been greatly strengthened by the closely opposed feathers. For several minutes the hawk thus flew alongside of the boat, with quite regular periods of flapping and soaring; then, suddenly shifting its course, it circled out, soaring, passing over my head at a distance of about twenty feet. I could then see plainly that the primaries of one wing (right) were interlocked—the condition of the other wing I had not time to observe.

My conclusion, therefore, is that the interlocking of the primaries of hawks takes place, as Mr. Trowbridge has shown, under the conditions of soaring in the face of a strong wind.

BASHFORD DEAN.

RINKAI JIKENJO, MISAKI-MIURA, JAPAN,
September 3, 1903.

SPECIAL ARTICLES.

THE CHROMOSOMES IN RELATION TO THE DETERMINATION OF SEX IN INSECTS.

MATERIAL procured during the past summer demonstrates with great clearness that the sexes of Hemiptera show constant and characteristic differences in the chromosome groups, which are of such a nature as to leave no doubt that a definite connection of some kind between the chromosomes and the determination of sex exists in these animals. These differences are of two types. In one of these, the cells of the female possess one more chromosome than those of the male; in the other, both sexes possess the same number of chromosomes, but one of the chromosomes in the male is much smaller than the corresponding one in the female (which is in agreement with the observations of Stevens on the beetle *Tenebrio*). These types may conveniently be designated as *A* and *B*, respectively. The essential facts have been determined in three genera of each type, namely, (type *A*) *Protenor belfragei*, *Anasa tristis* and *Alydus pilosulus*, and (type *B*) *Lygæus turcicus*, *Euschistus fissilis* and *Cœnus delius*. The chromosome groups have been examined in the dividing oogonia and ovarian follicle cells of the female and in the dividing spermatogonia and investing cells of the testis in case of the male.

Type *A* includes those forms in which (as has been known since Henking's paper of 1890 on *Pyrrochoris*) the spermatozoa are of two classes, one of which contains one more chromosome (the so-called 'accessory' or heterotropic chromosome) than the other. In this type the somatic number of chromosomes in the female is an even one, while the somatic number in the male is one less (hence an odd number) the actual numbers being in *Protenor* and *Alydus* ♀ 14, ♂ 13, and in *Anasa* ♀ 22, ♂ 21. A study of the chromosome groups in the two sexes brings out the following additional facts. In the cells of the female all the chromosomes may be arranged two by two to form pairs, each consisting of two chromosomes of equal size, as is most obvious in the beautiful chromosome groups of *Protenor*, where the size differences of the chromosomes are very marked. In the male all the chromosomes may be thus symmetrically paired with the exception of one which is without a mate. This chromosome is the 'accessory' or heterotropic one; and it is a consequence of its unpaired character that it passes into only one half of the spermatozoa.

In type *B* all of the spermatozoa contain the same number of chromosomes (half the somatic number in both sexes), but they are, nevertheless, of two classes, one of which contains a large and one a small 'idiochromosome.' Both sexes have the same somatic number of chromosomes (fourteen in the three examples mentioned above), but differ as follows: In the cells of the female (oogonia and follicle-cells) all of the chromosomes may, as in type *A*, be arranged two by two in equal pairs, and a small idiochromosome is not present. In the cells of the male all but two may be thus equally paired. These two are the unequal idiochromosomes, and during the maturation process they are so distributed that the small one passes into one half of the spermatozoa, the large one into the other half.

These facts admit, I believe, of but one interpretation. Since all of the chromosomes in the female (oogonia) may be symmetrically paired, there can be no doubt that synapsis in this sex gives rise to the reduced number of symmetrical bivalents, and that consequently all of the eggs receive the same number of chromosomes. This number (eleven in *Anasa*, seven in *Protenor* or *Alydus*) is the same as that present in those spermatozoa that contain the 'accessory' chromosome. It is evident that both forms of spermatozoa are functional, and that in type *A* females are produced from eggs fertilized by spermatozoa that contain the 'accessory' chromosome, while males are produced from eggs fertilized by spermatozoa that lack this chromosome (the reverse of the conjecture made by McClung). Thus if n be the somatic number in the female $n/2$ is the number in all of the matured eggs, $n/2$ the number in one half of the spermatozoa (namely, those that contain the 'accessory'), and $n/2 - 1$ the number in the other half. Accordingly:

In fertilization

$$\text{Egg } \frac{n}{2} + \text{spermatozoon } \frac{n}{2} = n \text{ (female).}$$

$$\text{Egg } \frac{n}{2} + \text{spermatozoon } \frac{n}{2} - 1 = n - 1 \text{ (male).}$$

The validity of this interpretation is completely established by the case of *Protenor*, where, as was first shown by Montgomery, the 'accessory' is at every period unmistakably recognizable by its great size. The spermatogonial divisions invariably show but one such large chromosome, while an equal pair of exactly similar chromosomes appear in the oogonial divisions. One of these in the female must have been derived in fertilization from the egg-nucleus, the other (obviously the 'accessory') from the sperm-nucleus. It is evident, therefore, that all of the matured eggs must before fertilization contain a chromosome that is the maternal mate of the 'accessory' of the male, and that females are produced from eggs fertilized by spermatozoa that contain a similar group (*i. e.*, those containing the 'accessory'). The presence of but one large chromosome (the 'accessory') in the somatic nuclei of the male can only mean that males arise from eggs fertilized by spermatozoa that lack such a chromosome, and that the single 'accessory' of the male is derived in fertilization from the egg nucleus.

In type *B* all of the eggs must contain a chromosome corresponding to the large idiochromosome of the male. Upon fertilization by a spermatozoon containing the large idiochromosome a female is produced, while fertilization by a spermatozoon containing the small one produces a male.

The two types distinguished above may readily be reduced to one; for if the small idiochromosome of type *B* be supposed to disappear, the phenomena become identical with those in type *A*. There can be little doubt that such has been the actual origin of the latter type, and that the 'accessory' chromosome was originally a large idiochromosome, its smaller mate having vanished. The unpaired character of the 'accessory' chromosome thus finds a complete explanation, and its behavior loses its apparently anomalous character.

The foregoing facts irresistibly lead to the conclusion that a causal connection of some kind exists between the chromosomes and the determination of sex; and at first thought they naturally suggest the conclusion that the idiochromosomes and heterotropic chromosomes are actually sex determinants, as was conjectured by McClung in case of the 'accessory' chromosome. Analysis will show, however, that great, if not insuperable, difficulties are encountered by any form of the assumption that these chromosomes are specifically male or female sex determinants. It is more probable, for reasons that will be set forth hereafter, that the difference between eggs and spermatozoa is primarily due to differences of degree or intensity, rather than of kind, in the activity of the chromosome groups in the two sexes; and we may here find a clue to a general theory of sex determination that will accord with the facts observed in hemiptera. A significant fact that bears on this question is that in both types the two sexes differ in respect to the behavior of the idiochromosomes or 'accessory' chromosomes during the synaptic and growth periods, these chromosomes assuming in the male the form of condensed chromosome nucleoli, while in the female they remain, like the other chromosomes, in a diffused condition. This indicates that during these periods these chromosomes play a more active part in the metabolism of the cell in the female than in the male. The primary factor in the differentiation of the germ cells may, therefore, be a matter of metabolism, perhaps one of growth.

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October 3, 1905.

THE GEOGRAPHICAL DISTRIBUTION OF THE BELL-TOADS.

AT the meeting of the Association of American Geographers in Philadelphia, December 29, 1904, I read a paper on the 'Geographical Distribution of the Discoglossoid Toads in the Light of Ancient Land Connections,'[1] in which I made the following statement:

> All indications point towards the country southeast[2] of the Himalayas as the original center of the radiation of the discoglossoid toads, as well as of their near relations the pelodytoid toads. The former are not now found in this region; but that fact weighs but little in view of *Ascaphus* having remained unknown on this continent till 1899, and thus far known only from a single specimen.

This statement assumes almost the character of a prophesy in view of the fact that Dr. G. A. Boulenger, a month later, announced the discovery of a bell-toad (*Bombina*) in the province of Yunnan, near Tong Chuan Fu, at an altitude of about 6,000 feet. This new species, *Bombina maxima* (Boulenger), thus indicates the central form from which both the European and the Korean bell-toads have sprung. Confirmatory of this, it may be mentioned that the new species in most essentials agrees with *Bombina orientalis* and *B. salsa,* the latter being the more southern and, in my opinion, the more primitive of the two European species.

The discovery of this species lends further weight to the theory propounded by me for the migration of this genus[3] in the following terms:

> Of the various theories which might be advanced in order to explain this distribution it seems most reasonable at present to select the one which presupposes a comparatively late immigration of this genus from southeastern Asia into Europe after a late Miocene land connection had been established—a theory which would account for the failure of these toads to reach Spain on the one side and Japan on the other.

The supposed original central form in southeastern Asia has now been found, and the theory to a great extent verified almost at the very moment of its publication.

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WASHINGTON, D. C.,
August 31, 1905.

[1] Résumé published in *Amer. Geogr. Soc. Bull.,* XXXVII., February, 1905, pp. 91–93.

[2] In the résumé quoted 'southwest' through a lapsus or misprint.

[3] *L. c.,* p. 93.

HYDRATION CAVES.

THE conclusions set forth in my paper 'On the Origin of the Caves of the Island of Put-in-Bay, Lake Erie,'[1] were based mainly upon observations, made last year, in Perry's Cave. The conditions, however, which exist on the island, led me to believe that the hydration of anhydrite has played an important rôle in the formation of all the caves. At that time I was able to visit three of the four caves open to the public, namely, Perry's, Kindt's and the Crystal Caves. Concerning the other cave, Daussa's, the following statement was, however, made in the paper referred to above: "But inasmuch as this cave is in very close proximity to Perry's Cave, the above explanation, no doubt, also applies to it."

During another visit to the island several weeks ago, Daussa's Cave was visited and it was noted that the fitting of the roof and floor is to be observed fully as well in this cave as in Perry's, leaving, therefore, no doubt whatever as to the origin of the same.

From the general topographic features of the island and the mainland in that vicinity —especially that which is known as Catawba Island—one is led to believe that careful searching should reveal more of these interesting caves, which differ so much in their origin and structure from the ordinary solution cave, that I would suggest they be termed

[1] *American Geologist,* XXXV., 167–171, March, 1905.