On two Sexual Races of *Asterina gibbosa* (Penn.)

True hermaphroditism, as well as intersexuality, which closely resembles it, must be studied in large samples of a population and not in a few isolated individuals. This was made particularly clear by researches on hermaphrodite Molluscs, where studies were initially made on *Ostrea* from extensive beds (SPÄRK[1], ORTON[2], COE[3]) and were later carried on, using the same principles, in other hermaphrodite Molluscs such as *Teredo* (COE[4], GRAVE[5]), *Venus* (LOOSANOFF[6]), *Patella* (ORTON[7], BACCI[8]), *Crepidula* (GOULD[9], ORTON[10], COE[11]) etc. Two main series of observations resulted from such researches, which could not have been disclosed by the examination of a few specimens only:—(1) in some hermaphrodite populations there are a few individuals which show one type only of sexual cells and remain always males or females;— (2) some hermaphrodite animals, which normally have completely male or female gonads, undergo sex reversal in a very short period of their existence and simulate therefore true gonochoristic animals. Although the first fact has been emphasized especially by COE, the existence of *true males* and *females* (COE[12]), or of *primary gonochorists* (BACCI[13]) in an otherwise hermaphrodite population, has been almost universally overlooked. The second series of observations points to the possible existence of many unknown *false gonochorists*, and more information regarding these may ultimately lead to a complete revision of our knowledge of the sexual conditions in certain invertebrate groups (BACCI[8]).

The writer has widely applied statistical methods to the study of these problems, basing his researches on the fact that in most hermaphrodites the functionally male and functionally female phases are sharply distinguishable during the breeding season. It is possible therefore to estimate the different proportions of individuals in the male and in the female phase of different ages and lengths, and consequently the periods when changes of sex phase take place in the different individuals. This method cannot, of course, be used alone, and the writer's results are clear only in variing degrees according to the animals studied. It has, in any case, an orientation value which permits us to place the problem of hermaphroditism on a genetical foundation.

The case of *Asterina gibbosa*, a small Asteroid living in shallow waters, is striking. CUÉNOT[14], studying it in Roscoff, demonstrated that *Asterina* is a protandric hermaphrodite, but LUDWIG[15] remarked that some old individuals in Naples are males and some young ones are females. In a later paper CUÉNOT[1] showed that in Naples and in Banjuls apparently gonochoristic and hermaphrodite animals are present together. This observation was long forgotten until the writer noticed the close resemblance of the sexual conditions of the Mediterranean *Asterina* with those observed in some Molluscs, especially *Patella* (BACCI[2]).

If we plot the number of individuals in the male phase against the number of individuals in each size class, we obtain curves such as those shown in Fig. 2, where the abscissa represents the arm length and the ordinate the percentage of individuals in the male phase. In a previous work on an *Asterina* population in Plymouth[3], the following main results were thus obtained:

(a) all the individuals of the population are protandric hermaphrodites;

(b) sex reversal takes place in individuals having an arm length between 9 and 16 mm.

The above facts are shown by the diagram in Fig. 2, left.

Histological study of the gonads showed that in the Plymouth population:

(c) the gonads appear ambisexual from a very early stage;

(d) the maturation of the male always precedes that of the female elements, which continue their growth during the male phase.

Thus the previous observations by CUÉNOT on the Atlantic race were confirmed.

LUDWIG's and CUÉNOT's observations on the Naples *Asterina* were made on individuals taken from a population living near S. Lucia, which is now almost extinct. The present observations have been made therefore on a population in Lake Fusaro near Naples, where individuals do not become so big as in S. Lucia, but are much more numerous. Observations made on a sample of 567 individuals collected in April showed that the population is composed of three different age groups; the first is formed by individuals born during the previous breeding season, with a mean arm length of 11–12 mm; the second by individuals of the second year (M between 17 and 18 mm); the third by three-year-old individuals of mean size 24 mm (Fig. 1, left). If we now divide the population into male-phase and female-phase individuals, we see that males are much more numerous (about 80%) in the first year group, less numerous (about 30%) in the second year group, and very scarce among individuals of the third year (Fig. 1, right). If we now plot the number of male phase individuals against the totals of each size class, we obtain a curve (Fig. 2, right) which differs widely from that obtained in the Plymouth *Asterina*. It is very irregular because sex changes take place *at different ages* and not *at one definite age*, as in the Plymouth *Asterina*. Additional samples of large size individuals were examined and showed about 15% of male-phase individuals. These data were not added to the illustrated sample in order to avoid an alteration in the proportion of the different age groups, as they result from a random collection.

The morphological aspect of the gonads of the Naples individuals is basically the same as in the Plymouth ones, but seemingly ripe oocytes are more frequent in

[1] R. SPÄRK, Rep. Dan. Biol. Stat. *30*, 5 (1924).
[2] J. H. ORTON, J. Mar. Biol. Assoc. *14*, 967 (1927).
[3] W. R. COE, Biol. Bull. *63*, 419 (1932); Bull. Scripps Inst. Oceanogr. *3*, 119 (1932); Ama. Nat. *68*, 236 (1934); Biol. Bull. *74*, 64 (1938).
[4] W. R. COE, Biol. Bull. *65*, 283 (1933); Science *80*, 192 (1934); Biol. Bull. *71*, 122 (1936); *84*, 178 (1943).
[5] B. H. GRAVE, Biol. Bull. *70*, 232 (1936); *82*, 438 (1942).
[6] V. L. LOOSANOFF, Biol. Bull. *72*, 389 and 406 (1937).
[7] J. H. ORTON, J. Mar. Biol. Assoc. *15*, 851 (1928).
[8] G. BACCI, Pubb. Staz. Zool. Napoli *21*, 183 (1947); *22*, 1 (1949).
[9] H. N. GOULD, J. Exper. Zool. *23*, 1 (1927); *29*, 113 (1919); Biol. Bull. *93*, 194 (1947).
[10] J. H. ORTON, Proc. R. Soc. London *81*B, 468 (1909); J. Mar. Biol. Assoc. *9*, 437 (1912).
[11] W. R. COE, J. Exper. Zool. *72*, 455 (1936); Biol. Bull. *75*, 274 (1938); J. Morph. *70*, 501 (1942); J. Exper. Zool. *108*, 155 (1948).
[12] W. R. COE, Quart. Rev. Biol. *18*, 154 (1943).
[13] G. BACCI, Arch. Zool. Ital. *34*, 49 (1949).
[14] L. CUÉNOT, Arch. Zool. Expér. Gen. (*2*) *5bis*, 1 (1887).
[15] H. LUDWIG, Fauna u. Flora des Golfes von Neapel *24* (1897).

[1] L. CUÉNOT, Zool. Anz. *21*, 273 (1898).
[2] G. BACCI, Pubb. Staz. Zool. Napoli *21*, 183 (1947); *22*, 1 (1949).
[3] G. BACCI, Arch. Zool. Ital. *34*, 49 (1949).

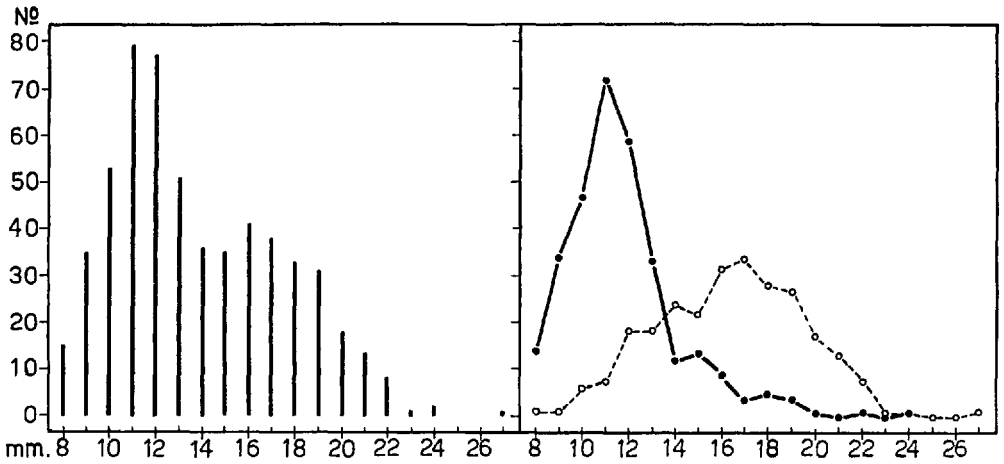

Fig. 1. – Frequencies of individuals of various arm lengths from a collection from L. Fusaro near Naples.

Left: total frequencies.

Right: frequencies of male-phase (continuous line) and female-phase individuals (broken line).

predominantly male gonads at Naples than they are at Plymouth, especially in the individuals of the older age groups. This fact may have considerable physiological consequences for the succession of sexual phases. Females of the smallest size classes have gonads with female and indifferent germ cells only. On the other hand, large males with very few small oocytes can be observed. The wide differences in the gonadal conditions in the Naples *Asterina* seem thus to provide the morphological basis for the differences in the succession of sexual phases in the various individuals of the population.

As already announced, the study of the different conditions in the Mediterranean and Atlantic *Asterina* was started in order to provide a basis for experimental research on sex determination (Montalenti[1], Bacci[2]). First, we wished to know whether young female phase individuals and old male phase individuals are, in Naples, genetically determined. Secondly, we wished to discover wether such determination might be due to a multiple-gene mechanism. It was found later that an answer to these general questions could better be provided by the Polychæte worm *Ophryotrocha puerilis*, which has a much speedier rate of reproduction and, moreover, has been so well investigated under certain aspects by Hartmann and his collaborators[3]. The first results on researches on *Ophryotrocha* will be published shortly.

In this preliminary note the writer wishes to point out particularly the wide distribution of sexually *unbalanced hermaphrodites* (Bacci[1]), which are exemplified by *Ophryotrocha*, *Grubea* and *Exogone* among Polychætes[2], by some Oysters and *Teredo* among Lamellibranchs, by *Patella* and *Crepidula* among Gastropods, and by Naples *Asterina* among Echinoderms. It is interesting to remark that many of these forms are false gonochorists or cryptohermaphrodite animals. These unbalanced hermaphrodites may be taxonomically allied to *balanced hermaphrodites*, that is to hermaphrodites that change sex at a definite age (Plymouth *Asterina* type). This is the situation outlined above.

The wide variety of the expression of sexuality in different hermaphrodite individuals and different populations, shows that hermaphroditism cannot properly be regarded as a uniform and neutral condition where external factors exert unchecked their different influences. On the contrary, various specifically reacting systems, in which racial and genetical factors must be taken into account, seem to play a fundamental role.

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Zoological Station of Naples, May 25, 1950.

Zusammenfassung

Mit statistischen Methoden wird für *Asterina gibbosa* ein in Plymouth stattfindender Geschlechtsumschlag

[1] G. Montalenti, Conference at the XIII Congress of Zoology in Paris (1948) (in print).

[2] G. Bacci, Pubb. Staz. Zool. Napoli *21*, 183 (1947); *22*, 1 (1949).

[3] M. Hartmann *et al.*, Zool. Jb. *56*, 389 (1936); *58*, 551 (1938); *60*, 1 (1940).

[1] G. Bacci, Arch. Zool. Ital. *34*, 49 (1949).

[2] In a paper by Abeloos (C. R. Acad, Sci. *231*, 179, 1950) similar sex conditions have been described also for *Platynereis dumerili*.

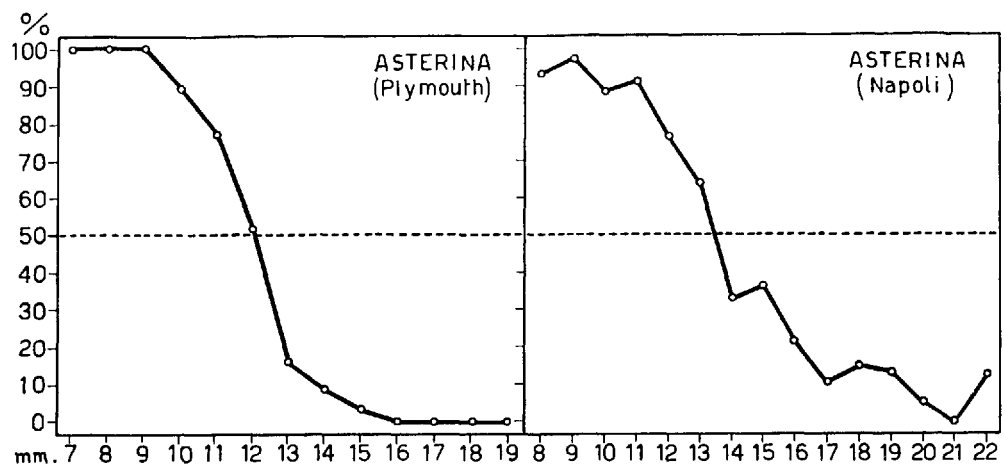

Fig. 2. – Percentages of male-phase individuals.

Left: Plymouth *Asterina*.

Right: Naples *Asterina*.

auf einer bestimmten Altersstufe bewiesen. In Neapel findet der Geschlechtsumschlag auf verschiedenen Altersstufen statt. Die Individuen der ersteren Art können als «ausgeglichene» (balanced) Zwitter, die der letzteren Art als «unausgeglichene» (unbalanced) Zwitter angesehen werden. Der Verfasser nimmt an, daß man den Zustand des ausgeglichenen Zwittertums auf die Segregation multipler Geschlechtsfaktoren zurückführen könne.

Influence du jeûne sur les oscillations nycthémérales du fer sérique

Dans leur monographie parue en 1937, HEILMEYER et PLÖTNER[1], se demandant s'il existe des variations physiologiques du taux de fer sérique, citent les expériences de leur élève ANTON qui constate d'une part une élévation de la sidérémie de 13% après 12 heures et de 25% après 24 heures chez un sujet à jeun et d'autre part une chute de la sidérémie atteignant 20% après l'absorption d'épinards, aliment pourtant riche en fer. Ils citent également un travail de LOCKE, MAIN et ROSBACH[2] qui signalent une élévation identique de la sidérémie après 24 heures de jeûne. Finalement HEILMEYER et PLÖTNER n'accordent pas d'importance à ces variations qui n'excèdent pas les différences de taux de fer sérique existant d'un jour à l'autre.

Les variations constantes de la sidérémie au cours du nycthémère sont signalées pour la première fois en 1941 par VALQUIST[3]. A la même époque, HEMMELER[4] constate également des taux différents au cours de la journée, plus élevés le matin que le soir. Il attribue ces variations de la sidérémie à la prédominance alternée du vague et du sympathique. La vagotonie de la convalescence de l'hépatite épidémique, qui se manifeste en outre par une bradycardie et une leucopénie avec lymphocytose, s'accompagne d'oscillations nycthémérales plus amples, dues surtout à l'élévation du taux de fer sérique du matin. Depuis lors, HEMMELER a pu préciser cette conception par l'étude de nombreux cas de troubles neuro-végétatifs. Recherchant la cause de ces variations, il admet qu'elles ne dépendent ni de la température du corps, ni du travail musculaire, mais uniquement de l'alternance de tonus des systèmes vague et sympathique dont l'équilibre est dominé par le sommeil; l'élévation du taux de fer sérique du matin est en relation avec la durée et l'intensité du sommeil. Pour expliquer le mécanisme de cette régulation nycthémérale, HEMMELER envisage plusieurs hypothèses telles que le rythme de stockage du fer, l'excitation diurne de l'hématopoïèse sous l'influence du sympathique avec utilisation de fer, l'augmentation des besoins de fer de toutes les cellules de l'organisme pendant l'activité, le passage du fer de la paroi intestinale aux organes de réserve pendant la nuit, les variations de taux de la protéine sérique qui lie le fer. Comme aucune de ces hypothèses ne donne satisfaction, il envisage la possibilité d'une relation avec les variations du p_H du sang.

[1] L. HEILMEYER und K. PLÖTNER, *Das Serumeisen und die Eisenmangelkrankheit* (Fischer, Jena 1937).

[2] A. LOCKE, E. R. MAIN, and D. O. ROSBASH, cités par L. HEILMEYER et K. PLÖTNER.

[3] B. VALQUIST, Acta Paediatr. *28*, suppl. V (1941).

[4] G. HEMMELER, Schweiz. med. Wschr. *35*, 1056 (1943); Helv. med. acta *11*, 201 (1944); Cah. mens. Méd. *1945*, N° 2, 42; *1946*, N° 2, 216; *1949/50*, N° 5, 363.

HOYER[1], qui a également étudié les oscillations nycthémérales du taux de fer sérique, ne constate aucune relation avec l'hydrémie du sang, l'exposition à la lumière, l'effort et le jeûne; lui aussi conclut que seul le sommeil a une influence sur les oscillations physiologiques de la sidérémie.

Si le sommeil est indispensable au rythme normal du nycthémère, la prise d'aliments nous a paru tout aussi importante, caractérisant, avec l'effort intellectuel et physique, l'activité diurne. Aussi avons-nous repris cette question en dosant le fer sérique le matin et le soir, lors d'une alimentation normale et lors d'une journée de jeûne. Les prises de sang du matin ont été faites entre 8 et 9 heures et celles du soir, 9 heures plus tard, entre 17 et 18 heures.

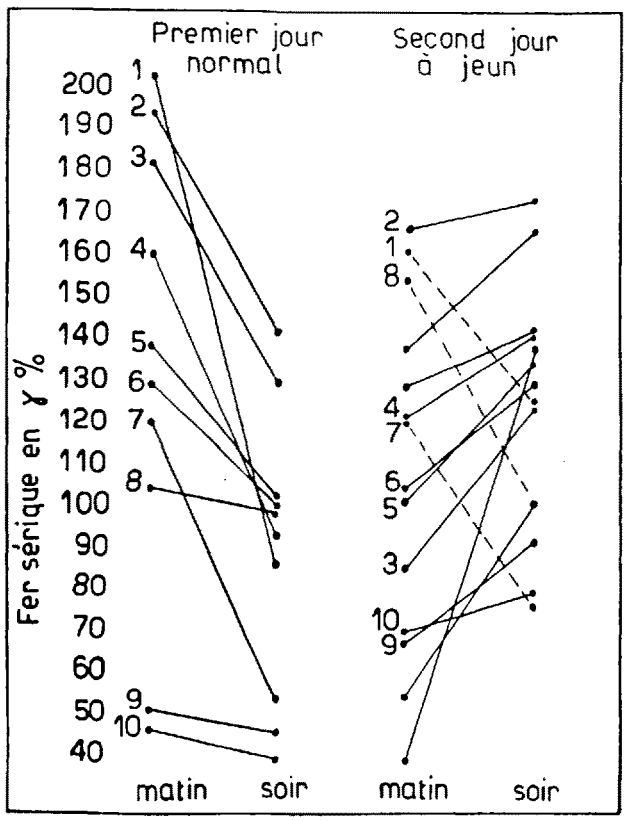

Fig. 1.

Nous avons constaté que *le taux de fer sérique s'élève en général au cours de la journée chez le sujet resté à jeun* (fig. 1).

Nous avons relevé un second fait intéressant: *l'élévation du taux de fer sérique qui accompagne le jeûne, est nettement plus marquée chez les sujets ayant une activité normale que chez ceux qui sont au repos.* Nous avons reporté sur la fig. 2 les amplitudes d'oscillation de la sidérémie au cours de la journée des cas présentés sur les fig. 1 et 3, en groupant à gauche les sujets actifs et à droite les sujets au repos.

Le taux de fer sérique des sujets actifs s'élève dans tous les cas pendant une journée de jeûne. Dès le réveil et jusqu'à la prise de sang du soir (entre 17 et 18 heures) les sujets n'ont absolument rien mangé et n'ont bu qu'un verre d'eau au plus, à midi.

[1] K. HOYER, *Serumjernets, fysiologiske variation* (Universitetsforlaget I Aarhus, Copenhague, 1946).