PREVIOUS LITERATURE
SALIVARY GLAND CHROMOSOMES

Out of a total of 2,680 species belonging to 33 genera and 120 subgenera of the family Culicidae (Stone, 1967), chromosomal information for about 100 species only, is available. This group has, however, now a unique and unmatched position in the field of cytogenetics for having just 6 as the diploid number of chromosomes, the only exception being that of the genus Corethra (2n = 8).

Some eighteen years ago Kitzmiller (1953) wrote in his first review of literature on the genetics and cytogenetics of mosquitoes, "It is apparent to any one who is even cursorily familiar with the literature on mosquitoes, that non-existence of mosquito-genetic information constitutes perhaps the largest single deficiency in the tremendous amount of information which has been assembled concerning the family Culicidae."

Frizzi (1947a-d, 1948, 1953a, b, and 1958a-c), a pioneer worker from Italy, has a commendable work to his credit concerning salivary chromosomes of the European Anopheles maculipennis complex which consists of several sibling species. He in 1947, published a salivary chromosome
map of *Anopheles maculipennis* var. *atroparvus* and this map is now accepted as the standard for the *Maculipennis* complex. He also found that better chromosome preparations could be obtained by giving a rich diet to the larvae and that the natural populations exhibited variations in the banding pattern of their salivary chromosomes.

In the same year he also established that the salivary chromosomes of varieties like *elutus*, *messeae*, *typicus* and *thiel* bore the diagnostic features and landmarks identical with those of *A. atroparvus* except for certain chromosomal aberrations. He, therefore, grouped all of them under the *Maculipennis* complex. The same was found true for the variety *labranchiae*.

Frizzi (1953a) worked on three species, *A. aquasalis*, *A. claviger* and *A. quadrimaculatus* and traced the phylogenetic relationships between *A. freeborni* and *A. atroparvus* (Frizzi and DeCarli, 1954). A similar sequence of bands on the X-chromosome of *A. quadrimaculatus* and *A. maculipennis* made him to suggest a place for *quadrimaculatus* in the *Maculipennis* complex.

*A. typicus*, *A. messeae* and *A. subalpinus*, which were, otherwise, quite indistinct morphologically, were sorted out by Frizzi (1958) on the basis of structural differences
in their salivary chromosomes. Some similar views were earlier held by Lewis (1955), Green (1955) and White (1957).

The work on mosquitoes actually commenced in an organized way with the publication of a monograph by Kitzmiller (1953) on "Mosquito genetics and cytogenetics." Until that time, genetic studies on these insects had been desultory and incidental to other research objectives. The development of insecticide resistance in the decade between 1945 and 1955 acted as a major stimulus for mosquito cytogenetics. Indeed insecticide resistance brought about an awareness about this type of research programme.

The first indications of a possible correlation between chromosome changes and insecticide resistance were given by Holstein (1957) who found a greater variety of inversions in a Dieldrin-resistant strain of A. gambiae than in a susceptible strain of the same species.

While mapping Anopheles albimanus, Hobbs (1962) tried to find out the probability of chromosomal aberrations due to the use of Dieldrin and DDT, but could not derive any relationship between the two. Mason and Brown (1963), while studying the same effect in A. quadrimaculatus, stated that insecticide resistance in this species is not, in any way, related to the appearance of certain autosomal inversions which they encountered.
Apart from the problem of insecticide resistance, the salivary chromosome studies provided valuable clues in solving problems of cytotoxicentric importance. Schreiber (1957) and Schreiber and Guedes (1959a,b, 1960, 1961) worked on Brazilian anophelines belonging to the subgenus *Nyssorhynchus* and stated that a large number of translocations, heterozygous inversions and asynaptic regions in salivary chromosomes serve as cytotoxicentric aids in understanding the speciation of a subgenus.

French, Baker and Kitzmiller (1962) published a special technique for the study of mosquito chromosomes. This largely solved some of the technical difficulties peculiar to the salivary chromosome preparations.

In the succeeding years researches were mainly aimed at producing the salivary chromosome maps for the various vector and non-vector anopheline species. Consequently at present we have maps available for the following:

*Anopheles aquasalis* (Frizzi and Ricciardi, 1955)
*A. gambiae* (Frizzi and Holstein, 1956; Caluzzi and Sabatini, 1967)
*A. stephensi* (Rishikesh, 1955, 1959b; Sharma et al., 1966; Sharma et al., 1969)
*A. albimanus* (Hobbs, 1962)
*A. freeborni* (Kitzmiller and Baker, 1963)
punetipennis (Baker and Kitzmiller, 1963a, 1964a)
A. aztecus (Baker and Kitzmiller, 1964b)
A. earlei (Kitzmiller and Baker, 1965)
A. occidentalis (Baker and Kitzmiller, 1965)
A. quadrimaculatus (Klassen et al., 1965)
A. pseudopunctipennis pseudopunctipennis (Baker et al., 1965)
A. hectoris (Baker et al., 1966)
A. neomaculipalpus (Kitzmiller et al., 1966)
A. vestitipennis (Chowdaiah et al., 1966)
A. algeriensis (Kitzmiller, 1966)
A. pulcherrimus (Baker et al., 1968)
A. fluviatilis (Sharma, Mittal and Chaudhry, 1968b)
A. maculatus (Sharma, Mittal and Sharma, 1968b)
A. splendidus (Sharma, Mittal and Pasahan, 1968b)
A. atropos (Kreutzer et al., 1969)
A. barbirostris (Chowdaiah et al., 1970)
A. cruciens (Kreutzer et al., 1970)
A. bradleyi (Kreutzer et al., 1970)

In each of the above mentioned papers, salivary chromosomes have been described in detail giving description of each of their arms. Pictures of the chromosome comple­ments are given and the aberrations discussed. A detailed standard chromosome map has been proposed for each species.
and homologies, based on chromosome comparisons, have been derived among different species.

Relatively less progress has been made in groups other than Anopheles. This is probably due to the fact that the chromosomes in Anopheles are shorter, spread more easily and in general are better to work with than those of either Culex (Kitzmiller, 1954; Kitzmiller and Keppler, 1961), Aedes or Mansonia.

Although Culex pipiens pipiens was the starting point for research (Stevens, 1910, 1911) on other genera and species, yet no map was published for this or any other species excepting, of course, those belonging to the genus Anopheles. Kitzmiller and Clark (1952) studied the salivary chromosomes in Culex mosquitoes and Kitzmiller and Keppler (1961) published only an abstract concerning certain details of the salivary chromosome map of Culex p. pipiens. The first map for any member of the genus Culex was published on Culex p. pipiens by Bennhöfer (1968) followed by another on Culex pipiens fatigans by Sharma et al. (1969).

GETM CELL CHROMOSOMES

Regarding the structure and behaviour of the mitotic and meiotic chromosomes, considerable information is on record. The earliest account is that of Stevens (1910, 1911) who studied the course of spermatogenesis in Culex pipiens
and observed the diploid number of chromosomes to be six. She also gave a brief account of spermatogenesis in *Culex tarsalis, Culiseta incidunt* and *Anopheles punctipennis*. Much of the later work done by the various other workers dealt mainly with two species complexes viz. *Culex pipiens* complex; Taylor, 1914; Whiting, 1917; Hance, 1917; Moffet, 1936; Berger, 1938; Grell, 1946a, b and Kitzmiller, 1954) and *Anopheles maculipennis* complex (Frizzi, 1947a, b, c; Frizzi, 1953a, b and Frizzi and Kitzmiller, 1959). Similar work has also been done on *Theobaldia longiareolata* and *Corethra plumicornis* (Callan and Montalenti, 1947).

Out of a total of 29 genera in the family Culicinae only in ten have one or more karyotypes been studied.

Moffet (1936), Berger (1936, 1938) and Grell (1946a, b) studied the phenomena of somatic pairing and chiasma formation in mosquitoes.

Later Akestien (1962), while studying the karyotypes in several species of mosquitoes, cited several cases of somatic pairing and chiasma formation.

As early as 1947, Gillchrist and Haldane studied the mechanism of sex linkage and sex determination in *Culex* when they noted the absence of sex chromosomes. According to them, the males appeared due to a dominant gene present in
the chromosomes.

An exhaustive account of the previous work including important techniques for a study of mosquito chromosomes and the compilation of considerable new material has been given by Breland and his team of workers (Breland, 1959, 1960, 1961, 1963; Breland and Gassner, 1961, 1962; Breland and Reimann, 1961; Long, 1961). Breland's 1961 publication is especially valuable as it gives the first cytogenetic knowledge of 16 additional species. He has discussed in detail, with suitable photographs, the mitotic and/or meiotic chromosomes of seven species of Culex, seven of Aedes, two of Orthopodomyia, three of Prosophsia and one each of Anopheles, Haemagogus, Culiseta, Toxorhynchites and Uranotaenia. In addition, the paper also contains the process of mitosis in Culex salinarius, and metaphase karyotypes of the other species. In all the species studied by him, the diploid number of chromosomes was found to be six and they were all metacentric chromosomes.

An interesting series of papers from Schreiber's laboratory in Belo Horizonte (Schreiber and Memoria, 1957; Schreiber and Guedes, 1959a,b, 1960, 1961; Guedes et al., 1957, 1962) indicates that in South American Nyssorhynchus different species reveal a progressive loss of material forming
the X chromosome as a result of which it becomes smaller and smaller. This condition was reported for Anopheles aqussalis, noroestensis, argyritarsus, darlingi and strodei.

Rai and Craig (1961) have reported mitotic metaphase from five species of Aedes and one each from Corethra, Culex and Anopheles. The usual diploid number of 6 (except Corethra: 2n = 8) was found by them. They agreed with Breland in locating one short pair and two relatively longer ones in Aedes.

Based on the length and the position of the centromere, the individual chromosome was numbered as I, II and III by Rai (1963a). He worked on 12 species viz. Anopheles quadrimaculatus, Wyeomyia smithii, Culex pipiens pipiens, C. restuans, C. territans, Aedes togi, Ae. vexans, Ae. albopictus, Ae. aegypti, Ae. atropalpus, Ae. stimulans and an unidentified species of Corethra. Chromosome I is the smallest and metacentric except in Culex p. pipiens. It is also dimorphic in Corethra and quadrimaculatus. Number II is the next larger and is submetacentric in 3 species of Aedes and metacentric in the rest. Chromosome III is the largest and submetacentric in Ae. stimulans and metacentric in all the rest. Similar observations were made by Rai (1964) on Aedes mascarensis, Ae. polynesiensis, Ae. sierrensis, Ae. simpsoni and Eretmapodites chrysogaster, in all of which the diploid number was six.
In the last one decade or so the karyotype studies have mainly centred around the genus *Anopheles* and valuable information has come up regarding the chromosomes at metaphase in the following species:

- *A. aquasalis* (Frizzi, 1953a; Frizzi and Ricciardi, 1955)
- *A. claviger* (Frizzi, 1953a)
- *A. freeborni* (Frizzi and DeCarli, 1954; Kitzmiller and Baker, 1963)
- *A. albimanus* (Frizzi and Ricciardi, 1955; Hobbs, 1962)
- *A. gambiae* (Frizzi and Holstein, 1956)
- *A. stephensi* (Pisnikes, 1959a)
- *A. quadrimaculatus* (Frizzi, 1953a; Kitzmiller and French, 1961; K, 1961, 1963a; Klassen et al., 1965)
- *A. pseudopunctipennis pseudopunctipennis* (Breland, 1961)
- *A. azteca* (Baker and Kitzmiller, 1964b)
- *A. neomaculipalpus* (Kitzmiller and Chowdaiah, 1965)
- *A. occidentalis* (Baker and Kitzmiller, 1965)
- *A. earlei* (Kitzmiller and Baker, 1965)
- *A. neomaculipalpus* (Kitzmiller et al., 1966)
- *A. vestitipennis* (Chowdaiah et al., 1966)
- *A. hectoris* (Baker et al., 1966)
- *A. algeriensis* (Kitzmiller, 1966)
- *A. fluviatilis* (Sharma, Mittal and Chaudhry, 1968a; Avirachen et al., 1969)
- *A. maculatus* (Sharma, Mittal and Sharma, 1968a)
- *A. splendidus* (Sharma, Mittal and Pasahan, 1968a)

Recently a comparative account of the karyotypes of A. fluviatilis, A. maculatus and A. splendidus has also been published by Sharma et al. (1970).

In all the above mentioned species the metaphase configurations have been found to exhibit the usual picture common to all anophelines in general, that is — two pairs of metacentric autosomes, with slight indications of different arm lengths and a pair of subtelocentric/acrocentric heterosomes. Similar investigations were carried out by Mukherjee et al. (1966) wherein they gave a comparative account of the karyotypes in 4 genera and 19 species of mosquitoes present in Utah. The course of mitosis and meiosis was also studied in Culex p. fatigans (Sharma, Mittal and Kaur, 1967) and Aedes aegypti (Sharma, Mittal and Toor, 1967).

Baker and Aslamkhan (1969) published a valuable account of their investigations on the karyotypes of some of the Asian mosquitoes of the subfamily Culicinae in which they have described the chromosome complements of 3 species of Aedes, 1 species of Armigeres and 11 species of Culex. While the karyotypes of 12 of these species were in conformity with those described earlier in the previous work, new karyotypes for 3 species, Culex (Lutzia) fuscatus, Culex
(Lutzia) raptor and Culex (Culex) gelidus, were described. The chromosome II, according to them, is considerably shorter and approximates chromosome I.

From the studies made so far it has been seen that in the family Culicidae three types of karyotypes have been found. The first of these is exhibited by the European punctipennis, maculipennis, freeborni, occidentalis and earlei. The small arm of the Y-chromosome in them is slightly smaller than the small arm of the X-chromosome. The second type has been exhibited by A. quadrimaculatus, wherein Y is considerably smaller than the X and is either metacentric or slightly submetacentric. The third type of karyotype is represented by A. punctipennis in which two types of X-chromosomes were found, one with equal and the other with unequal arms.

Aslamkhan and Baker (1969) have reported the karyotypes of 5 species of Anopheles, 3 of Ficalbia and 1 of Culex. In all, the diploid number of 6 chromosomes was found to be in conformity with that in the other mosquitoes studied so far. Anopheles karyotypes were found to be either maculipennis-type or quadrimaculatus-type. But A. balabacensis and A. subpictus, according to them, may turn out to possess two new types on further investigation. In this paper "pипiens-type" and "lutzia-type" have been suggested for culicine karyotypes.
Apart from the literature concerned with the karyology of mosquitoes, several general works on the cytology, cytogenetics or insecticide resistance of insects have been found to contain valuable reference material for mosquito chromosomes (Boyce, 1958; Brown, 1958; Mariani, 1959; Rozeboom and Kitzmiller, 1958; Smita, 1960 and White, 1957). The most recent publication of Chowdaiah et al. (1971) provides valuable information concerning the cytogenetical investigations on culicines. This paper is an attempt to review some of the recent investigations on oriental mosquitoes.