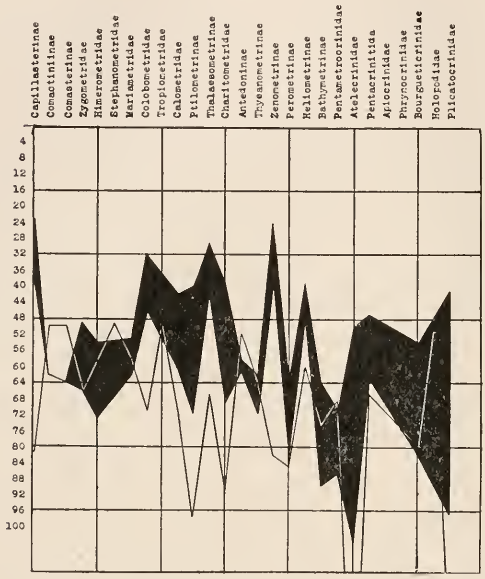

Fig. 1. Difference between the average range in depth, expressed as a percentage of the total range, and the average depth of habitat, expressed as a percentage of the mean depth of habitat, together with the average range in depth expressed as a percentage of the average depth of habitat.

As yet we have not sufficient information at hand to permit us to state with certainty that we shall ever be able to determine time factors of palæontological value from the study of the recent marine animals alone; but we have enough data to be able tentatively to suggest certain lines of procedure by which it may be possible in the future, when our knowledge of the present marine fauna is more detailed, to classify with more or less accuracy the various animal groups according to their comparative geological antiquity.

In the following lists are given for the subfamilies and higher groups of recent crinoids:

(1) The average range in depth expressed as a percentage of the total range in depth.

(2) The average depth of habitat expressed as a percentage of the mean depth of habitat.

(3) The average depth of habitat expressed as a percentage of the average range in depth.

	Average range in depth expressed in per cent of total range.	*Average depth of habitat expressed in per cent of mean depth.*	*Average depth of habitat expressed in per cent of average range.*
	per cent	*per cent*	*per cent*
ARTICULATA	14	41	144
PENTACRINITIDÆ	15	28	77
Comatulida	15	27	90
Oligophreata	10	15	70
Comasteridæ	18	23	63
Capillasterinæ	23	37	81
Comactiniinæ	62	62	50
Comasterinæ	64	64	50
Zygometridæ	49	66	66
Himerometridæ	54	73	66
*Stephanometridæ	100	100	49
Mariametridæ	53	62	58
Colobometridæ	32	46	71
*Tropiometridæ	100	100	50
Calometridæ	42	61	72
Thalassometridæ	25	34	68
Ptilometrinæ	40	72	98
Thalassometrinæ	29	42	67
Charitometridæ	39	69	91
Macrophreata	24	46	96
Antedonidæ	19	28	71
Antedoninæ	58	61	52
Thysanometrinæ	61	72	64
Zenometrinæ	24	39	82
Perometrinæ	63	82	85
Heliometrinæ	39	48	60
Bathymetrinæ	64	90	75
Pentametrocrinidæ	71	87	69
Atelecrinidæ	50	125	244
Pentacrinitida	47	63	67
APIOCRINIDÆ	()	()	()
PHRYNOCRINIDÆ	()	()	()
BOURGUETICRINIDÆ	54	82	80
*HOLOPODIDÆ	100	100	50
INADUNATA	41	97	145
PLICATOCRINIDÆ	41	97	145

It should, perhaps, be emphasized that, strictly speaking, the bathymetrical distribution of any animal type is of itself without biological significance. The only factor correlated directly with increase in depth, other than the decrease in illumination in the upper strata, is the increase in pressure, and increase of pressure has never been shown to exert any appreciable influence on the distribution of the higher invertebrate types either directly, or indirectly through the inhibition of the physiological processes.

The determining factor in the bathymetrical distribution of marine animals is the decrease of temperature with depth, and the study of the bathymetric distribution of any large group not directly dependent upon plants for food is in reality the indirect study of its thermal distribution. As our temperature observations in any one group are usually comparatively few, while our bathymetrical records are numerous, we are able to discuss to advantage the bathymetrical distribution of the component types in any unit, while at the same time we are unable to consider similarly the thermal distribution of the same types. But we must always remember that in discussing the bathymetrical distribution of a subfamily or higher group we are really considering its thermal distribution, and our bathymetric records may be readily transposed into thermal records by means of comparisons with tables showing the decrease in the temperature in the sea according to latitude and depth.

The average range in depth of the families of recent crinoids (excluding the Stephanometridæ, Tropiometridæ and Holopodidæ, monotypic, and the Apiocrinidæ and Phrynocrinidæ, insufficiently known), calculated as the average of the ranges of all of the included genera, represents a very varying percentage of their total range—from 23 per cent in the Capillasterinæ to 71 per cent in the Pentametrocrinidæ.

The sequence of the families according to the relation of the average to the total range in depth is as follows:

	per cent		*per cent*
Capillasterinæ	23	Atelecrinidæ	50
Zenometrinæ	24	Mariametridæ	53
Thalassometrinæ	29	Himerometridæ	54
Colobometridæ	32	Bourgueticrinidæ	54
Charitometridæ	39	Antedoninæ	58
Heliometrinæ	39	Thysanometrinæ	61
Ptilometrinæ	40	Comactiniinæ	62
Plicatocrinidæ	41	Perometrinæ	63
Calometridæ	42	Comasterinæ	64
Pentacrinitida	47	Bathymetrinæ	64
Zygometridæ	49	Pentametrocrinidæ	71

Average for all families 48 per cent.

From this list it is evident that there is no definite correspondence between the relation of the average to the total range and the systematic scheme, for closely related families, such as the Capillasterinæ and the Comasterinæ in the Oligophreata, and the Bathymetrinæ and the Zenometrinæ in the Macrophreata, occur at opposite extremes.

But it is interesting to observe that it is within the interval 41 per cent to 54 per cent, a range of only 27 per cent, or a little more than one-fourth, of the total range, that the families Plicatocrinidæ, Calometridæ, Pentacrinitida, Zygometridæ, Atelecrinidæ, Mariametridæ, Himerometridæ and Bourgueticrinidæ fall, these eight families, the average range of which is 48 per cent, or exactly that of all of the crinoid families together, including not only all of the stalked types, but also the Zygometridæ, the only comatulid family satisfactorily represented as a fossil, and the Atelecrinidæ, the only comatulid family in which the primitive basals persist in the adult. In other words, we find here all of the families of which we possess any definite palæontological history.

This would suggest that in ancient types still persisting the normal condition is for the average range of all the genera in any given family to be about one-half the total range of the same family, while in the later types there is a departure toward both extremes.

Within the first half of the list there are 7 oligophreate, 2 macrophreate and 2 stalked groups; within the second half 4 oligophreate, 6 macrophreate and 1 stalked groups.

The families toward the beginning of the list are chiefly families with a comparatively large temperature range; that is, in which one genus has extended itself into water considerably warmer or (usually) colder than the optimum for the family; while those toward the end of the list are largely families which cover a comparatively small temperature range, but which, however, may be confined either to cold or to warm water.

A family confined either to very cold or to very warm water would be in almost all cases a family of comparatively recent origin, for the coldness of the abysses and the warmth of the tropical littoral are themselves of comparatively recent origin. Also a family with a large temperature range would be of comparatively recent origin (or at least development) for the temperature of the ancient seas was fairly uniform.

Thus we should expect the more ancient types to occur at or near the centre of our series.

If we consider the families which are confined to a depth less than 1000 fathoms in contrast to those which occur below 1000 fathoms we find that the two groups are as follows:

Not occurring below 1000 fathoms.	*per cent*	*Ranging to below 1000 fathoms.*	*per cent*
Capillasterinæ	23	Zenometrinæ	24
Colobometridæ	32	Thalassometrinæ	29
Ptilometrinæ	40	Charitometrinæ	39
Calometridæ	42	Heliometrinæ	39
Zygometridæ	49	Plicatocrinidæ	41
Atelecrinidæ	50	Pentacrinitida	47
Mariametridæ	53	Bourgueticrinidæ	54
Himerometridæ	54	Bathymetrinæ	64
Antedoninæ	58	Pentametrocrinidæ	71
Thysanometrinæ	61		
Comactiniinæ	62		
Perometrinæ	63		
Comasterinæ	64		
Average	50	Average	45

Each group has approximately the same range, and approximately the same average, and neither appears to possess any distinctive characters.

Similarly if we compare the families the total range of which is less than 1000 fathoms with those in which it is greater we find that neither group possesses any marked characteristics.

Ranging more than 1000 fathoms.	per cent	*Ranging less than 1000 fathoms.*	per cent
Thalassometrinæ	29	Capillasterinæ	23
Charitometridæ	39	Comactiniinæ	62
Zenometrinæ	24	Comasterinæ	64
Heliometrinæ	39	Zygometridæ	49
Bathymetrinæ	64	Himerometridæ	54
Pentametrocrinidæ	71	Mariametridæ	53
Pentacrinitida	47	Colobometridæ	32
Bourgueticrinidæ	54	Calometridæ	42
Plicatocrinidæ	41	Ptilometrinæ	40
		Antedoninæ	58
		Thysanometrinæ	61
		Perometrinæ	63
		Atelecrinidæ	50
Average	45	Average	50

But if we consider the larger groups we are at once struck by the fact that of two comparable types the more highly specialized always shows a much lower figure than the more primitive, the figure for the former being only from 28 per cent to 41 per cent (with the average 35 per cent, or little more than one-third) of the figure for the latter. In the following list four strictly comparable groups are given:

More specialized	per cent	*More primitive*	per cent	per cent
Articulata	14	Inadunata	41	(34)
Pentacrinitidæ	15	Bourgueticrinidæ	54	(28)
Comatulida	15	Pentacrinitida	47	(32)
Oligophreata	10	Macrophreata	24	(41)

This is due to the great predominance of the more specialized and more recent types in the warm shallow water, from which they have not as yet spread into the deep sea, but from which, through their superior economic equipment, they have to a greater or lesser extent extirpated the preceding less specialized and more ancient forms which, persisting chiefly, therefore, in the deeper and consequently cooler and more uniform water, naturally show much greater generic ranges, and consequently higher percentages representing the mean range as compared with the total range of any one family.

In this connection it must be borne in mind that the crinoids are confined to clear water of a comparatively slight range in salinity and in composition, and with a very low maximum of silt. They therefore are unable to exist in many of the localities in which other ancient types, such for example as *Artemia*, *Xiphosura* and *Lingula*, find a safe refuge from more efficient competitors, with the result that each succeeding type is necessarily brought into direct and intimate contact with the greater part, or even all, of its predecessors.

A comparison between the average depth inhabited by each group (excluding the Stephanometridæ, Tropiometridæ and Holopodidæ, monotypic, and the Apiocrinidæ and Phrynocrinidæ, imperfectly understood) calculated as the average of the mean depth of all of the component genera (or higher groups), and the mean depth of each group as represented by the mean between its two extremes, expressed as a per cent obtained by dividing the former by the latter, gives the following figures:

	per cent		*per cent*
Antedonidæ	28	Zygometridæ	66
Capillasterinæ	37	Charitometridæ	69
Zenometrinæ	39	Ptilometrinæ	72
Thalassometrinæ	42	Thysanometrinæ	72
Colobometridæ	46	Himerometridæ	73
Heliometrinæ	48	Perometrinæ	82
Antedoninæ	61	Bourgueticrinidæ	82
Calometridæ	61	Pentametrocrinidæ	87
Mariametridæ	62	Bathymetrinæ	90
Comactiniinæ	62	Plicatocrinidæ	97
Comasterinæ	64	Atelecrinidæ	125
Average	66 per cent		

Contrasting older and less specialized with more recent and more specialized groups, we have:

More specialized	*per cent*	*More primitive*	*per cent*
Articulata	41	Inadunata	97
Pentacrinitidæ	28	Bourgueticrinidæ	82
Comatulida	27	Pentacrinitida	63
Oligophreata	15	Macrophreata	46

The groups including stalked species show the following relationship:

	per cent
Pentacrinitidæ	28
Pentacrinitida	63
Bourgueticrinidæ	82
Plicatocrinidæ	97

It is evident from the preceding two tables that the average depth of the habitat of all the genera of any group among the more highly specialized types is only a comparatively small fraction of the mean depth of the group as a whole, and that this fraction increases with the age and with the progressive decrease in the specialization of the group, reaching, in the chiefly palæozoic Inadunata, 97 per cent. It is, of course, also high in highly specialized groups confined to a very small range in depth, such as the Perometrinæ, Himerometridæ and Thysanometrinæ.

Any new or very vigorous group continually gives rise to new forms in the region most favourable for their existence, namely the littoral or sublittoral zones. The existence of a number of such juvenile types within a vigourous group therefore lowers the average depth of the group, which is consequently far less than the mean depth. But in the older mature or senile groups the formation of new types in the littoral is inhibited through group senility, and prevented by the occupation of the available economic territory by types derived from more specialized and more efficient stock. Therefore, theoretically, the older and less specialized the group the closer should the average depth approach the mean.

In the Atelecrinidæ the average depth exceeds the mean depth by 25 per cent; but we know only two genera of this family, one merely from a single specimen of a single species taken only once, in 907 fathoms. This family should therefore be disregarded in forming general conclusions.

Putting aside the Atelecrinidæ as insufficiently known, it appears to be demonstrable that no crinoid type ever originated in the deep sea, for if such had ever been the case the primarily abyssal types should be immediately disclosed through showing an average depth of habitat considerably greater than the mean depth.

The approximation of the average to the mean depth in the older types, taken in connection with what we know in regard to the association of genera in the older horizons, suggests that the older types not only possessed a very limited range of possible creative evolution and development, but that, in contrast to the later types, the new forms which they gave off were not adapted to meet special conditions, but rather to exist side by side with the parent types, utilizing the excess of available food. As would be expected, a small number of the groups of the present day (for instance the Comasteridæ) appear to be giving off, or attempting to give off, new types in this way.

The series of figures showing the average range expressed as a percentage of the average depth suggest that in the older and less specialized groups the tendency is for the average range to equal or to exceed the average depth of habitat, but in the more recent and more specialized types to be less. The figures (which are given in the following tables) are, however, not conclusive.

	per cent		*per cent*
Comasterinæ	50	Colobometridæ	71
Comactiniinæ	50	Calometridæ	72
Antedoninæ	52	Bathymetrinæ	75
Mariametridæ	58	Bourgueticrinidæ	80
Heliometrinæ	60	Capillasterinæ	81
Thysanometrinæ	64	Zenometrinæ	82
Himerometridæ	66	Perometrinæ	85
Zygometridæ	66	Charitometridæ	91
Pentacrinitida	67	Ptilometrinæ	98
Thalassometrinæ	67	Plicatocrinidæ	145
Pentametrocrinidæ	69	Atelecrinidæ	244
Average	68 per cent.		

Contrasting the more specialized with the less specialized types:

	per cent		*per cent*
Articulata	144	Inadunata	145
Pentacrinitidæ	77	Bourgueticrinidæ	80
Comatulida	90	Pentacrinitida	67
Oliophreata	70	Macrophreata	96
Average	95	Average	97

Considering the groups including stalked forms:

	per cent
Pentacrinitidæ	77
Pentacrinitida	67
Bourgueticrinidæ	80
Plicatocrinidæ	145