BIRDS

BREEDING STRATEGIES IN ESTRILDID FINCHES OF DIFFERENT CLIMATE ZONES: EFFECTS OF ULTIMATE AND PROXIMATE FACTORS

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INTRODUCTORY REVIEW ON BREEDING PERIODICITY IN BIRDS

Birds are dependent upon environmental factors for successful reproduction more than other classes of vertebrates. "All species of birds breed at those times of the year when, on the average, young can be profitably raised (Lack 1950). This statement sums up a great number of observations and investigations on breeding periodicity and related ecological factors in many species of birds. The general correctness of Lack's rule raises two questions: (1) Why are the birds programmed to breed only at those times when young can be profitably raised? and (2) How does the bird "know" when to breed; that is, in what way is the timing of breeding periods accomplished?

The first question deals with the ultimate control of breeding periodicities and the second with the proximate control. With the exception of very few habitats (e.g., tropical islands, Ashmole 1968), in most places on earth there is a succession of periods more favorable to reproduction and periods when reproduction is impossible (or at least requires much more energy input with a decreased probability of success). The duration of the favorable conditions can be very different: three quarters of a year, as in many tropical areas, or one month only, as in some subarctic places. The favorable period can reappear at regular intervals, linked to annual seasons (for review, see Immelmann, 1971), or irregularly, as in some deserts with sporadic rainfalls (Serventy, 1971). The favorable period is characterized by the presence of that environmental factor or combination of factors which actually guarantee the breeding success. These factors are called "ultimate factors" (Thomson, 1950). In many populations of birds, food is the most important factor. After the young are hatched, much more food is needed than before and often a special type as many species raise their young with food different from their normal adult diet (Marshall, 1951). That is why species of the same area, specialized on different food sources, often
differ in their breeding periods.

Further ultimate factors are the abundance of nesting sites and nest material, protection against predators, and the absence of adverse climatic factors such as heavy rainfalls or low temperatures. During the phylogeny, each species had its breeding period restricted to those times of the year when these ultimate factors were present. Individuals who tried to reproduce outside the favorable period had much higher energy costs and were less successful. They gave their genes – which had information for not restricting reproduction to the favorable season – to their young which, born in the absence of the ultimate factors, had a reduced chance of survival and reproduction. That is why selection favored those genomes which restricted breeding to the favorable times of the year only.

While the ultimate control acts during evolution, the proximate control of breeding periodicity takes place in the individual. The birds, whose gonads are in a state of quiescence outside the breeding period (to prevent them from breeding at the "wrong" time and to conserve energy, e.g. by reducing weight during flight) have to activate the entire sexual system. This means that the hypophysial-hypothalamic axis has to release gonadotropic hormones which activate the gonads. The ovary and testes must increase in size, the germinative cells undergo maturation, and sexual hormones must be produced. The latter substances (in some species gonadotropins also) cause some changes in seasonal secondary sex characteristics (e.g., bill coloration or nuptial plumage) and are responsible for the appearance of a variety of sexual behavior patterns. All these events have to take place before the onset of the favorable season. There are two ways to start these preparatory processes in time: (1) External factors trigger the activation or (2) Internal factors (endogenous rhythms) are responsible for the activation.

If any external factor shall start the gonadal activation, this factor must be noticeable to the bird and must occur at a certain interval before the onset of favorable conditions. It has to predict highly reliably the appearance of the ultimate factors in advance.

If such an external factor exists, then during evolution each species’ respective population will develop response mechanisms to these predicting factors which then are called "proximate factors" (Thomson, 1950).

One of the most important proximate factors in birds living in the moderate climate zones is the photoperiod. Many species and subspecies of birds respond to a certain population-specific length of daylight with gonadal recrudescence. Twelve to fourteen hours after sunrise a short light sensitive phase occurs in each individual which, stimulated by long day conditions, is able to transform this stimuli (perceived by the eyes or by extraocular receptors in the central nervous system) into neuro-secretory activity of some specialized cells in the hypothalamus, which results in the release of gonadotropic hormones (Farner, 1970). In the more equatorial zones, the resident species of birds often have a reduced or no photosensitivity. Other environmental factors are known to act as proximate factors; for example, rainfall and related phenomena (Moreau, 1950).
If the favorable season reappears regularly, the gonadal activation can be started by internal factors. An endogenous circ-annual rhythm can induce gonadal maturation at intervals of nearly one year. This was proven in birds kept in laboratories under absolutely constant conditions (Gwinner, 1969). Their endogenous cycles, running free in constant illumination, had an average period length of eight to eleven months. In feral birds this endogenous rhythm becomes synchronized to the annual seasons by external factors (proximate factors in a wider sense), which then are called "Zeitgeber" (Aschoff, 1954). In many of the species of birds investigated thus far, internal and external factors both take part in the regulation of breeding periodicity.

Each population has evolved a pattern of reproductive activity and inactivity and mechanisms regulating the onset and the end of gonadal activity which are highly adaptive, according to the climatic conditions of the area from which it is derived.

MATERIAL AND METHODS
To investigate some parameters of sexual maturation, we selected three species of Estrildid Finches from very different climatic zones.

The family of Estrildidae is known to be a well-defined group of closely related genera (Delacour 1943). Therefore, one should expect to find a generally uniform type of sexual maturation, probably modified by some species specific adaptations. The Estrildids originated in the tropical areas of mid-Africa. From there they dispersed in several waves to India, Southeast and East Asia and to the Australian region (Delacour, 1943, Mayr, 1968). The three species we investigated are: (1) the Fire Finch Lagonosticta senegala from Africa, (2) the Zebra Finch Poephila (Taeniopygia) guttata castanotis from Australia and (3) the Spice Finch Lonchura p. punctulata from India.

We restricted our investigations in the first study to the process of sexual maturation in young individuals, which had the advantage that the confounding factors of prior sexual activity and gonadal atrophy were not present. The ultimate control is the same in first year breeding birds as in adults, and most of the physiological mechanisms regulating the gonadal activation should be the same as well (Sossinka, 1970).

The birds were bred in indoor aviaries or cages. Non-domesticated or only slightly domesticated strains were used (Sossinka, 1970). The young were separated from their parents at about thirty-five days of age and were kept in bisexual groups under relatively constant laboratory conditions (light-dark cycle 14 : 10 hours, temperature 21 to 24° C, relative humidity 55 to 70%). They were fed a diet of mixed millets and seeds, sprouted millet and water ad lib, and three times a week a multivitamin emulsion was added to the water. Additional egg-food and insects (beetle-larva) were given during the first thirty-five days of life when nestlings were being fed by their par-ants.

At regular intervals body size, moult and gonadal size were checked. The following measurements were taken in young males: body lengths; wing length, bill length and width; body weight; number of renewed feathers; volume of the left testis, as measured by laparotomy with an ocular micrometer in a surgical microscope (Sossinka, 1974).
RESULTS

Body growth slows down in all three species after a continuous linear rise. Adult measurements are reached in the Spice Finch (13 g body weight) and Zebra Finch (12 g body weight) about day 28 to 30 and in the smaller Fire Finch (8 g body weight) at about day 25. The onset of juvenile molt, when the first feathers of the adult plumage appear, is not later than day 35 in the Fire Finch and Zebra Finch and day 40 in the Spice Finch. The end of this juvenile molt, however, differs markedly between the three species. Here the principal differences in time patterns which are typical of the maturation of all primary and secondary sex characters can be seen. The Fire Finch finishes juvenile molt at about 150 days of age, the Zebra Finch around day 90, and in the Spice Finch it takes 200 to 300 days (in some birds even more than one year).

These three differing patterns – a medium, an accelerated and a retarded development – appear even more pronounced in the growth curves of testes volume. Plotted logarithmically, in all three species an initial volume increase in the nestlings is followed by a period of quiescence. Growth is resumed at different ages in each species, and the time needed to complete gonadal growth is very different also. Adult male testes volume is reached in the Fire Finch at 130 days, in the Zebra Finch at 70 days and in the Spice Finch at 250 days. The latter shows the largest intra-individual variation while the Zebra Finch shows the smallest (Figures 1 – 3). In Figure 1, the curve of testes volume in the Fire Finch is slightly corrected to equalize the differences in both weight. For absolute data, subtract 0.2 units.

DISCUSSION

In general, the type of gonadal maturation is the same in all three species, characterized by an intermediate phase of quiescence. This takes place at the same developmental age in the three species and is comparable to the juvenile refractory period in photosensitive species (Miller, 1954). Besides this homology, the species investigated showed pronounced differences in the rate of maturation. By considering the climatic conditions in the area of origin in each species, the selection pressures responsible for these adaptations become evident.

The Fire Finch lives in and at the edge of the tropical forest of Africa. As reported by Morel (1967), its breeding period is extended to nine or ten months a year with only a short restriction. Independent of the time of the year in which they were born, nearly all young birds can reproduce successfully themselves if their maturation is not too fast or too slow. Very fast maturation means high energy costs and the risk of inexperienced parents insufficiently foraging for food for the nestlings. Very slow means a disadvantage in competing with conspecifics. This presumably primitive pattern of a moderately rapid rate of maturation is not advantageous in central Australia where the Zebra Finch is found nor in India, the native habitat of the Spice Finch. Zebra Finches live in almost all parts of Australia, especially in the arid areas of western and central Australia. Here the rainfalls, which are essential for the food supply of the young, are rare and occur irregularly (Serventy, 1971). The Zebra Finch is an opportunistic breeder, starting to breed immediately after rain (Immelman, 1962). Only those young birds which have an extremely
rapid rate of maturation can reproduce in the same vegetation period in which they were born. Otherwise, they have to wait until the next erratic rain falls, which in some places may not occur for twenty or more months. For this reason, natural selection has favored an extreme precocity in this species (Sossinka, 1970, 1974).

In the Spice Finch, on the other hand, egg laying in northern India takes place only during two months of the year (Thapliyal, 1968). Outside this strongly restricted season, successful reproduction seems to be nearly impossible. That is why young birds have to wait for three quarters of a year to start reproduction themselves and, therefore, their rate of maturation is retarded.

While in the Fire Finch and the Zebra Finch, under constant laboratory conditions, the rate of sexual maturation appears rather uniform, in the Spice Finch there are great intra-individual variations. This indicates the relatively environment-independent, internal type of maturation in the Fire and Zebra Finches in contrast to some possible influence of external factors in the Spice Finch. There is evidence that a cold and wet period acts as a proximate factor inducing the onset of sexual activation.

SUMMARY
The ultimate factors in the different climatic zones from which the species investigated come cause different patterns in breeding periodicity. According to these differences, the rate of maturation is quite different in the young of these related species: moderately in the tropical Fire Finch, extremely rapid in the precocious, opportunistic-breeding Zebra Finch, and retarded in the yearly breeding Spice Finch.

REFERENCES
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There is no such thing as one correct way in the handling, care or breeding of psittacine birds.

One of the key factors in the breeding of psittacine birds is nutrition. If we look into the investigations that have been done on these birds in their wild or native habitats, we will find that they are predominantly grain eaters. This is to the exclusion, for the most part, of seeds. We normally think in terms of seeds representing flowering type plants and grain representing non-flowering plants, which would include what we call grass seeds. However, we have to be cognizant of the fact that there is no such thing as a grain or combination of grains or seeds that can give a bird the total nutrient levels that it requires and has been able to obtain in its natural habitat. Certainly, birds eat many things; berries, fruits, nuts, grains, some seeds, grubs, etc. Realizing that we cannot duplicate these exactly, we certainly hope to be able to nutritionally or chemically duplicate the intake of these total nutrient compounds that the bird needs in order to be healthy and to give us good breeding results.

The ways we can effectively duplicate the natural habitat nutrients are to give good and complete grain mixes and various oils, and to use chemical, vitamin or nutrient additives, fruits, fruit supplements, soft food mixes and sprouted seeds. It would seem that, at least from my experience, the primary supplemental items that the birds want are apple and soft food mixes, including sprouted seeds and greens. They seem to have a time clock in their heads. If you don’t give them the mix they are used to on a given day and/or you don’t give it to them at approximately the time of day they are used to getting it, they certainly are vociferous in letting you know about it.

One of the primary supplements given near and during breeding season is fresh corn on the cob. The birds seem to enjoy it, it is nutritious, is easy for the hens to make crop milk, and thus takes
Another type of feeding that we have on occasion employed or will encounter is Gevage, hand feeding, tube feeding or whatever you may call it. This method of feeding may be done by choice or by necessity. There are on occasion hens that will refuse to feed their young or may feed them to a certain point and then discontinue feeding. Rather than take a chance that the young will perish in the nest with a bird of this type, we naturally will pull them and hand feed. We can further increase the productivity of these birds by permitting the to lay and hatch their eggs and then pull the young and hand feed them. We generally find that these hens will go back to the nest, though we only permit them to have one further clutch as we do not feel that over-breeding can be of any advantage to the bird.

We know that we cannot duplicate the exact foods that the parent birds would ordinarily feed their young. However, we do attempt to come as close as possible by making up mixes of grain and cereals with supplemental additives, such as vitamins and electrolytes. We cook these mixes and thus give it some semblance of the pre-digested quality that the parent will have when feeding the baby. The formula that we use is a fairly standard one, made up basically of safflower or soy meals, baby foods of high protein level, oatmeal, cream of rice, wheat heart cereal, masa harina (which is a corn meal) with additives such as baby vegetables (predominantly Spinach) for the greens, tri-calcium phosphate to help the growth of the babies’ bone structure and vitamins. Through experience we have found that this particular formula is successful in feeding baby birds literally from day of hatch to the day they are weaned. We have used it successfully on every Psittacine bird we have in our collection with the exception of the pure fruit and nectar eaters, such as lories.

Another key area of consideration in breeding of psittacine birds is housing. These do not have to be aviaries of any particular type, size or method of construction. We experienced successful results in breeding many birds, including some of the larger parakeets, parrots and macaws, in relatively small breeding cages. I am quite convinced, however, that nutrition is the primary factor in bringing any bird into good condition and ultimately breeding that bird. However, when we do breed birds in small cages, we give those birds rest periods in larger flight areas so that they can maintain their good body condition through exercise and normal flight. Some of the largest birds, such as macaws and cockatoos, have been successfully raised in amazingly small cages by many aviculturists. Macaws have been known to regularly breed in areas as small as two and one-half feet by three feet. The breeding urges are rather strong in all these birds, and unusually confining conditions do not necessarily preclude successful breeding. One aspect we have found that will at times preclude breeding, particularly in cockatoos, is where a bird has been hand fed and played with and made inordinately tame. We do find many of these birds will have absolutely nothing to do with other birds, and we have found no practical way to get them to breed. When we hand feed babies we want to use as breeding stock, we handle them only for the short period of time necessary to get the food into them and then ignore them, leaving them (hopefully with other babies) in the nest or box in which they are held during
feeding. We find that this gives these birds a far greater opportunity to realize they are birds.

An important feature in any aviary or cage is the perches. Both the diameter and the stability or steadiness of the perch are of paramount importance. Naturally, if the perch moves, proper mating frequently cannot take place. Further, the comfort of the birds and their ability to hang on to the perch, particularly the hens, is of great importance. The perch should be of such size that when the bird has its feet clamped on it, the claws are approximately two-thirds of the way around the total circumference of the perch. One of the best types of perches is the natural tree limb. If possible, stay away from the dowel perch, which is often found in commercial cages and, I am afraid, all too frequently used by breeders. The dowel is much too round, smooth, small and, in general, unnatural for the bird. To find a dowel of adequate size in a hard wood that these birds will not eat up in a matter of minutes is very difficult. Realizing that all psittacines are chewing animals (as they need this chewing to keep their beaks in good condition), we certainly should give them something to chew on, hopefully something other than their perches. Assuming that we use perch woods hard enough that the birds cannot destroy, such as dry eucalyptus, then provide some other wood, such as 2 x 4's in small pieces, hung in various places around the aviary so that the birds will have something not only to keep them out of mischief but to give them the constant ability to satisfy their instinctive chewing action.

Nest boxes also play an important part in the breeding of psittacine birds. There is no such thing as an absolute rule in the use of a nest box of given size or type for any particular bird. We have seen a pair of birds use a box 9 x 9” x 6” deep for their first clutch and for the second clutch in the same aviary in the same year use a box that is 10 x 12” x 12” deep. However, we do attempt to standardize on a particular box for a given type of bird. We have found in approximately eighty percent of our breeding stock that the same size and type of box will be readily accepted year in and year out by the same species of birds. When we find birds that do not seem to be well settled or properly acclimated to a particular box, these birds will be given a choice of up to four different types, sizes and shapes of nest boxes. We will let them pick the box they want, and if they seem totally content in that box, we will pull the others. On occasion we will leave the other boxes simply because the birds do not seem to be fully content, and we generally find that in subsequent clutches they will take a different box. As a general rule, we attempt to make our nest boxes approximately one to one and a half inches greater in width and front-to-back dimensions than the bird is long from head to tail. The only exceptions to this are those rather long tailed parakeets, such as the Ring Neck, Princess, Plum Head, etc. In those cases we found that a box approximately one to two inches longer than the body of the birds seemed not only to be satisfactory but generally preferred by the birds. In the case of large macaws, we use steel drums or garbage cans, generally the thirty-two gallon size, and the various cockatoos will use anything from twenty gallon steel drums up to fifty-five gallon steel drums.

Of paramount importance in any nest box is a ladder which the bird must have. Otherwise, many hens will enter the nest box by jumping on the eggs, subsequently breaking them and/or killing young that
may be in the box. These ladders should be made of wire and preferably spaced away from the inside frontal facing of the box at least one quarter to one half inch so the birds cannot get their feet or nails hung up.

The hole for entry is generally ten to fifteen percent wider than the dimension of the body of the particular bird to use that nest. There are certain exceptions to this, such as in the case of the Blue Bonnets where the hens are obviously much smaller than the males. In those cases, we make a box where the body of the bird will easily fit through the hole and then cover it entirely with a piece of bark, drilling only a small eighth inch or quarter inch hole. The hen will pick out her own entry to the exact size of her own body, thus precluding entry to the male. He, for some reason, will not attempt to get into the box. However, should you leave a normal nest entry hole, you will ordinarily find that the male will go into the box, disturbing the hen and frequently killing the young.

Other types of nest boxes used for various birds can be found of a specialty type. A good example would be Hooded Parakeets where we found successful breeding in two types of conditions. One is a bale of moss where the birds will burrow into the moss, generally from the top, going almost straight down and then off at an angle. We also make nest boxes for these birds in an “L” shape where they can enter the box, go down and off to the side. We found with these particular birds (evidently being termite hill or ant hill nesters in their native habitat) that they have a peculiar habit of circling the box. As a result, we staple bark on the outside of the box, not for a natural appearance but merely to give them a footing. We find that the hens prefer to be able to run entirely around their boxes.

I realize that many people refer to any box of more than two feet in depth as being a grandfather type. However, the majority of our nest boxes range in depth from sixteen to thirty inches. What we consider the grandfather boxes are nests that are from five to seven feet in depth. Particular birds that seem to enjoy boxes of that type are the King Parakeets, Crimson Parakeets, Barraband Parakeets and the Princess of Wales. (The last bird mentioned is one I have seen very successfully breeding in boxes that are normally construed as cockatiel boxes.) As a generality, it is wise to make the size of the nest box smaller, rather than larger, than your estimation of what truly is necessary.

We had some problems several years ago in attempting to breed Plum Head and Blossom Head Parakeets. We found them constantly chewing through the bottom of the box and invariably cowering in one corner. Though we occasionally had clutches of eggs, we never really, in our estimation, successfully bred these birds. I finally designed a box that has the shape of an “A” frame where the top of the box is very narrow, only about three and a half inches to four inches in width. The bottom of the box is also quite narrow, approximately eight inches in width and nine inches front to back. These boxes are thirty-six inches deep. Since that time we found the Plum Heads are very successful breeders, all of them preferring this type of box.

The nesting material which we place in the boxes is fairly standardized for most birds. We happen to be fortunate in that we
have a ready supply available to us of coarse shavings (not sawdust, which we know can be dangerous as babies can ingest the material and die from it). We mix the coarse shavings approximately fifty percent with rotted wood and bark which has been sterilized by placing it in an oven at approximately 200 degrees F for a period of forty-five minutes to one hour. Once this mix is made, we will add one-third sterilized potting soil, which can be obtained from any nursery, and two-thirds of the previous mix. We then make this quite wet, squeeze all the excess moisture out and load the boxes from one and one-half to three inches deep with the mixture. We use a sterilized potting soil for two reasons, (1) because it retains a substantial amount of moisture as it has various types of moss and humus in it and (2) it is sterilized and thus precludes the possibility of unwanted and dangerous bacteria which other types of dirt frequently harbor.

If we are fortunate enough to select our breeding stock and pick only the best breeders, we certainly have precluded many of our problems. However, the majority of us are not so fortunate. As a result, we occasionally find hens that are going to jump into their nest boxes, destroying the eggs and/or the young, regardless of the ladders we may install. I have seen specialty boxes constructed to curtail this wherein a long tunnel was built extending from the hole of the box. The bird lands at the entrance of the tunnel and has to walk at a rather slow pace to get through the narrow tunnel until she gets to the nest box itself. We have not had much success in using this. However, I have seen other aviculturists use it quite successfully. We use another method to curtail the problem. We create a cross of perch material that will be installed inside the nest box, going from front to back and side to side, generally installed approximately two to three inches above the height of a sitting hen in the bottom of the box. We discovered that the hens will jump onto these cross perches and then rather gingerly step down to the bottom of the box. This has eliminated a lot of problems of that type. Behavioral patterns are of great import in the successful breeding of psittacines. However, few of us really have the opportunity to observe our birds to learn all their habits. The peculiarities of each bird can be as varied as the differences found in human beings.

We find in certain birds, particularly the rosellas, that the hens seem to come into breeding condition slightly after the males. Thus, the males are quite active in attempting to breed and force the hens toward the nest boxes, driving them quite hard on occasion. Death sometimes results. To preclude this possibility, we catch the males and cut every other primary feather back to the point of the secondaries on one wing. They can still fly, yet it slows them down enough so that the hens can stay ahead of the males. On one occasion approximately three years ago a pair of Golden Mantels that had bred successfully for approximately five years went into the normal breeding season. Since I knew the bird well, I did not observe them too closely. What I did not realize was that the hen evidently came into breeding condition earlier than the male. The female, acting as the aggressor, debeaked the male, and we lost him. If I had not seen it, I would not have believed it. This particular case illustrates the fact that we can never know our birds too well. Constant observation is always necessary for successful breeding. It is very important to get to know on a personally familiar basis every bird in our breeding collection. It is not realistic to expect all
individuals of a species to follow the exact same pattern. We must expect variances from bird to bird.

The proximity of birds to each other is also important. We attempt to keep pairs of the same species separated by at least three or four flights. All flights should be double-wired because birds are likely to fight with adjacent neighbors when they are in breeding condition. There are certain exceptions, however. Pileated Parakeets, for example, have far greater breeding success when we keep them in every other flight. It seems when one male comes into breeding condition, each male down the line follows his lead. When widely separated, breeding is spotty and scattered. We have also found greater success in keeping the Princess of Wales Parakeets close enough to hear each other. The call of one bird tends to bring the others of the same species into breeding condition. On the other hand, we never put two varieties of rosellas next door to each other.

There are a few psittacines that can be successfully bred in colonies rather than in individual pairs. The love birds fall into this category with the exception of the more difficult species such as Abyssinians and Madagascars. Budgerigars certainly will colony breed, and this is often done when breeding for commercial quantity rather than for quality. We find, however, only one Australian parakeet, the Crimson Wing, is distinctly more likely to breed successfully in colonies than as single pairs. All cockatoos will also colony breed quite successfully. The key point with the cockatoos is to be certain that the nest boxes are widely separated, preferably at either end of the flight. As long as the birds can stay out of the way of each other, they seem to do better when they have company in their flight rather than one pair per flight. With cockatoos the size of the flight cage is not really of great importance.

I am firmly convinced that virtually any psittacine can be cage bred, including birds as large as cockatoos and macaws. All of our flights are the same size. They are four feet wide, fifteen feet long and eight feet high at peak of the roof. We have a drop front on these flights, thus making them draft free. Roosting perches must be in an area that is draft free. The wire areas of our flights are eight feet long. They are approximately eighty inches in height, extending out from front. The rear of the flight is approximately seven feet long and entirely made of plywood. In certain of our flights, such as those for cockatoos and macaws, we wire the entire interior of the plywood area so they cannot chew their way out.

Temperature in the aviary (and particularly the chill factor in cold weather) will be warmer in the roosting area. We have not actually taken the temperature of the birds. However, it is known that many animals tend to lower their body temperature when they sleep. We believe this may well be the case with the birds. Since birds have normally high metabolism rate and body temperatures, we believe that it is important that they be given as much shelter as possible when roosting. One of the greatest detriments to our Dirds is drafts. A draft does not necessarily mean cold air. Moving air constitutes a draft for a bird. Many times we have seen pet birds kept indoors at absolute constant temperatures. Then the slightest draft, such as a forced air furnace going on and creating moving air, seems to lead to upper respiratory infections or so-called “colds”. Cold air tends to go in straight lines, not around corners, and if an aviary is properly constructed, the birds will be able to remain totally draft free.
The directions the aviaries face are not nearly as important as has been reported on occasion in the past. The primary or preferred direction in the northern hemisphere has been stated as south, the second most preferred direction is east, etc. Our aviaries face virtually every direction, and we found great success in breeding our birds in any one of these aviaries. Should we find a pair of birds that does not breed in a particular aviary, we may move them to another cage, perhaps to an aviary immediately adjacent to the one they were in or perhaps at the opposite end of the breeding pens.

In-breeding any birds can be disastrous. This should never be done because it can ruin the strain, strength and, ultimately, the overall health of the birds. We know that when birds (particularly budgerigars, are bred for show purposes, in-breeding and line-breeding are used. Line-breeding is slightly varied from in-breeding in that there is (to a degree) a certain amount of out-crossing of stock. However, my personal belief is that line-breeding is just a sophisticated way of saying in-breeding. The attempt to get the best show animal and the best pedigree line frequently seems to cause some of the weakest animals and those must susceptible to sickness and disease. We know that certain faults can be eliminated in birds through selective theoretic line-breeding. However, what constitutes a fault to one person may not necessarily be a fault to another. The so-called show standards which have been set up for birds seem to vary from show to show and from judge to judge except for budgerigars.

If this happens to be your forte, do what you see fit in the breeding of your birds, but remember first, foremost and always, that the strength of the bird is far more important to continual successful breeding than the appearance of its shape or color.

In summary, we cannot say that all birds are bred in captivity the same way. However, in general, we can say that the majority of psittacines are effectively bred the same way with few exceptions. First, nutrition is of greatest importance. Second, proper surrounding or housing is essential, whether it be cage or aviary. Third, adequate and properly designed nest boxes, as to size, overall dimension, depth and nesting materials, is important. Virtually any psittacine will breed within a reasonable period of time upon proper acclimation to its surroundings, its conditions and the aforementioned necessities. There are no mysteries in the breeding of these birds, only the application of good common sense with judicious observation of your birds and a few simple rules properly applied.
INTRODUCTION
Each animal possesses a genome which endows it with dispositions to respond in a certain range of ways, to a certain range of appropriate stimuli, and thus feeds itself, finds shelter, acquires a mate and contributes to the gene pool (Manning 1972). Gene mutations are continually emerging. As environment changes, genomes may also have to change to adapt to these changes. Thus, individuals possessing dispositions to perform new behavior patterns that enable them to cope with environmental changes will be selected for and leave progeny. The heritability of behavioral traits has been a long debated issue often referred to as the “Nature versus Nurture” controversy. Ethologists have long been aware of the heritability of behavior patterns (nature), whereas many psychologists, preoccupied with learning phenomena (nurture) were slow to be convinced.

That dispositions to perform specific behavior patterns may actually be inherited and thus be subjected to the forces of natural selection, comes from studies of interspecific hybrids, artificial selection of extreme behavior traits, and intraspecific hybrids between selected strains of animals. Data from studies on invertebrates are plentiful (Gould 1974). Data on birds are relatively few. This paper reviews some of the changes brought about during the process of domestication of birds and summarizes studies on behavior of natural and artificial interspecific avian hybrids. These include my own unpublished studies on hybrid Estrildid Finches study of domesticated species can be very instructive as to how natural selection operates on behavior, especially if the ancestral forms are still available for comparison. Both natural and artificial selection (e.g. domestication) operate on mutations resulting in reduction of variation (Frank 1974). The process of speciation requires isolation of gene pools. Domestication is the result of artificial isolation of segments of a gene pool from the wild population (Goodwin 1965, Nicolai 1976).

EFFECTS OF DOMESTICATION

Tameness

Canaries
Birds that lend themselves to domestication must be easily maintained and bred in captivity. Indeed, Goodwin (1965) points out that most domesticated forms are granivorous species (Galliformes, Columbiformes, Psittaciformes, Fringillids and Estrildids), the groups that are easiest to maintain in captivity.

Man must also have selected for individuals that would breed readily in captivity. Throughout the world today, societies exist for the propagation and perpetuation of the many domesticated breeds of canaries (Serinus Canaria). These birds are docile and are often bred in small cages. Nicolas (1960) compared the behavior of domesticated and wild caught canaries. He found that wild birds remained skittish for a long time while held captive and seldom came into breeding condition. Clearly, man must have selected good breeders as ancestors of our domesticated forms. That tameness in domesticated canaries is heritable was demonstrated by Hinde (1956). He presented canaries, Goldfinches (Carduelis carduelis) and hybrid Goldfinch x canaries with stuffed owls. Goldfinches
mobbed the owls, but many canaries showed only a passing interest in the models. The latter was interpreted as a by-product of artificial selection for tameness by man. Hybrid Goldfinch x canaries also mobbed the models but less vigorously than pure Goldfinches.

Turkeys
Loeplod (1944) studied the heritability of tameness in turkeys (Meleagris gallopavo). Wild turkeys are difficult to keep and breed in captivity, frequently fighting so that game farms usually cross domesticated birds with wild ones and release the hybrids for the hunter’s gun. Leopold noted a lack of alertness and wariness in wild hybrids. Wild birds had an uncanny ability to see the observer before he spotted the birds and would immediately run for cover. Hybrids could be approached more closely. If the observer withdrew a few hundred yards at the first sign of alarm from the hybrids, the latter would resume normal activity and permit further observation.

Ducks
Another measure of tameness is the speed at which an animal habituates to a novel stimulus. Desforges and Wood-Gush (1975a) presented wild mallards (Anas platyrhynchos) and domestic Aylesbury Ducks with a model of a stuffed brown Leghorn Hen. The domestic breed habituated faster to the presence of the model. They then replaced their food pellets with colored pellets. Although the latency to respond increased in the Aylesbury, they eventually consumed the pellets. The mallards never ate the colored pellets.

Recognition of Young

Chickens
Heinroth (in Lorenz 1971) noted that females of Burmese Jungle Fowl (Gallus gallus) will only lead chicks with markings on the head typical of the wild form. Chicks of domesticated breeds lacking head markings will be killed. This recognition of species’ specific characteristics in chicks is still found in some domestic breeds (e.g. some gamecock breeds, Phoenix chickens). However, in many domesticated breeds man has apparently selected against the ability to recognize species’ specific characteristics so that even ducklings or goslings may be brooded and led. Indeed, in some breeds (Orpington, Plymouth Rock) even the response to the acoustic character of the releasing mechanism has been selected out so that hens will even try to care for young mammals (Lorenz 1971).

Estrildid Finches
Nestlings of Estrildid Finches have species’ specific colors and markings on their palates and beg with species’ specific head-twisting movements and vocalizations. That these palate markings serve as species’ specific releasers was tested quantitatively by Immelmann, et al (1977). The authors placed nestlings of domesticated strains of Zebra Finches (Poephila guttata) which lacked palate markings with “wild-colored” Zebra Finch nestlings which had five black spots on their palates. Wild-colored nestlings had significantly higher survival rates, had priority to the first feedings of the day and received more food during the later phases of the nestling stage so that they grew at a more rapid rate. Nicolai (1964) performed cross-fostering experiments with various Estrildid species. He noted that these finches would not feed newly-hatched chicks with mouth markings differing from those of their
young. If mouth markings of fostered heterospecific nestlings were similar to those of their own, the strangers would be fed for a while and then deserted.

As in some domesticated breeds of chickens, man has bred out the selectivity of response to the species’ specific releasers (mouth markings) of their young in the domesticated Bengalese Finch (Lonchura striata). Guttinger and Nicolai (1973) report that Bengalese Finches in their experiments raised 122 individuals belonging to 15 species in 7 genera (Lagonosticta, Uraeginthus, Ptyilia, Spermestes, Lonchura, Heteromunia, Erythrura) with diverse palate markings. In other cross-fostering experiments, Bengalese have been used to raise the genera Poephila, Euodice, Chloebia and Odontospiza (Immelnmann 1969, Baptista 1973a, 1973b). Indeed, Gouldian Finches (Chloebia gouldiae) are frequently raised by Bengalese Finches in Japan and exported to Europe (Nicolai 1967). The list of genera raised by Bengalese is probably incomplete.

Social Behavior

Turkeys
Leopold (1944) found differences in the social behavior of wild turkeys and free-ranging wild x domestic turkey hybrids. Wild turkeys tended to gather in small flocks ranging from 2 to 12 animals (X 2.5 to 6.3 between 1940 and 1943). Even at low densities, hybrid turkeys gathered in large flocks ranging from 7 to 33 birds (X 14.8 to 19.2 between 1940 and 1943). There is a partial segregation of the sexes in wild turkey flocks, i.e. adult males tended to winter separately from adult females and young of the year. This segregation was not found in the hybrid strains.

Pigeons
Edrich and Keeton (1977) performed homing experiments with feral and domestic “homer” pigeons (Columba Livia). Ferals had on the average longer homing times and lower return rates than “homers”. This was partly due to weaker homing drives in the feral pigeons but partly due to a selected change in the social behavior of homers. Feral pigeons tend to be easily “distracted” by other pigeons, tending to join other pigeons flocking in the air or on the ground. Man has apparently selected out this tendency to flock in the homer.

Cockerels
A number of game-cock breeds have been selected for aggression. Fennel (1945) compared the behavior of some game-cock breeds and more docile domestic chickens. He found that game-cocks were able to tolerate more punishment, were shiftier, faster and not as clumsy as “domestic” cocks. He also noted that different breeds utilized different methods of fighting. “Kentucky Dominiques” attack from above by flying at the opponent. “Allen Roundheads” move to within striking distance, then strike forward or toward the enemy on either side.
Cockerels have also been selected for high and low sex drive through three generations (Wood-Gush 1960). Siegel (1965) performed bidirectional selection experiments for completed matings over six generations.

Japanese Quail
Kovach (1974) has reviewed the literature on genetic factors in
sexual behavior in this species. Strain differences have been found in the sexual receptivity of females. Another investigator successfully undertook bidirectional selection for high and low mating activities in male quail in one generation. Strain differences were also found in mating frequencies.

**Ducks**

Desforges and Wood-Gush (1975b) reported selection against aggression in domestic Aylesbury Ducks. Individual distance was smaller for Aylesbury than for mallards during feeding and resting. For example, mallard drakes maintained an individual distance of 45.7 cm from another drake during feeding, whereas the domestic drakes maintained distances of only 30 cm.

**Vocalizations**

**Domestic Chickens**

Kruijt (1964) studied the ontogeny of behavior in Burmese Jungle Fowl (Gallus gallus), ancestor of our domestic breeds of chickens. When distressed (hungry, cold or isolated), chicks utter a loud shrill call at the rate of 2 to 3 per second. Kruijt's spectrograms showed that shrill calls of domestic chicks differed in morphology from those of their wild ancestor.

Konishi (1963) showed that crowing in domestic cocks is genetically determined, developing normally even in birds deafened at the time of hatching. Selection for differences in crow duration in two different breeds was demonstrated by Siegel et al (1964) who studied Athens-Canadian Random breds and White Rock roosters. Crows of White Rocks were significantly longer. They suggested polygenic inheritance in crow duration as evidenced by the fact that variation between individuals was greater than within individuals.

Crow duration in the above breeds averaged 1.58 to 2.43 seconds. Masui (in Siegel et al 1964) reported that the Totenko breed of ornamental chickens had crows lasting 15 to 20 seconds, again a result of artificial selection.

Goodwin (1965) noted that males of most of the largest breeds of domestic chickens have crows that are more long-drawn with the last syllable lengthened out, whereas bantams have shorter crows more similar to the ancestral Gallus gallus.

**Domestic Ducks**

When performing the sexual display known as the grunt-whistle (see Figure 2), mallards utter a clear flute-like whistle. Desforges and Wood-Gush (1976) found that in one of the domestic breeds (the Aylesbury) the whistle has been reduced to a low grunting sound.

**Domestic Pigeons**

In his treatise on domestic animals, Darwin (1875) pointed out that man has selected for distinct qualities of voice in at least two breeds of pigeons. Levi (1965) describes 13 "voice" breeds known collectively as "Trumpeters). A second voice breed noted by Darwin is known as the "Laugher."
Levi (1965) describes the courtship song of the Thailand Laugher as a “who-a, who-a” followed by 8 or 10 wock-wock, wockwock. The male English Trumpeter begins its courtship song with several coo-coo-roo-coo’s similar to the ancestral Rock Dove, but this is followed by a long series of who-oo-oo-oo-oo, who-oo-oo-oo-oo-oo, etc. (Baptista and Abs 1981). The peculiar sounds used by other breeds are also used in the nest showing ceremony. In this display the male sits in the nest cup, bows rhythmically, flicks the wings up and down rapidly and vocalizes. Another breed, the Altenburg Trumpeter, has a much more rapidly uttered series of vocalizations following the
Courtship coo. The Altenburg's trumpeting is also more uniform in rhythm than in the English breed (Baptista and Abs 1981).

Domestic Quail
The Japanese Quail (Coturnix coturnix japonica) was domesticated as a “good song bird” during the Muromachi era, some 600 years ago (Yamashina 1961). In Central Europe, Coturnix Quail were independently selected for qualities of voice. All breeds of Japanese singing quail were lost during World War II, and the European strains were lost because of loss of popularity of the hobby (Howes 1964).

Goodwin (1965) noted that wild Japanese Quail give a call (crow) which sounds like “Quah–kah”. Domesticated birds give a call which sounds like “Quah-grrr”. This was selected for because it suggested to the Japanese the sound of “distant thunder”. During the Tokugawa Period, they were kept in elaborate cages and judged in competitions on quality of song. Moreau and Wayre (1968) compared sound spectrograms of wild Japanese Quail with extant domestic stock. Although calls of wild quail are similar to those of the domestic birds, the latter are “louder” and harsher.

Greater and Lesser Prairie Chickens
The vocalization associated with the “booming” display in a hybrid consisted of six syllables in contrast to the three syllables in both parental species. Duration of the directed display was 1.96 seconds in the greater, 0.60 seconds in the lesser, versus 0.97 seconds in the hybrid (Crawford 1978).

Canary
Along with differences of appearance in the various domesticated canary breeds, man has selected for different qualities of voice/voice. Marley (1959) studied spectrograms of Roller Canary songs and compared them with songs of their wild ancestors. Roller songs are softer, lower pitched, consist of long repetitive trills with shorter intervals between notes and are simpler in structure than songs of wild canaries. Poulson (1959) also noted that Rollers sing with their bills virtually closed, whereas “common” canaries (= choppers?) sing with their bills open. Common canaries may imitate Roller songs but sing them with bill open. He found also that the soft and low pitched quality of the songs developed in Rollers raised in isolation. Syllable diversity, however, is learned (Poulson 1959, Marler and Waser 1977, Waser and Marley 1977).

Poulson (1959) also compared two social calls of Roller and “common” canaries. Both contact and alarm calls of the Roller Canary are also lower pitched than those of common canaries and exhibited differences in patterns of pitch modulation. Recent studies by Murdinger (1970) indicate that at least some social calls in Carduelid Finches are learned. Thus the relative contributions of nature versus nurture in the development of canary calls remains to be ascertained.

Courtship

Pigeons
As a result of artificial selection by man, various breeds of domestic pigeons exhibit breed specific behavior patterns. The latter appear to be derived from various components of courtship and other social
displays of Columba livia.

Pouting
Columba livia inflates its neck with air (pouts) during courtship and during the nest-calling display. Pouting may continue for a while after courtship (Whitman 1919). In the 40 or so extant breeds of pouter pigeons, pouting is exaggerated and occurs at the slightest disturbance, e.g. during aggressive displays against conspecifics or a human intruder. Pouting is, therefore, the hypertrophy of a universal instinct in pigeons to inflate the neck (Whitman 1919, Nicolai 1976).

Wing Lifting
The aerial display of C. livia is territorial and sexual in motivation. In this display the pigeon claps its wings loudly several times, then glides with its wings held slightly above the horizontal, finally gliding with its wings held out horizontally. The Swing Pouter holds it wings almost vertically above its back during the gliding phase so that it quickly loses altitude and must flap its wings to return to a greater height.

Wing Clapping
Two breeds, the Swing Pouter and Rhine Ringbeater, perform exaggerated loud clapping phases during their display flights. This leads to premature fraying of the primaries early in the breeding season. The clapping phase of the flight display is lengthened in the Swing Pouter. Nicolai (1976) once counted as many as 30 claps during the display flight of this breed, whereas it is usually 4 to 6 claps in the ancestral C. Livia. Nicolai crossed these two loud clapping breeds with some of the normally (softer) clapping breeds, and found that loudness was intermediate in the F1 generation.

Rolling
Levi (1965) has cataloged some 22 breeds of roller and tumbler pigeons. These may be further segregated into flying rollers, parlor rollers, flying tumblers and parlor tumblers. Tumblers differ from rollers in that whereas tumblers perform only one or two backward somersaults per series, rollers may perform many, often falling 50 or more feet in the course of rolling. Young individuals of both types fly normally for the first weeks or months but eventually all perform intermittent somersaults. The parlor types eventually lose their ability to fly altogether, rolling or tumbling on the ground.

Nicolai (1976) traced rolling behavior in Birmingham Rollers to the glide phase of the display flight, noting that loss of altitude is a prelude to rolling in young birds. However, Entrikin and Erway (1972) and Kerry Muller (personal communication) report that any attempts to fly initiates rolling or tumbling in the air or on the ground.

Nicolai (1976) crossed rollers with non-rolling breeds and noted that F1 hybrids could perform only incomplete somersaults. A more detailed study of the inheritance of rolling behavior in pigeons was performed by Entrikin and Erway (1972). Crosses between flying rollers and normal breeds produced 38 non-performers and one bird that somersaulted only once or twice. F2's were split 50-50 into rolling and non-rolling birds. F1's back-crossed to flying rollers produced about equal numbers of performers and non-performers. Flying rollers crossed with parlor rollers produced about equal
numbers of parlor and flying rollers. The authors suggest that rolling behavior is controlled by a single autosomal mutation. However, the penetrance and expressivity of the gene appears to be modified by other genetic factors.

Ringbeating
During its ground courtship bow-cooing display, a domestic pigeon may sometimes jump into the air, clap its wings loudly several times, then drop just behind or beside the female and recommence his bow-coo display. In the extinct English breed called the Finnikin (Goodwin 1965) and the extant German Ringbeater (Nicolai 1976), the clap display is elaborated so that the courting male will fly one to four times in a tight circle over the female with a constant loud clapping of the wings. Nicolai points out that even the female Ringbeater claps louder than other breeds, although not as loudly as the male.

Nicolai isolated an unpaired female Ringbeater for some time, and then placed her in the middle compartment (1.5 x 2.5 x 2.3 m) of a three-compartment enclosure. In one of the other compartments he placed a male Ringbeater and in the other he placed a male of another breed. She was visually isolated from both males by partitions of cloth but could hear both displaying. She was attracted to the clapping display of the male Ringbeater and ignored the other male. The author suggested that a parallel change in the signal receiver also occurred which was genetically fixed with artificial selection.

Ducks
Desforges and Wood-Gush (1976) compared the courtship displays of domesticated Aylesbury Ducks and the wild ancestors, the mallard. As mentioned earlier, the acoustical component in the grunt-whistle display of the Aylesbury has been reduced to a grunt. Following the head-up-tail-up display, mallards turn the back of the head to the female. The last display is absent in the Aylesbury. Moreover, the preliminary shaking preceding the head-up-tail-up display of the mallard was sometimes absent in the Aylesbury.

The down-up display was performed at lower intensity by the Aylesbury. The nod-swim display was less often seen in the female Aylesbury and reduced to an intention movement.

Pair-formation displays were always directed at only one female in the mallard. Aylesburies would direct these same displays (e.g. precopulatory pumping, preen-behind-wing) at several females. Mallards were thus thought to form pairs in captivity, whereas Aylesburies did not.

Behavior of Hybrids

Maintenance Activities

Diving versus Dabbling in Ducks
The different tribes of ducks tend to forage in different ways. Mergansers (Mergini) dive beneath the water’s surface to pursue their prey. Shelducks (Tadorna tadorna) belong to the surface duck tribe (Anatini) which typically feed by (1) “dabbling” on the water’s surface to pick up vegetation and small animals in their bills or (2)
“tipping”, wherein half the body is submerged under water, and the hindquarters remain on the surface. Lind and Poulson (1963) studied the feeding behavior of a Goosander (Mergus merganser) x Shelduck hybrid. The latter never dived but dabbed and tipped like its Shelduck parent. However, whereas Shelducks tip with their body 90° with the horizontal, the hybrid tipped at 45°. The authors attributed tipping angle to the body shape of the hybrid.

Scratching versus Digging
Typical of many galliformes, Lady Amherst Pheasants (Chrysolophus amherstiae) feed by scratching the ground with alternate backward movements of the feet. Impeyan Pheasants (Lophophorus impeyanus) dig the soil with the bill when feeding. A hybrid Impeyan x Lady Amherst Pheasant fed by digging with its bill like its male parent (Huxley 1941).

Foraging for Worms
Whitman (1919) observed that whereas many species of pigeons and doves feed occasionally on earthworms, Passenger Pigeons (Ectopistes migratorius) seemed to relish these food items more than did other species. A Passenger Pigeon hatched under Ring Doves (Streptopelia risoria), never having seen an earthworm before, immediately approached the worms when presented with them, handled and ate them. Whitman went on to present one naive Passenger Pigeon x Ring Dove hybrid and two “pure” Ring Doves with some earthworms and soil. Whereas the Ring Doves ignored the earthworms, the hybrid immediately approached the worms and quickly acquired the skill of extracting worms from their burrows and eating them. Whitman suggested that the recognition of earthworms as preferred food was inherited from the Passenger Pigeon parent.

Holding Items with the Foot
A number of avian taxa have independently derived the ability to manipulate food items or nest material with the feet (Clark 1973). Even within the same family or subfamily, species differ in the frequency with which this behavior is exhibited. The European Goldfinch frequently uses its foot, the canary sometimes and the Greenfinch (Carduelis chloris) rarely. Hinde (1956) noted that several Goldfinch x Greenfinch and Goldfinch x canary hybrids often used their feet, whereas Greenfinch x canary hybrids seldom did. Hybrids inherited their holding ability from their Goldfinch parents.

Among Estrildid Finches, Zebra Finches never use their feet to hold items on a perch, whereas African Silverbills (Euodice cantans) regularly do so. Four Silverbill x Zebra Finch hybrids regularly manipulated seeding heads of grass with their feet, indicating inheritance of a dominant trait (Baptista personal observation).

Biting Versus Pulling of Grass
Poulson (1950) observed that Greylag Geese (Anser anser) are equipped with “tooth-like knots” along the sides of their mandibles enabling them to “bite” grass while grazing. Ducks are not so equipped and thus “pull” grass while foraging thereon. A hybrid domestic duck x Greylag Goose bit grass like the goose parent. However, not being equipped with the bill "teeth" of the goose, the hybrid bit grass with the tip of the bill which was equipped with a large nail.
Drinking Behavior
Most finches in the family Estrildidae drink in the manner of chickens, i.e., water is scooped into the bill, and the head is subsequently raised so that the bill is pointing skyward and the water runs down the throat through gravity. Some Australian Finches in the genus Poephila, independently of the doves and pigeons (Columbiformes), drink by dipping the bill in the water and sucking without raising the head. Immelmann (1976 and personal communication) studied drinking behavior in hybrids between Mannikins (Lonchurae) which scoop, and Poephila species which suck. Hybrids sucked in pigeon fashion, but bills were not dipped as deeply into the water as in Poephila species.

Vocalizations

Chickens x Pheasants
McGrath et al (1972) artifically inseminated female Ring-neck Pheasants (Phasianus colchicus) with semen from White-Leghorn Chickens. One year old hybrids were of two size classes: males weighted 1,775 gm and females weighed 875 gm. Adults of both parental types and their hybrids were hand-held with the wings and their distress calls recorded.

Duration and pitch of the principal component (= darkest and most distinct harmonic) of these calls were measured (Figure 1). Duration of hybrid calls was similar to that of the pheasant. Pitch of the hybrids was intermediate between the parental forms. However, the smaller hybrids had higher pitched calls than the larger hybrids. There was little change in frequency in the chicken calls, whereas there was an initial rise and then a fall in pitch in the pheasant calls and those of the hybrids. Harmonic structure of some of the hybrids of both size classes resembled either the pheasant or the chicken.

It was suggested that the inheritance of duration was controlled by one or few genes, whereas principal component (pitch) was polygenic.

Palearctic Quail
Moreau and Wayre (1968) studied the "crows" of European and Japanese "races" (species?) of Coturnix coturnix. The call of the European bird was clear, brief and consisted of sharp notes, whereas Japanese Quail calls were harsh and blurred on the spectrograms and were less far-carrying. Moreover, the rhythm of the European's call was "dactylic".

Calls of European x Japanese hybrids approximated the European's in rhythm but showed a coarsening in the second and third notes that characterized Japanese calls. Calls of Japanese x European hybrids showed nothing approaching the European rhythm and only a limited coarseness. Although more or less intermediate, hybrid calls tended to be more similar to the male parent.

Greater x Lesser Prairie Chickens
Courtship displays of Prairie Chickens (Tympanuchus spp.) consist of drooping of wings, tail-fanning, erection of pinnae, inflation of vocal sacs and the "booming" vocalizations (Crawford 1978). The Greater (T. cupido) tail-shakes prior to vocalizing and tail-fans at the end of the third syllable in its booming vocalizations. In the Lesser (T. pallidicinctus) tail-fanning occurs during the first syllable of the vocalization. A hybrid tail-fanned during the first (as in Lesser) and
third (as in Greater) syllables of the vocalizations. The hybrid did not tail-shake and was thus similar to the Lesser.

Duration of the displays in the Greater and Lesser Prairie Chickens was 2.8 versus 0.6 seconds respectively. The hybrid’s display directed at a female (= Epigamic display) lasted 1.22 ± 0.24 seconds. When performed solitarily (= Antaposematic display), the display lasted 1.11 ± 0.29 seconds. Thus directed and undirected displays were intermediate in duration between the two parental types.

Doves
Lade and Thorpe (1964) studied the coos of five species of doves and their hybrids. Species crossed included the Barbary or Ring Dove (Streptopelia risoria), Turtle Dove (S. turtur), Collared Dove (S. decaocto), Necklace Dove (S. chinensis) and Senegal Dove (S. senegalensis).

Cross-fostering experiments failed to change the coos in any way, indicating that dove calls are genetically coded. In the Ring Dove, vocal signals developed normally even in individuals deafened soon after hatching (Konishi and Nottebohm 1969).

Lade and Thorpe (1964) concluded that specific rhythms of the songs (coos) of doves were coded in the central nervous system. The effect of hybridization on the rhythm varied. In some crosses (e.g. Senegal x Barbary) a complete breakdown of the coding ensued so that only simple monosyllabic coos were produced by the F1 hybrids. Other hybrids (e.g. Barbary x Collared) produced coos which were rhythmically intermediate or resembled one parent. In back-crossed F2 hybrids, disorganization of the rhythm seemed to have disappeared, and the dominant species rhythm appeared in almost normal form.

Whitman (1919) studied the intervals between perch-coos of Zenaidura macroura, Streptopelia risoria and their hybrids. He noted that fifteen seconds usually elapsed between each perch-coo of Zenaidura. A Zenaidura x Streptopelia hybrid called 17 times in 20 seconds, or even once per second, a rhythm similar to the Streptopelia parent.

Carduelid Finches
Syllablic structures in the songs of canaries and Greenfinches are learned. However, Guttinger (1979) has found that rhythmic structure (temporal organization) in Greenfinch song is innate.

Syllables of both Carduelid species are grouped together into units he calls tours. In canaries, groups of tours may be separated into phrases by intervals exceeding 1 – 2 seconds of silence. Thus a histogram of intervals between tours in canary song is bimodal with a break at 1 second. Songs of Greenfinches are not broken up into phrases, and silent intervals between tours are modal in distribution. A Greenfinch raised by canaries learned canary syllables but sang them in a Greenfinch tempo, i.e. with the absence of phrases. A hybrid Greenfinch x Goldfinch likewise learned canary syllables, but temporal organization was Greenfinch-like, i.e. silent units were modal (Guttinger et al, 1978). However, whereas intervals between tours shorter than 0.5 seconds are rare in Greenfinch song, they are frequent in songs of canaries and the hybrid Greenfinch x Goldfinch.
Oiseaux d'Amérique canadienne

Estrildid Finches
Cross-fostering experiments have shown that social calls of Grass Finches (Poephilae) and Mannikins (Lonchurae) develop normally independently of learning (Guttinger and Nicolai 1973, Zann 1975). Nestlings of the African Mannikins of the Spermestes/Odontospiza group are distinguished from the Asiatic Lonchura on the basis of begging calls. In the former, begging calls are bisyllabic, whereas in the latter they are monosyllabic. Guttinger’s (1970) spectrograms of begging calls of a Spermestes bicolor x Lonchura striata hybrid indicate that they are bisyllabic as in Spermestes.

Harrison (1962) described the contact call of the Bengalese Finch (L. striata) as a dry “tritt”, and that of the African Silver-bill (Euodice cantans) as a thin-shrill “psit”. The call of a hybrid E. cantans x L. striata was described as a nasal, low-pitched “kent”, thus resembling neither parent. Baptista (personal observation) has obtained spectrographic evidence to support Harrison’s description. Besides being lower pitched, contact calls of the hybrid are harmonically rich whereas those of the parental forms are relatively pure-toned, accounting for the audible differences in tonal quality.

Hummingbirds
A number of authors have suggested that the loud sounds produced at the culmination of the nuptial (aerial) dive displays of Calypte hummingbirds are produced by the specialized outermost rectrices. However, recent spectrographic evidence indicates that these sounds are mostly, if not entirely, vocal (Wells et al, 1978, Baptista and Matsin 1980). The dive sound of the Anna (C. Anna) hummer are harmonically rich, those of the Costa (C. Costae) and their hybrid are pure toned. Dive sounds of the Costa are longer in duration and higher pitched than those of Anna. Dive sounds of their hybrid are intermediate in pitch and duration between the two species.

Crowing in Phasianids
Stadie (1967) analyzed the crows of Ring-neck Pheasant x domestic cock hybrids. The crow of Gallus consisted of four indistinct syllables, with the fourth somewhat lengthened and sometimes emphasized. The crow of Phasianus consisted of two distinct “hoarse-sounding” syllables. Stadie found that not all hybrids crowed, and those that crowed rarely did so. As in Phasianus, crows of hybrids were confined to the spring. Crows of hybrids consisted of four syllables as in Gallus, but as in Phasianus syllables were clear-cut and no syllable was emphasized.

Crows of Gallus sonneratii consisted of ±5 syllables (rarely four). There was a pause between the second and third syllable, and the second and fourth syllables were emphasized. Crows of hybrids between G. sonneratii x G. gallus consisted of 3 to 6 syllables. In most cases syllables were monotoned and a little hoarse-sounding and thus unlike either parent. All hybrids sometimes had a long introductory call preceding crowing found in sonneratii but not in gallus.

Courtship

Ducks

Ethologically, ducks (Anatidae) have been the best studied of any...
The early studies on the behavior of duck hybrids by Lorenz (1941, 1971), Ramsay (1961) and von de Wall (1963) have been followed by two important studies: namely, those of Sharpe and Johnsgard (1966) and Kaltenhauser (1971).

Kaltenhauser (1971) studied the behavior of fifteen Anas species and their hybrids. These species possess a number of display postures in common (see, e.g. Figure 2) with some species specific variations. Some postures are absent or rare in some species (see discussion in Lorenz 1967:92 on rare behavior in ducks). Some are obligately coupled motor sequences. For example, the male Mandarin Duck (Aix galericulata) has a ritual drinking display which is always followed by sham-preening. During sham-preening he touches the raised wing “flag” on the side immediately facing the female (Lorenz 1971). Kaltenhauser (1971) chose four postures which exhibited “typical intensity” for analysis: grunt-whistle, headup-tailup, downup, and bridling. (Figure 2).

Kaltenhauser found that when two species had a display posture in common, the hybrid would exhibit the posture in an intermediate form. Sometimes a behavior was rare in one species or was present only during behavioral ontogeny, or during contexts other than courtship. Hybrids involving one such parent would exhibit the posture in an intermediate form, but during courtship as in one parent. For example, bridling is performed during courtship and as a postcopulatory display in A. flavirostris. In A. platyrhynchos, bridling is performed only by juneviles during behavioral ontogeny, or as a postcopulatory display in adults. Hybrids between these two species performed an intermediate form of bridling both as courtship and as a postcopulatory display.

Sometimes behaviors that were rare or absent in the parental forms were present in the hybrids. For example, A. acuta x A. spinicauda hybrids performed downup and bridling displays both of which were apparently absent in the parents. A. platyrhyncho x A. strepera backcrossed to A. platyrhynchos performed bridling displays absent in the parental forms as well as Fl hybrids.

The inheritance of coupled sequences was also studied. She found that coupled sequences found in both parents appeared also in Fl hybrids, albeit sometimes rarely (e.g. the grunt-whistle coupled with the headup-tailup in A. acuta x A. castanea, Table 1). If a coupled sequence was absent in one parent, it was also absent in the hybrids (e.g. A. penelope x A. strepera and A. castanea x A. spinicauda). The time intervals between coupled sequences were often longer in hybrids than in their parents. For example, the interval between grunt-whistle – headup-tailup sequences in A. crecca and A. flavirostris ranged from 0.8 – 1.8 sec. (x = 1.3 seconds); in their hybrids, intervals ranged from 1.6 to 2.0 seconds (x-bar = 1.8 seconds). In two cases hybrids showed coupled sequences not found in either parent. Indeed, in A. sibilatrix x A. strepera, two new coupled sequences appeared (Table 1).

Sharpe and Johnsgard (1966) (see also Johnsgard 1967) studied the behavior of hybrids between A. platyrhynchos and A. acuta and correlated these with plumage inheritance. Both mallard and pintail perform grunt-whistle and headup-tailup. However, only the mallard
performs the downup, whereas only the pintail performs the burp (Figure 2). Nod-swim is commonly performed by the mallard but is rudimentary in the pintail. In F1 hybrids the downup is lacking and burp and nod-swim appear in reduced form. F2's exhibited plumage and behavioral variation ranging from almost pure pintail to almost pure mallard-like. In the most mallard-like F2's, downup and nod-swim are well developed. The most pintail-like F2's performed well-developed burp displays. Hybrid scores were constructed for plumage and behavior, and a positive correlation was found between inheritance of plumage and behavioral characteristics. The considerable segregation and independent assortment observed suggested to the authors that both plumage and behavior were under fairly simple genetic control, probably involving relatively few genes.

No abnormal coupled sequences were found in F2's. However, an F3 linked a bridling (postcopulatory) display with a headup-tailup social display. 

Lind and Poulson (1963) described the courtship displays of a Goosander x Shelduck hybrid. They found that during the ritualized drinking display, Goosanders normally held their head up 90 degrees with the horizontal, Shelducks held their heads at 45 degree, and the hybrid held its at an angle intermediate between the two parents.

Doves

Davies (1970) studied bowing displays in Streptopelia doves and their hybrids. These were the same five species studied by Lade and Thorpe (1964) who described their vocalizations. Bowing displays were performed only by males, were directed at either sex, were species specific, and involved an alternate upright and crouched posture which exhibited “typical intensity”. Bowing displays of
hybrids also exhibited typical intensity. Some of the components of the bows were intermediate between the parents, some resembled one parent closely, and others exceeded either parent. For example, the display of Collared x Barbary Dove hybrids (Figure 3) resembled the Barbary parent at the top of the bow in that the head was not held up as high as the Collared parent. However, the hybrid bowed lower than either parent. The exaggerated movements were lost in the F2 generation.

Similar results were obtained when Davies examined frequency of bouts of bowing, e.g. Turtle x Barbary hybrids bowed at a frequency intermediate between the parents, but frequency of bowing in Necklace x Barbary hybrids approximated the Barbary parent.

Hummingbirds
North American Hummingbirds of the genus Calypte exhibit two displays during territoriality or courtship: (1) a static display during which individuals sing from a perch and (2) a dynamic display which involves singing and species specific movements through the air. Selasphorus Hummingbirds only perform dynamic displays. On the Palos Verdes Peninsula of Southern California, three species of hummingbirds, the Anna (Calypte anna), the Costa (C. costae) and the Allen (Selasphorus sasin) breed sympatrically and overlap extensively in breeding season. Occasional hybrids have been found and their displays analyzed (Wells, Bradley and Baptista 1978, Wells and Baptista 1979).

In the dynamic display of the Anna Hummingbird, the male sings while hovering some 25 to 50 meters above the female. He then ascends, continually looking down (bill pointed down). He pauses at the top of the climb and may sing once more, and then dives, swooping out of his dive just over the female and produces a loud chirp sound. In contrast, male Costa Hummingbirds climb up into the air over the female with bill pointed up, never sing, never pause at the top, then dive and produce a loud whistling sound. One male Costa Hummer was observed tracing a large horizontal circle at the top of his climb just prior to diving. Hybrid Anna x Costa hybrids perform the aerial display with the bill pointed down like the Anna parent, climb up into the air in silence like the Costa, then trace a large horizontal circle in the air before diving and making a sharp but short peek sound. These hybrids also possess a static display wherein they sing songs identical to the Anna parent. It is conceivable, however, that songs are learned in hummingbirds (see discussion in Mirsky, 1976).

Allen Hummingbirds begin their aerial display by flying back and forth tracing a pendulum path over the female. At each end of the pendulum, a high-pitched cricket-like chirping is produced at between 7.5 and 12 kHz. After a number of these horizontal arcs, the hummer climbs in silence 75 to 100 feet into the air, describing spirals or undulations all the way to the top. He never pauses at the top but dives immediately. As he breaks his dive over the female, he produces a loud sound which begins with a number of short pip sounds followed by a long whistle. A hybrid Anna x Allen climbed into the air with bill pointed down like the Anna parent, but traced an undulatory path to the top like the Allen. He sometimes paused at the top like the Anna but was silent like the Allen. The hybrid then dived and produced a loud peek sound at the bottom of the dive. The
The dive sound was spectrographically like the Allen in harmonic structure, but short in duration like the Anna parent. The pendulum display of the Allen Hummingbird was absent in the hybrid. The hybrid also had a static display like its Anna parent, but its song was unlike any hummingbird known.

Figure 3.
Bowing displays of doves:
a. Collared Dove
b. Barbary Dove
c. Hybrid Collared x Barbary Dove
After Davis, 1970.

Estrildid Finches
Eisner (1958) described the displays of Bengalese Finch (Lonchura
Males of both Silverbill species (E. cantans and E. malabarica) perform a precopulatory display holding a grass stem by one end, all of the body feathers sleeked, tail shut and pointed down, and inverted curtsies (a bobbing movement in which the main component is an upward thrust imparted by a straightening of the legs). Sometimes birds perform ritualized nest-building movements while holding the straw as if molding an invisible nest roof (= U-shaped movements). Hybrids from three crosses involving Silverbills as one parent, performed all the components of the straw display (Table 2), but with some of the feather postures of the other parent. For example, when performed at high intensity, Silverbill X Bengalese crosses spread their tail and fluff their belly feathers like the Bengalese parent, but tails are always pointed down like the Silverbill parent. Silverbill x Zebra Finch (Poephila guttata) crosses always ruffle their nape and belly feathers like the Zebra parent. Some Spice Finches (L. punctulata) sometimes perform inverted curtsies during their precopulatory display as do Spice Finch x Bengalese hybrids. Spice and Bengalese Finches bow before singing at strangers or prior to precopulatory displays. When isolated and then presented with a female, two hybrid combinations involving Spice and Bengalese Finches also bow prior to singing.
at the singing male at left. After Morris, 1958.

Some Estrildid Finches also perform a display known as peering when one bird sings and other members of the social flock sleek their feathers and appear to be listening intently at close range (Figure 4). This display may serve to strengthen flock bonds (Immelmann 1965). All crosses involving peering (E. malabarica, E. cantans, L. punctulata) and non-peering (P. guttata, L. striata) species performed the peering display (Table 2).

Viduine Finches
Payne (1980) studied displays of Village Indigobird (Vidua chalybeata) x Paradise Whydah (V. paradisaea) hybrids in Lonchinvar Park, Zambia. Viduine Finches usually oviposit in nests of specific host Estrildid Finches. The parasite then learns the songs of its host, and later learns the song of its own species. Since the hybrids sang songs of Paradise Whydahs and Melba Finches (their host), Payne suggested that the crosses he studied must have involved the Paradise Whydah as the female.

Paradise Whydahs perform an elaborate aerial display which was absent in Indigo birds and their hybrids. One observation was made of a hybrid performing a courtship display termed a “fast sideways head bent”, given by Paradise Whydahs. Indigo birds seem to sing and display throughout the day, whereas Whydahs and the hybrids sang only during mid-morning and mid-afternoon. Hybrids were also similar to Indigo-birds in that most songs were delivered from one tree rather than from several singing trees as in Whydahs.

Absence of Courtship Displays
A number of authors have reported the absence of displays in some intergeneric hybrids between distantly related species. Asmundson and Lorenz (1955) produced Ring-neck Pheasant x turkey hybrids by artificial insemination. They reported the absence of eggs or semen in the hybrids and never observed courtship. Huxley (1941) kept an impeyan x Lady Amherst Pheasant hybrid with a female Impeyan and reported no trace of sexual interest in the hybrid. Poulson (1950) studied a domestic duck x Greylag Goose hybrid. Despite injections of testosterone, no courtship displays were observed. Poulson interpreted this as an absence of response from the nervous system.

Nest Building in Agapornis Lovebird Hybrids
Nest building behavior in the African Peachface (Agapornis roseicollis) and Fisher’s (A. personata fischeri) Lovebirds (Psittacidae) and their hybrids was studied by Dilger (1962a, 1962b) and his student Buckley (1969). A. fischeri cuts strips of paper about 7 inches long and 3/8 inches wide and carries these with the bill one at a time into the nest box. Sticks, strips of bark or leaves are also utilized in their nest. A. roseicollis cuts strips 3 to 4 inches long, then tucks several pieces under the feathers of the rump and lower back and thus carries them into the nest box (Figure 5).
Figure 5.
Nest building by Agapornis roseicollis. The female is tucking a cut strip of paper under its rump feathers. After Dilger 1962a.

Hybrids between roseicollis and fischeri cut paper strips that were longer than those of either parent. Strip-cutting is normally practiced by females of both species: occasional males of roseicollis cut strips, and males of fischeri almost never thus perform. FI hybrid males cut and carry with greater frequency than males of either parental form. Indeed, these males were continually interfering with strip-cutting attempts of the hybrid females; males of the parental forms rarely do.

Hybrids also exhibited various conflict behavior patterns and were rarely successful in completing a tucking sequence. They might perform the proper movements of tucking, but appeared unable to let go of the strips. They might perform frequent intention movements to tuck without completing the act. Sometimes they attempted to reach the rump with the bill by running backwards. Hybrids often grasped the strips other than by either end, thus making tucking difficult. They were often distracted, so that tucking attempts often passed into drinking or displacement activities (e.g. head-scratching). Sometimes inappropriate items, e.g. twigs, were tucked. This behavior, Buckley (1969) pointed out, was understandable since fischeri often incorporated twigs in their nests. Hybrids would sometimes tuck in inappropriate places, e.g. the breast. Examination of movie footage indicated that hybrids lacked the proper act sequence for successful tucking. That is, items were not correctly placed in the rump. indeed, an important component called “tremble-shoving” was lacking in the hybrids.

Dilger (1962a) observed that hybrids would gradually abandon the abortive tucking attempts in favor of carrying in the bill. After three years, tucking became very infrequent and behavior was very much like A. fischeri. However, Buckley (1969) studied a mixed batch of hybrids ranging from six months to four years old and reported that they could not be reliably divided into age groups on the basis of relative tucking and bill-carrying frequencies. There appears, thus, to be individual variation in hybrids in their abilities to learn to bill-carry. All Buckley’s birds showed both rump-tucking and bill-carrying behavior, with bill-carrying as the last resort.
DISCUSSION

In this paper I have brought together some of the literature on the behavior of domesticated birds, showing how man has modified some of these behavior patterns including social behavior, displays and wildness. Some of these behavior patterns are inherited in crosses between strains in the same way as in F1 hybrids between species. Some of these behavior patterns are clearly mal-adaptive and are permitted to survive only because of protection by man. For example, the aberrant flight behavior of the Swing Pouter Pigeon causing him to lose altitude and the clapping behavior which causes premature fraying of the primaries would probably have been selected out long ago by predators had these mutations occurred in the wild (Nicolai 1976). Since courtship behavior patterns may function as species isolating mechanisms, extreme modifications of these behaviors may prevent an individual from acquiring a mate in the wild, and thus also be eliminated from natural populations.

In the second portion of this paper I have summarized studies on the behavior of artificial and natural avian hybrids involving five different orders: Galliformes, Anseriformes, Columbiformes, Apodiformes and Passeriformes. Since most F1 hybrids are sterile, few of these studies were carried on to the F2 generation. The studies by Sharpe and Johnsgard (1966) on duck hybrids and Entrikin and Erway (1972) on rolling in domestic pigeon breeds are especially noteworthy, both because of the excellent analyses and sample sizes involved.

Frank (1974) and Payne (1980) have summarized the various trends in the behavior of hybrids which are as follows:

1. Hybrids may acquire behavior patterns similar to one or both of the parental forms (e.g. foraging behavior patterns) suggesting genetic dominance.
2. Hybrids may perform behavior patterns intermediate between the two parental forms (e.g. duration and pitch of distress calls of chicken x pheasant hybrids).
3. Hybrids may perform exaggerated versions of the parental behavior patterns (e.g. amplitude of bow in the Collared x Barbary Dove hybrids).
4. Behavior patterns rare in the parental forms may be common in the hybrid (e.g. horizontal circle flight of the Anna x Costa Hummingbird hybrid).
5. Behavior of hybrids may be incomplete (intention movements), e.g. tucking attempts of Agapornis hybrids, or may be otherwise disorganized (e.g. cooing of S. senegalensis x S. risoria hybrids) due to alteration of the genome.
6. Complex behavior sequences may be reorganized or new combinations of behavior components may arise (e.g. movements and feather-postures of Estrildids are recombined in the hybrids), suggesting segregation and recombination.
7. Behavior patterns may appear in the hybrid not found in either parent, e.g. Agapornis hybrids tucking in the breast rather than the rump.
8. Behavior patterns of both parents may fail to appear in the hybrid (e.g. absence of displays in some hybrids). Hinde (1956) has suggested that this is due to the general developmental breakdown of the hybrid.

A number of authors have interpreted some of the behavior of
hybrids as a recapitulation of ancestral behavior patterns (Lind and Poulson 1963, Dilger 1962b, Buckley 1969). For example, Dilger and Buckley noted that some primitive Agapornis species as well as the related Blue-crowned Hanging Parrot (Loriculus galgulus) regularly tuck nest material in the breast. Breast-tucking in Agapornis hybrids, found in neither parental form, has been interpreted as an atavistic behavior which has emerged as a result of changes in the genome. Franck (1974) has taken exception to this idea suggesting that the altered genotype has perhaps disrupted the parental behavior pattern resulting in a behavior accidentally resembling the primitive forms.

Rare parental behavior occurring commonly in hybrids have been interpreted as a lowering of thresholds to perform these behavior patterns due to the altered genome (Kaltenhauser 1971). Indeed, Manning (1963) has suggested that many evolutionary changes in behavior are due to altered thresholds to perform these behaviors. Franck (1974) argues against this, pointing out that we have as yet no actual understanding of the action of genes on behavior or a physiological understanding of the changes that can be described as threshold changes.

SUMMARY
Studies on the behavior of domesticated birds were reviewed. During the process of domestication man has selected for certain behavioral, traits including tameness, changes in social behavior, qualities of voice and changes in courtship patterns. Since the ancestral wild forms still exist, comparison of these behaviors in wild and domesticated forms give us some ideas as to how natural selection operates to change dispositions to perform behavior patterns. Certain behavior patterns are inherited in crosses between domestic strains in much the same way as inheritance of behavior in Fl interspecific hybrids.

Studies on the behavior of natural and artificial (laboratory produced) interspecific hybrids were surveyed. Heritable characteristics included maintenance activity patterns, quality of voice, courtship patterns, and nest-building behavior. Since Fl hybrids are usually sterile, few studies continued on to F2 generations. Behavior patterns in hybrids may (1) resemble one parent, (2) be present in intermediate form, (3) resemble neither parent or (4) be absent altogether. Behavior rare in parental forms but common in hybrids have been interpreted as changed thresholds to perform these behavior patterns or recapitulation of ancestral behavioral traits due to altered genomes. Alternate interpretations of these data are discussed.

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I have been involved for the past twelve years, 1966 through 1978, with the genus commonly known as Rosellas (Platycercus). Indigenous to Australia, they comprise a group of eight species which are quite colorful, not excessively noisy or destructive and fairly willing to reproduce in captive situations. They range from ten to fourteen inches long, medium in body size, and are of the typical parakeet type. They are fairly active, capable of rapid flight and move easily on the floor of the aviaries while feeding or bathing.

All of the species have cheek patches and reasonably long full tails. Hence, the descriptive term “Broadtails” and the feathers of the mantle, back and wings are black with a bordering of another color which produces a scalloped effect. An attempt to describe each species would be lengthy and laborious as all of them are complicated in their coloring. There are many excellent books available containing photographs of them, or better yet, a visit to a collection will be worth a thousand words.

Five of the species come from the eastern portion of Australia, one from Tasmania, one from the northern area and one from the southwestern area. Both sexes are colored alike in all species except for the Stanleys. In some cases very slight differences in color intensity does exist between sexes.

Sexing can be quite difficult unless you are fortunate enough to deal with specimens that show distinctive physical differences. Ideally, the size and shape of the head will often offer clues. The males should have a larger head with plenty of brow or frontal while the hen’s will be lacking in brow or frontal. Nevertheless, a side view study of both is helpful. H. D. Groen in his book "Australian Parakeets" does an excellent job indicating differences photographically. When viewed from the front, the mandible of the male should be larger and broader than that of the hen. As they mature, a close study of their behavior will be most informative with the males quite aggressive with each other. I have not found the wing stripe to be accurate enough to depend on in determining sex. The Stanley shows a definite difference in color with the hen lacking much of the red seen on the male and the yellow cheek patch is smaller and less colorful.

In an effort to understand the needs of Rosellas, I have read all of the publications I could find not only concerning the birds and their behavioral habits but any information regarding their native...
habitats. With the quarantine regulations permitting their entry in 1968 I was able to obtain good European stock to enlarge the breeding program. Our move to a rural San Diego location from Los Angeles area in 1972 gave us more room to expand, cleaner air, untreated well water, natural open surroundings and, most important, climate like that of their native habitat.

We have bred four species, the Eastern Platycerus eximus; blue, Platycerus adscitus; Crimson, Platycerus elegans; and Stanley, Platycerus icterotis; and recently acquired the Adelaide, Platycerus adelaidae. The crimson or pennant has been our main interest from the beginning and has produced approximately eighty youngsters at the present location.

Because of the area’s temperatures, average lows of 25 and highs of 110, the aviaries are designed without closed shelters or heat. The aviaries are four feet wide and 125 feet long, running north to south and divided into six units ranging from 16 to 25 feet per unit. The shelter end of each unit backs to the north, blocking the cold winter winds that blow down the valley and thus becomes a solid end to the flight behind. The closed sides of the shelter extend 4 feet on the side, allowing a 4 x 4 foot area for nest boxes, feeding arrangements and privacy. The sides of the flight area are 112 x 112 inch welded wire which allows plenty of sun both early and late in the day. During the summer the prevailing winds from midday on are from the ocean ten miles to the west and keep the temperatures quite comfortable. The roof is fully covered, providing good protection from sun and rain but, just as important, limits the visibility of the many varieties of birds of prey in our valley.

Perches of eucalyptus branches are placed on each end of the aviaries, allowing the maximum unobstructed flight, thereby maintaining strength, vigor and fertility. This also allows them to satisfy their emotional need for early and late flights as they might in the wild in their quest for feed and water. The crimsons are kept in the 25 foot flights, and the rest in sixteens. This end on end arrangement of aviaries has eliminated the problems previously experienced and added no new ones except construction costs which has been absorbed by increased productivity. Fighting between males in adjoining aviaries over territorial rights as well as the courting of the other’s hen has been eliminated. Therefore, the pairs must concern themselves with each other without distraction.

As the breeding season approaches, the males begin the courting calls which stimulates the entire group which all are close enough to hear but unable to see. These long units are separated by 20 feet which are planted to limit visibility of other units and provide natural surroundings. This has resulted in a greater percentage of pairs working. The end of the flight being solid has put an end to broken necks caused by flying into wire as previously experienced in flights with wire ends.

The seeds provided are on a free choice basis: straight canary, small finch millet, large proso millet, hulled oats, safflower, sunflower, flax and niger (or thistle) and poppy (or maw). A small portion of the whole wheat bread, apple and cooked feed corn are offered daily. The seeds are all offered in dishes and feeders approximately three feet above the floor, and the bread, apple and corn fed on the floor
as these birds enjoy running about the flight looking for food. Granite grit and natural cuttlebone are also placed in each flight. Regarding the feeding of greens, we feel that only home grown greens are to be considered safe. The many insecticides used today are either directly sprayed on the plants or are included in the fertilization process, and all must be considered as unsafe. Home grown swiss chard and New Zealand spinach maintain themselves for years without additional planting and the birds thrive on a small amount of these dark greens. Grated carrot is of great benefit and readily acceptable. Vitamins in some form are considered to be beneficial when added to their diet. The above is a practical diet from a nutritional point of view and is not time consuming. More elaborate diets can be fed, but unless it is possible to be consistent it is not always practical. Fresh eucalyptus growth is provided weekly and seems to provide medicinal effects both internally and externally as well as emotional satisfaction. We have not experienced external parasites since this practice was introduced. Leaves of the blue gum, Eucalyptus globulus, seem to be most satisfactory for this purpose. Entry into the flights is only necessary once a week to feed. The bread, apple and corn can be supplied without entry, and the water is changed daily from the outside. Thus, daily servicing is minimal, providing the birds with almost total privacy and freedom from stress. During the breeding season the area is closed to all but those attending to their needs on a daily basis.

The boxes furnished for nesting are of the grandfather clock type, have proved successful and are constructed from 112” plywood, 12” x 12” and 24 to 48” deep. The greater the depth, the longer the young seem to stay in the nest to mature and so are not apt to go to the floor when they fledge. The entrance hole is 3” in diameter and 6” from the top. A 6” porch 2” below the entrance hole is used rather than a perch. It allows room for the birds to sit by the entrance hole and does not become loose as a perch quite often does. As we are all aware, loose perches can be the cause of infertile eggs. The inside of the front of the nest is lined with 1/2 x 112 wire for access to the bottom of the nest. Nesting materials include a mixture of dirt, pine shavings and old eucalyptus leaves placed in the bottom of the nest to a depth of 12” in a 48” box. This mixture is soaked with water in late January and is ready for the hen in the middle of March. The hen will dig a depression in this mixture about 4” to 6” deep. She will lay every other day. Clutches usually number four to eight eggs. Incubation takes approximately eighteen to twenty-one days with the hen doing the setting. She will generally leave the nest twice daily to be fed by the male and for water. At hatching time she will leave the nest to bathe, returning to the nest quite wet, which adds moisture to the nest site. Soaking the nesting material in January is also an aid to this end. As the moisture softens the eggshell, the young are better able to escape in good time from the shell. Hens generally set fairly tight until the young are a week or more old, at which time she will leave for longer intervals. The young are fully covered with white down and cluster together. As our practice is never to disturb them at this point, it is quite often impossible to ascertain the number of young present. At approximately ten days of age the pin feathering starts and the chicks separate from this cluster.

Up to this point the male feeds the hen who, in turn, enters the nest
to feed the young. By the time the chicks are two weeks old, we generally find both parents at the feed station and entering the nest to feed the young. The young will fledge at about six weeks, depending on the weather and size of clutch. It is best to leave the young with the parents for six weeks after fledging if the male will allow. This gives them a time to be thoroughly independent and the parents to imprint behavior traits. We have found that the longer the young are left with parents, the more satisfactory the results are when they are used as breeders. Our pairs have double clutched every year except 1977. The month of June, which is generally cool, was quite warm and the birds did not return to nest as in the years before.

Rosellas are capable of producing when one year of age. However, we wait until they are two years old before using them for breeding. In doing so, we have not lost hens to egg binding and our males have not been wife-beaters. They also seem to do a better job of raising their young. With the present supply of birds available today, there can be no satisfactory excuse for breeding brothers and sisters as was the practice years ago.

Acquiring stock for breeding purposes must be done selectively with the final results kept fully in mind so seldom is a pair of proven breeders sold. There are times when an aviculturist must dispose of his good pairs, but this is not a common situation. We, therefore, have acquired our share of problem birds in the past, such as the “old and sterile”, wife-beaters, egg eaters, feather pickers and poor feeders. Therefore, the only birds purchased today are in juvenile plumage from stock known to be productive.

When buying domestic-bred birds, this is a fairly simple matter. A visit to the seller not only offers the opportunity to view the number and quantity of the young produced but also a chance to see the parent stock, methods of breeding and management.

When purchasing imports, it’s a bit difficult. I would rather purchase from a large group. It indicates that the source in Europe is productive. It also gives a better choice. In either case (as well as when judging your own young), select only a small number of the group for your purposes as expanding too rapidly generally results in lowering your standards. A small group of quality specimens is far better than a larger group of lesser quality. In making your choice, we suggest picking the hens first. We place great importance on as large a hen as possible, broad in breast and shoulders, good clear eyes, calm but alert and firm in the hand.

Flighty hens are apt to break eggs and step on the young if something disturbs them while on the nest. If possible, choose hens from mothers that lay large clutches and are successful in raising their young.

The choosing of males is a bit easier. Points of importance are: color and aggressiveness, or vigor. We try to breed size from the hen and color from the male. If the male has excellent color and is also large, so much the better.

Learn to whistle a challenge call and try it on a group of males. The males we choose will not let a challenge go unanswered.
After our choices are made, we place them in flights that are 8 x 8 feet, which allows plenty of room for exercise and growth.

Rosellas continue to grow and develop size up to twenty-four months. We hold them in these flights until they are eighteen months old. By that time, they have chosen mates and become aggressive toward each other and separation is necessary. This is a good time to re-evaluate and cull out those that have not developed to our standards. They are then ready to be moved into the breeding flights and thus will be settled in nicely by the time spring arrives. It should be pointed out that only one pair per flight is possible.

On the subject of medication, the average aviculturist is far too quick to put something in the water. Many birds are lost annually due to over-medication. Even more distressing is the use of incorrect medications in the treatment of ailing birds, which produces negative results. We agree that a well-stocked medicine chest is necessary, one that contains a complete assortment selected by your veterinarian. An excellent veterinarian in our area has become interested in our problems and has undertaken to specialize in birds. We, in turn, supply him with all literature available to us, including tape recordings of meetings and printed matter with the end result of a better program of care available to us. It is, therefore, in the best interests of a serious aviculturist to help interest and inform a veterinarian in your area so that if a real problem occurs he can take charge effectively.

Rosellas are susceptible to internal parasites and must be watched closely. The purchase of a small microscope helps in this matter. With a little practice you can determine the type of infestation and take appropriate action.

We feel that in terms of general management that all too often the aviculturists interfere with their birds. In the wild the many species have developed and prospered on their own and not until man moved in did many of their problems develop. When we place them in a captive environment we alter their lives. It is our obligation to furnish proper and adequate facilities. The birds neither read our books nor attend our meetings, and yet it is they who hold the key to the reproduction process.

A group of ten Rosella breeders will offer ten different methods for successful results. In truth, there is not one secret to success. Meetings are necessary for us all to provide the opportunity to exchange ideas. We cannot read enough. However, I suggest that we spend as much time as possible quietly observing our birds. By doing this, we will often detect things that make them feel uncomfortable. We have all heard of the many instances involving an unproductive pair that upon being moved into a different flight or even sold, went straight to nest and successfully reared young.

Perhaps a bit more time spent watching them would have informed the owner of the source of the problem.

Rosellas are not complicated in their habits, so neither should their management be complicated.
By "softbill," bird keepers mean any small bird that feeds primarily upon insects rather than seed. Many softbills also live largely on berries or other fruit. Some eat a certain amount of seed. Of course, many kinds of "hardbills" will live wholly or mainly on insects and fruit when they have the opportunity.

Seed-eating birds are relatively easy to feed. Insect-eaters have always been considered more difficult and troublesome. In temperate climates their natural food is scarce and hard to come by in wintertime and, therefore, a substitute for it must be found. Such a food is often called a successful "softfood" and to be successful needs to be readily acceptable to the birds, nutritionally adequate, free from injurious elements, accessible and reasonably convenient for the bird keeper.

A survey of the literature dealing with bird keeping at once reveals great diversity of opinion on what is the best way of feeding birds that are predominantly insectivorous in nature. At the same time it reveals the conservatism of some bird keepers in holding fast to archaic methods and recipes.

Bird keeping, including the maintenance of softbilled birds, dates back at least to the time of the Roman Empire. The Roman writer, Varro, claimed that bird keeping in Rome was initiated by Marcus Laenius Strabo of Brindisi (1). There is reason to believe the art is much more ancient (2).

Varro describes large aviaries in which fieldfares and European Blackbirds were held in numbers and fattened on a paste of figs and meal (ficis et farre) until they were in demand for a banquet and could be sold at a good profit. Varro’s own splendid aviary was kept strictly for pleasure, and in it were nightingales and blackbirds, among others. We are not told how they were fed.

Pliny writes of a white nightingale bought at a fabulous price and given to Agrippina, the emperor’s consort, and also of nightingales, magpies, a starling and a thrush that had been taught to imitate human speech (3). He says nothing about their food.

In the sixteenth century, early ornithologists, including Gesner (4) and Aldrovandi (5) give some indication of how certain birds were fed, but at least one writer dedicated a whole book to the art of bird keeping, including the keeping of softbills. He is Cesare Mancini Romano (6). A rather bad piracy of his work in French is better known (7). Mancini tells us how to keep and feed nightingales, blackcap warblers, rock-thrushes, songthrushes, blackbirds, calandras and skylarks as well as something he calls a "birdling"—
Mancini advocates two alternative methods of feeding.

The first method of feeding is of raw sheep’s heart, cleared of fat and tough strings and finely chopped and ground. Yolk of hard-boiled egg can be substituted occasionally when fresh heart is not available. By way of a purgative or medicine, softbills should be given “those worms found in pigeon-lofts and also in flour” – presumably mealworms.

The second method of feeding is on a dry “paste”, which Mancini says is “marvelous” for softbills. He gives rather confusing instructions for making it.

If Mancini’s instructions in the sixteenth century are obscure, Oliva, in the succeeding century makes up for it. He gives a whole page of instructions and provides a splendid whole-page engraving showing the work in progress (8). This is what he advocates:

Peel half a pound of almonds. Break and grind them up fine. Stir into them four ounces of butter and the yolks of four hard-boiled eggs. Work this mixture into two or three pounds of chickpea flour. Put all this into a pan over a charcoal fire and keep stirring it until it appears to be fairly cooked. In a separate small pan melt and boil together a pound of honey and three ounces of butter. Remove any scum. Have one person to dribble the hot honey gradually through a perforated ladle onto the other ingredients while another person stirs constantly until the honey is well incorporated, when the paste will become granular. This is for summer use.

For winter use, add a half-pennyworth of saffron.

When the paste has become granular and is yellow in color, work it through a colander with round holes the size of vetch-seeds. Spread the grains on a white cloth to dry. Store them in a tin can or box.

The dry paste will keep for up to six months. If it becomes too dry, add a little honey to soften it.

R. L. Wallace was still recommending a paste almost identical to this at the end of the last century (9). A cheap and degenerate descendant of the original was available commercially in Wallace’s day under the name of “German paste”. It sold at three pennies a pound or less and usually consisted of pea-flour cooked with a little fat, sweetened with treacle or molasses and sprinkled with maw (poppy-seed) and hemp-seed. Superior samples had a few dried ants’ eggs and were then sold as “insectile food” (10).

German paste came under severe criticism among the more progressive fanciers of the 1900s. The Rev. C. D. Farrar had German paste in mind when he wrote “If you intend to feed only on peameal, I have done with you.” (11)

Despite its bad reputation, German paste seems to have been a fairly adequate staple diet for skylarks (12).

An Anonymous writer of 1697 continues to recommend the raw
heart and the paste for feeding nightingales, but says he himself gives to his nightingales ground almonds, cake (massepain), chopped cabbage, lettuce and chickweed, cooked mussels, beets, peas and beans, sugar and other items (13).

By 1738, Eleazar Albin is recommending a mixture of the heart and hard-boiled egg as food for small softbills (14). The anonymous author of The Bird-Fancier’s Necessary Companion and Sure Guide does likewise (15).

Raw meat and egg remained popular through much of the last century. In 1826, the Rev. William Floyer Cornish of Totness in England claimed that he had been successful in keeping whitethroats and other small softbills on “beef, veal, mutton or lamb, not over-dressed, cut very small and mixed with hard eggs, yellow as well as white, and a little chopped hempseed, on which they have thriven very well” (16).

Similarly, in 1832, a Mr. Cox exhibited a nightingale in full song to members of the Zoological Society in London. He had kept it for four years. In the Arcana of Science, Mr. Cox expressed the opinion that failure with nightingales “and other Silviadae (sic)” was often due to over-elaborate feeding. He used finely ground meat and hard-boiled egg and considered insects by no means necessary (17).

Hemp-seed was recommended as an item of softbill diet by some bird keepers at an early date. Our nightingale author of 1697 condemns it, blaming it for causing fits in nightingales and starlings. On the other hand, Robert Sweet recommends for British warblers a staple diet consisting of scalded and finely “bruised” hemp-seed mixed to a moist paste with soft bread. He considers insects, fresh or dry, to be essential extras and accepts meat and egg as a useful occasional change. He observes that limy grit is essential and that the birds will not long stay healthy without it (18).

A contributor to the English journal Cage Birds was still advocating the use of crushed hemp-seed and bread in 1960. He added grated cheese. He mentions wrens, thrushes, blackbirds, larks and meadow pipits, and seems to consider it a recommendation for his food that birds fed on it develop white feathers in their wings and tails (19).

Dr. Bechstein, like Robert Sweet, recommends the use of fresh and dried insects, and in his Chamber-Birds gives instructions for laying in a stock for winter feed. However, his birds were largely fed on a “universal food” consisting of milksop mixed with either coarse wheatmeal or barleymeal. Alternatively, grated carrot could be mixed with the bread in place of the milk. Nightingales were given ants’ eggs, elderberries and cooked beefheart (20).

Dr. Bechstein set the style for softbill feeding in nineteenth century Europe. His universal foods may appear to us to be excessively austere. It would seem that some bird keepers of the last century saw things in a different light. In 1873 Swaysland considered oatmeal or barleymeal damped with milk to be the ideal diet for starlings, thrushes and blackbirds. For “warblers” (which in his day included chats and other small thrushes) he was still with Mancini in the sixteenth century and with Sweet in the early nineteenth (21).
Sumner Birchley was still using and promoting the use of dampened barleymeal for thrushes and starlings in 1909 (22). The birds were occasionally given a small earthworm or a snail “as a tit-bit”.

Apparently, some softbills were kept on what must surely be the ultimate in prison diets — wheat bran dampened with water. Field-fares seem to have survived on it. Bechstein says blackbirds will not. In our own century, Konrad Lorenz was still recommending it for starlings (23).

Since egg yolk has been a favorite bird food from time immemorial, it must have required moral courage on the part of Dr. George W. Creswel’ to condemn it roundly in the years 1903 and soon after (24).

Dr. Arthur Butler, a Founder-Member of the Avicultural Society, vigorously took up the defense of egg, boiled and as dried egg yolk (25).

A bitter correspondence between the two doctors soon divided the members of the Avicultural Society and the Foreign Bird Club into hostile camps — “eggists” and “non-eggists”. The non-eggists had considerable influence. It was soon obvious that Dr. Creswell was far better informed than his rival.

Even non-eggists of this period often fed their softbills largely on “stale sponge cake” — stale because they bought it at a reduced price as a bakery shop leftover.

While the no-eggist contention was at its peak, protagonists of both sides sought support for their opinions from distant cultures, especially from the Orient where bird keeping was known to be an accomplished art.

They found that in India softbilled birds were fed on satoo — a paste made from gram (chickpea flour) and ghee (clarified butter). This was supplemented with grasshoppers, maggots and other insects (26).

In China the traditional softbill food was made from finely chopped mutton or other meat soaked in a little water for a few hours and then rolled in egg powder and soya flour. (To this day, soya flour mixed with dried insects is still the staple diet for Zosterops spp. Eds.) Insects were only offered during the moulting season (27). Frank Finn claimed that, in his day, softbills were sent from China to India on a diet of small shelled millet and dried insects and that they arrived in very good condition (26).

In Japan softbills were fed on fishmeal made from a smoke-dried freshwater fish. This was mixed with varying amounts of equal parts of rice flour and rice bran. Chopped greenfood was provided (28).

Towards the end of the nineteenth century, expanding international trade made available to European bird keepers dried insects that could be used in making acceptable mixtures called “insectile” foods. These soon became the accepted norm as soft food for insectivorous birds.
They were expensive compared with the older-fashioned diets, but every one agreed that they were more natural and, therefore, better (29). The Rev. C. D. Farrar wrote of his own rather typical insectile mixture, "On the mixture and a few mealworms daily any sort of bird will do well." (30)

A typical insectile food would be made up of equal parts by weight of dried ants’ eggs, dried flies and meatmeal, with a quantity of biscuit meal equal in weight to the rest of the ingredients combined. Some bird keepers used dried and ground silkworm pupae. Others added dried egg yolk. Still others put in some powdered cuttlebone. The mixture was made crumbly rather than powdery by the addition of fat, honey, or both, and was usually moistened before use with hot or cold water, milk, grated carrot, grated apple, chopped lettuce or mashed potato (31). Cheese, though an old-fashioned and unnatural item, retained its prestige as an additive to insectile mixtures. Its chief protagonist in England was P. F. W. Galloway (32).

Mealworms have been considered a suitable food for captive soft-bills at least since Mancini’s time in the sixteenth century. Like Mancini, many bird keepers have believed that they could easily be overdone and that an excess would lead to gout, fits, obesity and other disorders. At the same time, the benefit to the birds of adding a generous ration of live food to some of the traditional staple diets has led to the belief, which I have often heard expressed, that live food must contain some mysterious vital element necessary to the birds and lacking in dead soft food. It is only in recent times that the “richness” of mealworms has been seriously questioned and their nutritional limitations indicated (33).

In the last hundred years, mealworms, maggots and, to a lesser extent, cockroaches, have been the live foods that have been most relief upon by keepers of softbilled birds. Live ants’ eggs and wasp-grubs have been important in their season, as have miscellaneous insects taken in the field with a sweeping-net or by beating. In recent years, considerable progress has been made in culturing a variety of different insects in quantity (34) and in developing methods of harvesting honeybee larvae for bird food (35). House crickets and locusts are being raised commercially. Since many kinds of softbilled birds will refuse to feed anything but fresh live food to their nestlings, these developments are of great practical importance to the aviculturists.

The development of moth-traps having an ultraviolet light and an electric fan that draws in night-flying insects attracted to it has opened up unprecedented opportunities for gathering wild insects in quantity. I, myself, have sometimes taken a pint of Noctuid moths in one night and have sometimes had two or three gallons of moths on hand, frozen, ready for use as needed. I am indebted to Mr. Harry Halff of San Antonio for pointing out the value of this device.

Insectile mixtures are probably still the main standby for bird keepers who only maintain small collections. Those who have to cater for considerable numbers of softbills have been able to benefit from a development that has gone counter to the natural food tradition. This counter-movement has been made possible by
progress in our understanding of the elements of avian nutrition. A name particularly associated with the application of these principles to the feeding of captive birds is that of Dr. H. L. Ratcliffe (36).

Dr. Ratcliffe and others have set out to devise a diet that will be readily acceptable to the birds, more than adequate nutritionally, free from objectionable elements and reasonably economical, available and convenient for the bird keeper. Instead of insects, these foods are compounded from ingredients known to have superior food value. Considering the proportion, availability and quality of their proteins, carbohydrates, fats, vitamins and minerals, etc. They are rather readily modified according to local conditions. Local variations have given good results in Switzerland (37), Canada (38), Texas (39) and no doubt elsewhere.

The poultry industry has been revolutionized in recent decades and mass-produced standard foods having controlled nutrient values have been devised to suit precisely the needs of poultry at different ages and stages.

No comparable detailed investigation of the precise nutritional needs of softbills has been feasible. Nevertheless, various mass-produced “Mynah Foods” and “Mockingbird Foods” are on the market. It would seem to be rather risky to assume that every brand put up for sale at a commercially competitive price is suitable in itself for any except the least demanding of omnivorous softbills. However, the potential of these convenient and economical foods should not be underestimated. I have seen Red-billed Leiothrix, Blue-winged Sivas and an American Blue Jay kept in immaculate feather and apparently in perfect health on an exclusive diet of dry “gamebird-starter”. They compared very favorably with lots of specimens of the same species I have seen maintained on more conventional diets.

Perhaps some mass-produced bird foods are already ideal for any except the most specialized feeders among softbills. These birds will always be a separate problem. It is certain that practical and satisfactory diets for the majority of softbills are now easily compounded by any bird keeper, diets that are far superior to those on which birds have been kept with at least some degree of success in the past. The day of insectile mixtures is probably past, and live food nowadays may be regarded as an expensive item reserved for birds that are newly acquired and are unused to any other food, or for breeding birds that are feeding young.

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The Genus Amazona contains the very rare and endangered Amazona leucocephala and its four subspecies.

Amazona l. leucocephala, known as the Cuban Amazon, is found on the eastern and central part of Cuba. Its current status in the wild is unknown, although volume 17 of the International Zoo Yearbook has forty-four Cuban Amazon recorded in captivity. Of the forty-four recorded, twenty-five are in the Soviet Union, eighteen are in Europe and the remaining one bird is in the United States. I believe a more accurate count would be closer to ten to fifteen birds in the United States.

A. l. palmarum, also known as the Cuban Amazon, is restricted to western Cuba and the Isle of Pines. The difference between the two species is that the general plumage of palmarum is a darker green, the red abdominal patch is darker and the throat is a deeper red. The status is also unknown.

A. l. caymanensis, known as the Cayman Amazon, is found on Grand Cayman Island. The estimated population of the species is two hundred individuals. It may have been as low as seventy-five at one time. There are about forty-five birds in captivity, mostly in the United States. However, there are some birds in Europe. On a visit to Grand Cayman two years ago, a local enthusiast showed me a newspaper article which reported that one resident had shot one hundred of these beautiful parrots in a three month period. There is a law that makes it illegal to shoot the parrots, but when I contacted the Ministry of Agriculture, they had a definite “don’t give a damn” attitude. The Cayman Amazon is the best established in captivity of any endangered Caribbean Parrot, with young being raised every breeding season. There have been approximately fourteen Cayman Parrots raised in Florida since 1974. The breeding birds are kept in aviaries which measure one meter high by four meters in length. A nest box which measures 30 x 30 x 50 cm, in depth is attached to the outside of the aviary. These aviaries are suspended about 1 1/2 meters above the ground. They are situated in a simulated rain forest. Some of the advantages of the suspended aviaries are that the birds do not have access to their droppings or discarded food which might become sour within a few hours. Predators such as rats and mice find it impossible to gain access to such aviaries. At no point in the aviaries’ construction is the parrot’s view obstructed, and with the rain forest being so similar to the bird’s native habitat, it is doubtful that they are aware they are contained. This undoubtedly contributes to their breeding success. The Cayman Parrot is prone to obesity in captivity. Therefore, it must be supplied with large amounts of green food daily and sunflower seeds must be kept at a minimum.

A. l. hesterna, known as the Cayman Brac Amazon is the smallest of the four subspecies. Its population is estimated to be thirty birds left
in the wild. There are approximately eight in captivity. Because of
the limited habitat, the Cayman Islands, the two subspecies are the
most endangered of the four representatives of leucocephala. This is
especially true of the Cayman Brac Parrot, for the island of Cayman
Brac is less than 20 kilometers in length and not more than four in
width. There are no specimens to be found on Little Cayman. This
makes Cayman Brac undoubtedly the smallest inhabited area of any
Amazon species or subspecies. The island is so small that if one is
dedicated enough to face the rough terrain which forms the “Bluff”,
he may know precisely where the majority of these parrots will be at
any given time. They usually forage in a group of about fifty birds up
and down the length of the island. Stragglers can be found almost
anywhere. These concentrations begin to thin out when the nesting
season begins in March. Unlike Grand Cayman with its lush
vegetation, Cayman Brac receives little rainfall which causes most of
the terrain to be dry, and the tree growth to be stunted. Only in
areas where rain falls did I see trees large enough for a parrot nest.
Due to the many holes in the rock bluff, one might think hesterna
would resort to using the “bluff” for nesting as bahamensis has done
on Abaco Island. There have been no captive breeding results as yet
because the captive birds are too young.

A. l. bahamensis, known as the Bahamas Parrot, is found on Abaco
and Great Inagua Island. Its population on Abaco is approximately
four hundred and on Great Inagua its population may be as high as
seven hundred. There are none known to be in captivity. The
breeding season in the wild lasts between April and July. Nesting
takes place in crevices on the sides of limestone rock ridges or in
natural holes in the limestone on level ground. This is an unusual
nesting site for a parrot of the genus Amazona, for all other species
of this genus nest in cavities in trees. There is one exception, and
that is the Yellow Shouldered Amazon, Amazona barbadensis
rothschildi which nests in cavities or clefts in rocky escarpments on
Bonaire and apparently in tree cavities on the South American
continent. There is good evidence that at one time the range of the
Bahamas Parrot was more extensive. On Crooked Island, bones of
this parrot have been found in a cave shown to have been used by
Arawaks between 1500 and 3000 years ago. More recently the
Bahamas Parrot occurred on Acklins Island, at least into the 1940’s.

The Cuban and Cayman Island Birds are not the only Caribbean
Parrots in danger of extinction. Of the two parrot species found on
Dominica Island, there are only three hundred and fifty individuals of
the Arausiaca Amazon remaining in the wild, and one hundred and
fifty individuals of the Imperial Amazon remaining in the wild. There
are only one hundred and twenty-five individuals of the St. Lucia
Amazon on St. Lucia Island remaining in the wild. There are
approximately five hundred and twenty-five individuals of the St.
Vincent Amazon remaining in the wild on St. Vincent Island.

But, without a doubt, the Amazon Parrot whose population is in the
worst shape is the Puerto Rican Amazon with only thirty-nine birds
left in existence worldwide.
Doves are one of the simplest forms of birds to propagate in captivity, if a little common sense and basic expertise is used. Sometimes it is necessary to colonize doves for convenience’ sake, and this is permissible, providing one knows which species to colonize and which ones not to colonize.

Doves are relatively defenseless when compared to other forms of bird life, such as members of the Parrot family. Although they can give a bruising cuff with the carpal joint of the wing, most of them have no means of quickly doing serious damage. They can, however, peck an unresisting enemy to death if they are shut up in a cage and given plenty of time. Such things do not occur with plenty of freedom.

Let’s look at colony caging first. An aviary ten feet by ten feet will house satisfactorily any species of doves one can think of, from the largest form (Crowned Pigeons) to the smallest form (Pigmy Ground Doves). Generally speaking, one can put together one pair of small doves such as Diamond Doves and one pair of larger doves such as Senegal Doves without much danger. The Diamond doves are too small to harm the Senegal Doves, and the Diamond Doves are too fast for the Senegal Doves to harm. One must remember to make several nest sites available, however, or confrontation will result. No problems will occur if nesting sites too small for the Senegal Doves to utilize are used for the Diamond Doves and, of course, larger sites for the Senegal Doves should be made available.

Another variation of the same method is to place one pair of Ground Doves (Bronze-Wings, etc.) and one pair of perching doves, such as members of the Turtle (Streptopelia) Dove group together. The Bronze-Wing spends most of its time on the ground, and the Turtle Doves on perches. With a bit of experience, one can get the maximum from the aviary by placing one pair of small ground doves and one pair of large ground doves, one pair of small perching doves and one pair of large perching doves in the same ten by ten aviary. That, in my estimation, is the maximum number of birds for an aviary of that size.

Doves, especially ground doves, require an absolutely dry ground. Without it their life span is considerably shortened. I have found by placing black plastic on top of the ground and placing about four inches of good clean, dry sand on top of the plastic to be a practical solution. I would suggest that a roof cover at least a portion of the aviary. Shrubbery does create more privacy, particularly for ground doves, and it provides excellent nesting sites. An added bonus of shrubbery is the appearance of your aviary. I have always believed
that doves in their native habitat consume substantial amounts of insect life. Shrubbery seems to attract insects, and I have seen the doves picking insects from the shrubs. I have noticed several species eat the leaves also.

Colony breeding several specimens of the same species or several species in the same aviary requires a great deal of space to be safely accomplished. My main colony is housed in an aviary forty feet by twenty feet. It is heavily planted with shrubs and houses twenty species, equally divided between ground dwelling and arboreal species. The only apparent danger is to the squabs when they first leave the nest. However, as long as there is adequate cover to hide in, the squabs will safely survive. Other suitable aviary sizes are ten feet by twenty feet, in which several specimens of the same species are housed. Once again, much cover and adequate nesting facilities are required.

The quality of feed is as important to the successful breeding of exotic doves as it is to any other species. They require, and must have, a balanced diet. There are individuals that feed their doves wheat only or corn only or chick scratch (a combination of cracked wheat and cracked corn), and they manage to raise a few offspring each year. However, the aviculturist that faithfully practices a program of an adequate diet consistently produces more offspring and healthier offspring. Most doves require a combination of seeds, such as large white millet, milo, corn, safflower, canary grass seed, rape, flax, shelled sunflower, etc. They also require some animal matter, such as meal worms, crickets or flying insects. However, a good crumbled dog food or commercial insectivorous food is suitable as a substitute. Fruit is also an important part of a dove's diet. It must be fed in moderation. I have found that certain commercial Mynah bird foods are completely adequate as a fruit substitute.

Fresh water daily is required, and I am firmly convinced that not a drop of water should be given unless medicated with bleach. I also recommend a small daily dosage of water soluble vitamin be given. Doves require vitamin A and D in substantial amounts, and there are several good vitamin solutions high in A and D3 on the market. It is far better to give a little each day in the year than it is to feed nothing during the fall and winter and heavy concentration in the spring and summer.

Cleanliness is also an important factor. There is a legitimate excuse for not cleaning the aviaries during the nesting season. Disturbance of exotic species of doves when they are nesting can be disastrous. However, there is no excuse during other times of the year. Dirty birds are unhealthy birds, usually harboring several bacteria and parasites. Nests should be changed after each nesting. If not, mites can and usually do build up rapidly, resulting in dead squabs as fast as they hatch. If pine needles are used as a nesting material, the pitch helps a great deal in controlling the parasite problem. It is also a good idea to sprinkle each new nest with a little insecticide powder before there are eggs in the nest. This allows the strength of the insecticide to deteriorate before the squabs are hatched. Strong insecticide is just as hazardous to the squabs as are the nest mites.

One of the first questions asked by the prospective dove owner is “What is the difference between pigeons and doves?” The answer is
often puzzling as to distinction between the two, ornithologically there is none. The word “pigeon” is of Norman-French, the word “dove” of Anglo-Saxon origin. In common speech, in English, the word “pigeon” is usually applied to the larger species such as the Nicobar Pigeon, Band-Tailed Pigeon, and the word “dove” to the smaller ones such as the Diamond Dove, Ring-Neck Dove, etc. The names given to the different species by ornithologists have not followed popular usage in this manner, however. The Stock Dove is a typical example. It is thought of as a “pigeon” by laymen, and it is the ancestor of all our domestic pigeons. However, ornithologists refer to the bird as the “Stock Dove”.

TECHNIQUES FOR REARING INSECTIVOROUS BIRDS

JANUARY 24, 2015 | LEAVE A COMMENT

By Donald Bruning, Ph.D.

IFCB 1978

Zoos and aviculturists have kept and reared insectivorous birds for many years. However, success has been restricted to a relatively few species. Many factors come into play when planning a breeding program.

1st You must provide an adequate diet.
2nd You must have pairs or an appropriate breeding group.
3rd You must have a suitable facility.
4th You must provide suitable nesting areas and materials.
5th You must provide proper environmental conditions - light, humidity, etc.

6th Careful observation and records are extremely important. Birds must be individually marked or identifiable. The natural habitat and nest structure for each species must be carefully considered. Once the birds produce eggs, the first major hurdle is over and now the real work begins. A number of decisions are now needed.

First, are the eggs to be left with the parents or removed for artificial incubation:

Ideally, the eggs can be left with the adults for incubation and rearing of the chicks. This is certainly the best way, but it also reduces production and may reduce the success ratio of the nest since chick mortality is generally high. Even so, this is the preferred method.

If the eggs are to be removed, a suitable artificial incubation system must be operating and ready to receive the eggs. Once again, the longer the eggs are left with the parents the better their chances of hatching, but this results in fewer offspring as recycling time is increased. Incubation time, temperature and humidity are critical.
We have found 97.5° F with 68% relative humidity are critical. We have found 97.5° F with 68% relative humidity works best for us with passerines. Except under unusual circumstances, the eggs should not be washed or handled any more than absolutely essential. Personnel handling eggs should wash their hands before handling eggs, as oil from fingers can adversely affect hatchability. Most eggs must be turned regularly and benefit from a daily cooling period. The eggs should be regularly candled to determine fertility and follow development.

Eggs should be moved into a separate hatcher once they pip. The humidity in the hatcher should be as high as possible. We regularly spray the inside of the hatcher and the hatching eggs with distilled water from an atomizer spray. Frequently eggs can be removed at this stage from nests where the parents have a record of not caring for their chicks.

A newly-hatched chick should be allowed to dry off in the hatcher. Altricial chicks should then be moved into another hatcher or an infant isolette incubator where temperature and humidity can be carefully maintained. The chicks should be placed in a suitable nest structure which allows them either small twigs or other material for gripping with their feet. Unless a proper substrate is supplied, leg problems are likely to develop. The material used will depend on the species involved. Green wood hoopoes develop severe leg problems if they cannot grip their nest with their tiny feet. A cork bark nest is ideal as they grip it just as they would the inside of a natural tree hollow nest.

Frogmouths have caused problems by swallowing the sticks used in their nests to prevent leg problems. As a result, the sticks must be changed in size every few days so that frogmouths have good footing but cannot swallow the sticks.

Once you have the chick, records become essential. You must maintain records of the chick’s weight along with what and when it is fed. A carefully planned schedule is important at this point. Normally a chick’s weight will drop the first day but should start to increase as soon as the chick starts feeding. The greatest danger at this point is to overfeed the chick because it continually gaps for food. The amount of food should increase gradually. Chicks can be fed very small amounts hourly the first day from 6:00 or 7:00A.M. to 6:00 P.M. Most chicks are far better off if they are not fed overnight. Most chicks are naturally only fed during the daylight hours.

Defecation of the chick becomes a critical factor and should be monitored carefully. Amount, frequency and form of the defecation tell a great deal about the progress of the chick. We have worked out a schedule for Tawny Frogmouths whereby we feed the chick until it reaches 25 grams, and then it is given no more foV until it defecates the first time. Then the chick can be fed until it reaches 35 grams or defecates a second time. Once the chick has defecated twice, it is well on its way and grows rapidly.

The diet of the chick is critically important. Ideally, the diet should be as close to natural as possible. This is usually impossible and an artificial diet must be used. A good basic diet is essential.
First, we try to determine what the parents feed to their chicks and utilize whatever the parents use. However, we realize that we must maintain a good balanced diet so we start with certain basic commercial diets and then modify them as necessary to satisfy specific chicks.

Gaines dog meal and baby mice are the two most commonly used items for our insectivorous birds. Moistened Gaines meal is readily accepted by most chicks. Tiny pieces of baby mice serve as a good substitute for most live insects. Commercial turkey starter and grower form the basis for our diet for adult insectivorous birds.

Feeding a small chick can be quite a challenge. Newly hatched chicks may not be able to hold their heads still while gapping or some chicks are simply too weak to hold up their heads. In these cases, the chick’s head must be held or propped up carefully so the chick can be fed. Pieces of food must be very small. This helps the chick swallow the food and helps prevent overfeeding. Overfeeding is a very serious potential problem during the first few days. It is far better to have an underfed, hungry chick than an overfed chick that is no longer interested in food. Everyone who cares for small chicks finds it very difficult not to give the chick just one more piece of food. Frequently that one extra piece makes the difference between life and death. This is something that we all learn the hard way. Frogmouth chicks are a good example; also Fairy Bluebirds.

The closer we can simulate natural conditions, the greater our chances of success. During the first few hours chicks are fed very small bits of food at intervals of every one or two hours. It is very important that everyone caring for the chick or chicks understand what is to be fed and how frequently. We have developed feeding charts to guide any keeper on the specific care of each species.

Most chicks should be fed only during daylight hours. Overfeeding or excessive buildup of waste materials can be serious threats to the welfare of a chick. Early attempts at hand rearing Fairy Bluebirds failed because they were overfed at night and became fouled in their own droppings.

Once the chicks are eating on a regular schedule and have regained their hatching weight, they are ready for a gradual and continual increase in food. Healthy chicks start slowly but grow more and more rapidly with each passing day.

Any change in the growth rate should be a warning flag of potential problems. Long legged birds are particularly susceptible to a sudden spurt of growth, resulting in leg problems. On the other hand, any sudden decrease in the growth rate may signal the onset of infection, disease or parasites. Inadequate or improper diet usually manifests itself within the first forty-eight hours or after five to seven days.

Lack of interest in food, change in body coloration and diarrhea are three additional indicators of serious problems. Time is of the utmost importance. Any delay will generally result in the chick dying. We have found that being prepared with medication can save many chicks. A veterinarian’s advice is needed to determine what medication is needed. However, once a veterinarian recommends a
treatment, you should be prepared to start treating a chick immediately when symptoms manifest themselves.

Monitoring the defecation of the chicks is extremely important. Proper fecal sacs or loose droppings are good indicators of the chicks’ health.

The nest structure must be kept clean and supplied with the proper substrate.

Hazards in the nest or in the incubator must be avoided, such as holes, grates, cracks, wires, fans, etc.

As the chicks grow rapidly, they can be fed less frequently and gradually the amount of each feeding can be increased. The progress of the chicks can be monitored by their growth rate, their appetite and the development of their feathers and legs.

The next critical period comes when the chicks are ready to leave the nest. A dramatic weight drop and a decline in acceptance of food are common occurrences at this time. Frequently the droppings of the chick will change from fecal sac to adult soft droppings at or a few days before fledging. Chicks should be gradually converted onto an adult diet before fledging as it is much more difficult to alter diet after fledging. Most chicks will begin to eat on their own shortly after fledging. Hand feeding should continue, however, until chicks are definitely feeding on their own. Hand feeding should stop immediately after self feeding starts. If hand feeding continues too long, chicks are more likely to be imprinted, tame or simply won’t eat on their own.

Chicks removed from their natural nest just before fledging should be treated just like hand reared chicks. Frequently naturally reared chicks will refuse to eat and as a last resource must be force fed. They most rapidly accept food left in pans for them. Getting chicks to eat the adult insectivorous diet can frequently be stimulated by placing mealworms into a shallow pan of the prepared insectivorous diet. The movement of the mealworms attracts their attention, and they soon learn that the other material is food.

Now that the chicks are on their own, they should be cared for like any other birds. However, a great deal of care and observation is required when these birds are moved into any new surroundings. Unless careful observation is maintained when the chicks are introduced to others or into new exhibits, the mortality rate will be high.

Chicks reared in captivity seem to show much greater success in breeding and rearing their own chicks.

These are just a few pointers that we have found to be useful and hope some of these ideas may help you.
Introduction

The cryopreservation of avian semen is another new propagation technique that has been successful in chickens (Sexton 1979) and recently on a limited basis in propagating cranes (Gee and Secton 1979) and ducks (Watanabe et al. 1981). The U.S. Fish and Wildlife Service, the U.S. Department of Agriculture, and Agricultural Research Council's Poultry Research Centre, Edinburgh, (Scotland) have active research programs in this area while several zoos, universities, and the International Crane Foundation have begun efforts to freeze and store avian semen.

AI as a Propagation Tool
AI programs have developed in response to a variety of needs in avian propagation (Smyth 1968, Martin 1975, Cooper 1977, Gee and Temple 1978). The most obvious need was to reduce or eliminate infertility (Szumowski et al. 1976, Lake 1978, Sexton 1979). In some mated pairs natural copulation can be difficult because of differences in body size, injury, or deformity, and in some, natural copulation maybe inhibited by behavioral difficulties. In other situations some females may be kept in separate pens because of incompatibility or the lack of a mate. Occasionally a productive female may be in a distant location separate from the male, where transfer of semen is the only alternative to infertility. Also, poor fertility in a mated pair can be improved through insemination with semen from another male.

AI is useful in carrying out the goals of special breeding programs for
captive propagation. The genetic influence of one male in a population can be increased by using his semen to sire young from several females each season. Semen from several males can be used at one time to increase fertility or semen donors can be interchanged during a season so that chicks from the same female could have different sires. Hybridization between incompatible species is possible with AI and has been used extensively in poultry and waterfowl. Certain information can be gathered more quickly using insemination. For instance, a male’s potential for producing superior progeny or his potential fertility with several females can be determined more quickly through AI than with natural matings.

Semen collected has other uses. Laboratory studies of semen can be used to evaluate its reproductive potential (Sharlin et al. 1979), to evaluate semen diluents (Sexton 1977), to detect disease (Thurston et al. 1975, Stipkovits et al. 1978 and 1979, Ferrier et al. 1982) and to separate species and subspecies (Sharlin et al. 1979, Russman and Harrison 1982). Semen can be used to evaluate sperm preservation techniques and kept in the frozen state indefinitely (Sexton and Gee 1978, Watanabe and Terada 1976 and 1980, Watanabe et al. 1981).

Reproductive Anatomy and Physiology
To use AI, it is helpful to understand avian reproduction and to avoid confusion between bird and mammal reproductive systems. Male birds lack the accessory reproductive organs typical in mammals (Marshall 1961). The paired testes are located deep in the body cavity, above the abdominal air sacs and ventral to the cephalic end of the kidneys (Sturkie 1965). The testes consist of seminiferous tubules, rete tubules, and vas deferentia, but no septa or lobules. The sperm are taken from the simple epididymis on the caudal wall of the testis to the cloaca by the vas deferens (Sturkie 1965). The vasa deferens terminate as erectile teats in the urodeum (Sturkie 1965) and in some small birds, form a coiled structure above the dorsal lip of the cloaca, the cloaca) protuberance (Howell and Bartholomew 1952, Salt 1954, Wolfson 1952 and 1960, Middleton 1974). A few avian species have a copulatory organ for delivery of semen into the female’s oviduct (Bump 1969, Skinner 1974, Fujihara et al. 1976). Semen contains fluids secreted from the seminiferous tubules, epithelial cells of the reproductive tract, lymph from the lymph folds and erectile tissues in the cloaca, and sperm (Mann 1964, Lake 1966, Buxton and Orcutt 1975, Nishiyama et al. 1976, Servouse et al. 1976, Burt and Chalovich 1978, Gasparksa et al. 1981).

Birds, the only class of vertebrates that consists exclusively of oviparous forms (Marshall 1961), lay eggs, generally within a day or two of ovulation. Although a few species have ovaries and oviducts on both sides, generally only the left side is functional (Sturkie 1965). The oviduct consists of an infundibular region, magnum, isthmus, uterus (shell gland), and vagina. The infundibular region receives the egg from the ovary and is the site of fertilization (Olsen 1942). The vagina is the passageway for the egg from the uterus to the cloaca and for the semen into the oviduct (Sturkie 1965). Sperm storage sites (sperm host glands) are present in the infundibulum and the utero-vaginal (UV) juncture (Bohr et al. 1962) and the UV-sperm host glands enable birds to lay several fertile eggs following a single copulation (Smyth, 1968).
Sperm host glands have been identified in ducks (Pal 1977), quail (Renden et al. 1981), and cranes (B. C. Wentworth, pers. comm.) as well as turkeys (Lorenz 1970) and chickens, and may be common to all birds. Sperm are released from the host glands on a continuous basis (Berke and Ogasawara 1969, Compton et al. 1977 and 1978, Compton and Van Krey 1979, Bakst 1980 and 1981). Although the release of spermatozoa from the uterovaginal sperm host glands at the time of ovulation or oviposition has been postulated, available information does not support the concept. Bakst (1980) reports that sperm numbers are less in oviducts with an ovum and may indicate that the lumina spermatozoa are sequestered by egg formation.

Collection and Insemination

AI techniques are often grouped into cooperative or massage categories reflecting the different degrees of cooperation by male and female birds toward the human handler during semen collection and insemination. Cooperative AI requires a great deal of cooperation from the bird, massage AI is more successful with cooperation, and electroejaculation is successful without active cooperation from the bird. Cooperative semen collection and insemination was pioneered with sexually imprinted birds of prey being used in falconry (Hammerstrom 1970, Temple 1972, Berry 1972, Grier 1973). Falconers' birds were already imprinted on their handlers and were encouraged to develop a sexual as well as social bond. The unrestrained male is encouraged to copulate, deposit semen in or on a suitable receptacle (Boyd and Boyd 1976, Boyd 1978). The semen, usually less than 0.1 ml, is aspirated into a suitable syringe or pipette to protect it from dehydration and contamination. The females are encouraged to respond to their handlers by assuming copulatory positions. The semen is deposited in the cloaca or everted oviduct of the receptive birds (Temple 1972, Berry 1972, Grier 1973, Boyd et al. 1977). Cooperative semen collections and inseminations require opportune timing to obtain an adequate number of samples and to obtain fertile eggs. Methods that intercept semen during natural copulation with other birds or dummy mounting devices are variations of the cooperative collection technique (Smyth 1968, Tan 1980).

The massage collection technique (Quinn and Burrows 1936) has been used for decades with domestic poultry and more recently with nondomestic birds (Gee and Temple 1978). With this technique, the bird is restrained by as assistant and an operator collects the semen. The process takes 5 to 10 seconds. A common practice is to have an assistant hold and stimulate the bird by stroking the inner shanks and the ventral abdominal region. At the same time the operator stimulates the region around the tail, abdomen, and vent by stroking with the left hand, from the post-dorsal region of the back to the interpelvic tail region, and then to the postlateral region below the tail. Next the operator forces the tail back with the left hand and the abdominal and sternal regions are stroked from anterior to posterior with the right hand. Usually the cloaca will respond to stimulation by a partial eversion and occasionally ejaculation. The cloaca is grasped dorsally by the thumb and index finger of the left hand. A small glass collection device (4-5 cm in diameter) is held in the right hand for semen collection. The first drop of semen is collected on the lip of the glass. The final steps (abdominal and cloaca massage) are repeated and the remaining semen expressed from the cloaca with the fingers on the left hand. There are
Numerous minor modifications to the message technique that allow one person to collect and to inseminate semen. The modification may be an altered position for holding or stimulating a bird or it may be the use of a restraining device. Restraining devices are also used in team operation and can greatly facilitate the process in turkeys and waterfowl (Wantanbe 1957, Smyth 1968).

Procedures used to stimulate the male are repeated to prepare the female for insemination. An assistant holds and stimulates the bird by stroking the shanks and abdomen. The inseminator strokes the region around the tail, abdomen, and vent. The female responds with a partial eversion of the oviduct (Figure 1). Next, the assistant applies a gentle but steady pressure to the abdomen and vent to complete the eversion process, exposing the vagina. The inseminator inserts the inseminating device (a syringe, straw, pipette, etc.) into the exposed vagina and the assistant releases the pressure being applied to the abdomen (Figure 2). The inseminating device is allowed to return with the vagina to the relaxed position, and the semen is deposited. A deep vaginal insemination is usually preferable (Lorenz 1969, Ogasawara and Fuqua 1972) since the storage site (sperm host glands) is located at the utero-vaginal juncture (Bohr et al. 1962); however, a moderate depth of insemination gives satisfactory results (Smyth 1968, Wentworth et al. 1975, Bird et al. 1976, Boyd et al. 1977). Because of the possibility of injury which could interfere with egg production and fertility (Ogasawara and Fuqua 1972, Wentworth et al. 1975), the inseminating device is not forced into the utero-vaginal juncture. Although it is not always possible because of various anatomical and handling problems, it is best to deposit semen in the oviduct. Inseminations should be more frequent and timed to coincide with oviposition when semen is deposited in the cloaca rather than the oviduct (Gee 1969, Temple 1972, Berry 1972, Grier 1973, Archibald 1974).

Electroejaculation has been used for years with domestic mammals to collect semen but is not a common method for collecting avian semen. Several investigators do prefer electroejaculation of ducks and geese to other methods of collection (Serebrovski and Sokolovskaja 1934, Watanabe 1957, Chelmonska and Geborska-Dymkowska 1980) and, if its reported advantages can be applied to other birds, it may become a more common form of collection. Both the cooperative and massage methods of semen collection require training and cooperation to obtain good semen samples, and this training takes time before semen collection can begin. Electroejaculation does not require training. Electroejaculation requires the application of an electrical current of up to 80 volts. A positive pole is attached to the skin in the sacral region and the negative pole in a basin of water. The bird’s bill is placed in the water and the current applied to cause spasms and ejaculation (Serebrovski and Sokolovskaja 1974). Watanabe (1957) attached one pole of the electroejaculator to the sacral region and the other probe (a blunt rod) was inserted into the vent. He applied 30 volts (0.06 to 0.08 amperes) for 3 seconds, rested the bird for 5 seconds and repeated the same process until the bird flapped reflexly and ejaculated. The process was repeated for up to 5 times to obtain ejaculation. Duck semen collected by electroejaculation contained a greater number of spermatozoa and was released in larger quantities than that collected by the conventional massage.
Special AI Techniques
Semen collection techniques can be modified for each species to compensate for anatomical, physiological, or behavioral characteristics (Figure 3). Many species of non-domestic birds produce small quantities of semen (about 10 ul) and special care must be taken in collection and protection. The volume of semen collected and sperm concentration varies greatly between species (Table 1), but in many species, part or all of the time, some birds produce samples too small for insemination.

Small samples can be aspirated into a small pipette or collected on the edge of a slide (Howell and Bartholomew 1952, Smyth 1968, Lake 1978). Small concentrated semen samples dehydrate rapidly and must be protected by adding a drop of diluent when collected. Although ejaculates produced by some males may be small, several collections may be made in a week (McDaniel and Sexton 1977, Gee and Temple 1978) and used to inseminate several birds. In the Japanese quail, it only takes one day for sperm to pass from the testis to the cloaca (Amir et al. 1973, Clulow and Jones 1982). Although semen can be collected daily from some males, too frequent collection can cause swelling and reddening due to
irritation of the vent. With special care, we have been able to obtain semen samples 5 days per week from cranes during the entire reproductive season.

Anal secretions is most birds do not complicate semen collection although many birds have anal glands (Quay 1967). However, the Japanese quail cloaca) foam gland produces a mucoid secretion, a meringue-like froth, that can interfere with semen collection. The froth is removed by gently squeezing on either side of the vent and wiping it away with a soft cloth before collecting the semen (Wentworth and Mellon 1963). Semen may be difficult to handle when contaminated with the secretion and it may be detrimental to sperm survival. The ani (Crotophaga sp.) is another bird that produces a large amount of anal secretions. However, few ani are kept in captivity and a semen collection technique has not been reported. In some larger birds like the rhea, a waxy or greasy material is present in the vent. Excesses of this material should be removed to avoid contamination of the semen.

Song birds are difficult to stimulate by massage but most have a well developed cloaca protuberance during the breeding season where the semen is stored (Howell and Bartholomew 1952, Salt 1954, Wolfson 1952 and 1960, Middleton 1974). Small quantities of semen can be obtained from many passerines by applying gentle pressure to the protuberance. Densely packed sperm in the tiny drop of semen are difficult to keep alive because of dehydration during aspiration. At Patuxent, adding a small amount of avian diluent on (not in) the tip of the micropipette to the semen in the cloaca before collecting it can help maintain sperm viability.

The copulatory organs (phallus) in waterfowl, ratites, and tinamous can interfere with semen collection. The phallus, coiled within the ventral cavity of the cloaca in waterfowl and tinamous, uncoils as it erects during sexual excitement and carries semen along a twisted groove that runs the length of the organ. Early in the massage collection process, the phallus is everted (Smyth 1968, Skinner 1974) and after ejaculation, semen is collected at the base and tip of the phallus with a small funnel, tube, or suction device (Figure 4). The copulatory organ is
Table 1. Semen volume, sperm concentration, and duration of fertility for a variety of birds

<table>
<thead>
<tr>
<th>Species</th>
<th>Volume Concentration (days)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canary</td>
<td>10 ul</td>
<td>J. G. Griffith (pers. comm.)</td>
</tr>
<tr>
<td>Chicken</td>
<td>0.5-0.8 ml 3.5×10⁹ 10-13</td>
<td>Smyth (1968)</td>
</tr>
<tr>
<td>Duck</td>
<td>0.3 ml 8</td>
<td>Watanabe (1957)</td>
</tr>
<tr>
<td>Japanese Quail</td>
<td>10 ul 5×10⁹ 4-5</td>
<td>Smyth (1968)</td>
</tr>
<tr>
<td>Pigeon</td>
<td>10-20 ul 15</td>
<td>Owen (1941)</td>
</tr>
<tr>
<td>Ring-necked Pheasant</td>
<td>50-250 ul 10×10⁹ 11</td>
<td>Smyth (1968), Cain (1978)</td>
</tr>
<tr>
<td>Turkey</td>
<td>0.2-0.3 ml 8×10⁹ 45</td>
<td>Smyth (1968)</td>
</tr>
<tr>
<td>Nondomestic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>American Kestrel</td>
<td>14 ul 8</td>
<td>Bird et al. (1976)</td>
</tr>
<tr>
<td>Brewer’s Blackbird</td>
<td>10 ul +</td>
<td>Wolfson (1960)</td>
</tr>
<tr>
<td>Eclectus Parrot</td>
<td>50-100 ul</td>
<td>Gee and Beall (unpub.)</td>
</tr>
<tr>
<td>Goshawk</td>
<td>20-30 ul</td>
<td>Berry (1972)</td>
</tr>
<tr>
<td>House Finch</td>
<td>10 ul + J. G. Griffith (pers. comm.)</td>
<td></td>
</tr>
<tr>
<td>Prairie Falcon</td>
<td>50-100 ul 10×10⁹ 6-8</td>
<td>Boyd (1978), Boyd et al. (1977)</td>
</tr>
<tr>
<td>Red-tailed Hawk</td>
<td>0.1 ml 6</td>
<td>Gee and Temple (1978)</td>
</tr>
<tr>
<td>Swamp Sparrow</td>
<td>10 ul +</td>
<td>Wolfson (1952)</td>
</tr>
<tr>
<td>Sandhill Crane</td>
<td>10-200 ul 0.3×10⁹ 10</td>
<td>Gee and Temple (1978), Putnam (1982)</td>
</tr>
<tr>
<td>Wood Thrush</td>
<td>10 ul +</td>
<td>Wolfson (1960)</td>
</tr>
<tr>
<td>Wattled Cassowary</td>
<td>1-5 ml C. Pickett (pers. comm.)</td>
<td></td>
</tr>
<tr>
<td>English Sparrow</td>
<td>10 ul + Gee (unpub.)</td>
<td></td>
</tr>
<tr>
<td>Seaside Sparrow</td>
<td>10 ul + Gee (unpub.)</td>
<td></td>
</tr>
<tr>
<td>Golden Eagle</td>
<td>0.2 ml 9</td>
<td>Grier (1973), Grier et al. (1973)</td>
</tr>
<tr>
<td>Cockatiel</td>
<td>G. Harrison (pers. comm.)</td>
<td></td>
</tr>
<tr>
<td>Budgerigar</td>
<td>G. Harrison (pers. comm.)</td>
<td></td>
</tr>
</tbody>
</table>
| + greater than domestic chicken less than domestic chicken 1 # sperm/ml of semen approximate

very delicate and rough treatment should be avoided or injury may result (Smyth 1968). In species that yield small semen samples,
careful manipulation of the vent permits collection of the semen before the phallus is everted. The everted phallus contains numerous crypts and crevices on the surface, and eversion should be avoided if possible since the small semen sample is difficult to collect if spread over this irregular surface.

Feces is another source of contamination often encountered in waterfowl that should be avoided. Although contaminated semen should be discarded, fertile egg production is possible if the semen is cleaned of the coarse contaminants and inseminated immediately. Cloaca insemination may be the better insemination route to avoid contaminating the oviduct (Perek et al. 1969). The cloaca should not contain feces at the time of insemination. Defecation will occur soon after insemination when the cloaca is full and fecal bacteria can kill large numbers of sperm and reduce fertility. It is possible to reduce semen contamination by withholding feed and water for 6 to 8 hours before collection (Smyth 1968). Also, forcing the bird to move around before capture may induce defecation and increase the number of clean samples collected.

From birds that do not respond to conventional collection techniques, semen can be collected after natural copulation with other birds or dummiers. The semen is intercepted during copulation by a collection device. In chickens, semen has been collected after copulation from the cloaca of the female, from an artificial cloaca, or from a collector fastened to the male (Smyth 1968). Lamert and McKenzie (1940) describe and illustrate in detail a male collection device used in the chicken. Semen has been obtained after copulation from blackbirds (Howell and Bartholomew 1952), chickens (Smyth 1968), and ducks (Tan 1980).

Insemination methods, frequency, and volume inseminated should be adapted to the needs of each species. Deep vaginal inseminations with large numbers of sperm produce the best fertility. In some nondomestic birds, eversion of the oviduct may be difficult or cause too much stress, reducing or terminating production. In some, the oviduct can be located by palpation and the inseminating device guided into the vagina to deposit the semen (Watanabe 1957) and others can be trained to open the cloaca in response to massage stimulation, exposing the oviduct and allowing vaginal insemination (Temple 1972). Satisfactory fertility can be obtained from semen deposited in the cloaca if inseminations are frequent (Gee 1969, Temple 1972, Berry 1972, Grier 1973, Archibald 1974).

Insemination frequency is dependent on other species specific characteristics such as sperm concentration and duration of fertility as well as the method of insemination. Birds with a short duration of fertility following insemination require more frequent inseminations than those with longer durations of fertility. Recommended insemination frequency varies from once every other day in Japanese quail (Lepore and Marks 1966) to once every other week in turkeys (Smyth 1968). The duration of fertility varies from 4 to 5 days for Japanese quail (Wentworth and Mellen 1963), and 6 to 8 days in some raptors (Grier 1973, Bird et al. 1976, Boyd et al. 1977) to 45 days in turkeys (Lorenz et al. 1959, Smyth 1968) (Table 1). Also, several repeated inseminations at the start of the insemination period improved subsequent fertility (Smyth 1968).
Semen volume inseminated depends on the sperm concentration and capacity of the reproductive tract to retain the semen. Often semen is of sufficient concentration and volume to inseminate several females from each ejaculation. Semen may be diluted for this and other reasons (Sexton 1976a). The volume of diluted semen inseminated may exceed the capacity of the bird’s oviduct to retain the semen and, although an adequate number of sperm are inseminated, fertility can be less than expected. The number of sperm needed per insemination in nondomestic birds is unknown, but in chickens and turkeys, the number has been estimated between 80 and 100 million spermatozoa (Sexton 1977b, Lake and Stewart 1978). More frequent inseminations may be necessary when sperm numbers per insemination are marginal (Meyer et al. 1980). For instance, a single sandhill crane ejaculate (200-300 million sperm/ml; 0.05 ml/ejaculate – Gee and Temple 1978) may not contain enough sperm to produce a satisfactory fertility rate. Based on more than 10 years of experience with cranes, we recommend repeated insemination every other day thereafter, and inseminations after every oviposition to obtain satisfactory fertility.

Management

AI is only one of several methods used to correct infertility and all alternatives should be considered. AI is very time consuming and should be avoided if possible. Artificial insemination of nondomestic birds is labor-intensive since 2 persons are often necessary to collect and inseminate, and an additional person is often needed to help capture or separate birds (Gee and Temple 1978). Since natural copulation in properly mated birds generally results in better fertility than from artificially inseminated birds, a change of mates may improve fertility more than AI. However, AI can be as effective as natural coatings in the crane (Gee 1969), American kestrel (Bird et al. 1976), and chicken (Smyth 1968), and is more effective in the domestic turkey (Smyth 1968). Also, all eggs that fail to hatch need to be examined closely to determine fertility. A clear egg is not necessarily infertile. Improper incubation conditions such as overheating or cold, bacterial contamination, nutritional deficiencies, disease, and others can destroy the early embryo (Taylor 1949). Obviously, AI would not be a solution to such problems.

Proper physical, physiological, nutritional, and behavioral conditions must be provided to obtain reproduction. Of the environmental conditions, light, temperature, and humidity are three of the most powerful factors influencing reproduction. For a more detailed review of avian breeding seasons and proximate and ultimate factors, see Lack 1950, Moreau 1950, Lofts and Murton 1968 and 1973, Immelmann 1971, Seventry 1971, Farner 1973, and Murton 1978. In most birds, semen production begins before and continues until after the end of egg production. However, asynchrony, the production of semen and eggs at different times in the reproductive season, does occur and can be corrected by manipulation of day length in some species. For example, turkey toms can be exposed to long light days several weeks before the hens to guarantee good semen production before the first eggs are laid (Nestor and Brown 1971). Many birds will not produce eggs or semen if the length of day is too long (Murton 1978). Like light, improper temperature and humidity can terminate or delay reproduction, especially in desert birds (Seventry 1971, Immelman 1971). Building and nest design,
sickness, inadequate diets, and aging disabilities are other factors that can affect fertility rate.

Late in the season, semen production may cease before egg production is completed. However, in the chicken and turkey, most semen from older males or from males late in their reproductive cycle produces satisfactory fertility (Woodard et al. 1976, Ansah et al. 1980). An immune response against sperm may develop late in the reproductive season and reduce fertility (Yu and Burke 1979, McCorkle et al. 1981).

When circumstances indicate AI is necessary for increasing fertility or to complete special breeding programs, the birds should be trained to accept the technique. Behavioral accommodations are of great importance in artificial insemination of nondomestic birds, especially those taken from the wild. Stress is difficult to avoid in artificial insemination of nondomestic birds, but using the same team, training birds to accept artificial insemination procedures, and avoiding injury to the birds when handling all reduce stress. Disturbance can be further reduced by restricting visitation to the non-breeding season, and conducting all chores on a constant time table.

The training process in a few birds may upset the female rather than calm her down and if continued, may interfere with the onset of egg production. The training period in these cases should be terminated with both male and female. Insemination can be reinstated when egg production starts and the bird is more receptive to stimulation. Semen volume and response to semen collection often can be improved by placing a bird near other birds. Visual and auditory displays by other reproductively active birds may stimulate reproductive activity in surrounding pairs and even in single birds, and it can strengthen pair bonds (Wickler 1980).

Little can be done to increase semen yield from a content and healthy bird, but several steps can be taken to protect the semen collected and make the best use of it in insemination. A water bath or insulated container reduces temperature fluctuations and a closed tube reduces dehydration and contamination. A diluent increases semen volume, reduces the risk of dehydration, and if sperm concentration is adequate, makes it possible to inseminate several birds from each ejaculate. Diluent reduces sperm concentration, bacterial contamination, and controls pH and osmolality. All the tubes and inseminating devices that come in contact with the semen should be clean. Since detergents can be especially harmful to semen samples, all equipment and supplies should be thoroughly rinsed with clean water before use. For reviews of factors detrimental to sperm survival, see Mann (1964), Lake and Steward (1978), Lake (1969), and Smyth (1968).

Semen Evaluation
Although the most reliable semen test is the production of fertile eggs, semen for use in AI can be evaluated in the pen when it is collected and later in the laboratory. The color of good semen when it is collected is characteristic for each species. Most good samples range from a light white (frosted glass appearance) in species with low sperm concentrations, to a white chalky or milky appearance in species with high sperm counts. Fecal contamination discolors the
semen to shades of brown or green. In geese, a green color is common because of their large intake of grass during the breeding season. Occasionally, flecks of blood may be present resulting from excessive force during collection or injury (Smyth 1968). Samples that are consistently contaminated with feces may need to be diluted with antibiotics to reduce the loss of sperm and the antibiotic, tobramycin, may even increase fertility when used as a diluent in “clean” semen (Sexton et al. 1980).

The consistency of a semen sample ranges from that of water to that of heavy cream in species with the more concentrated samples. Samples that appear to be sticky or stringy are often contaminated. Some of these semen samples begin as a clear fluid in the collecting device and turn white as the urates precipitate out. A watery semen may indicate an excessive amount of lymph (transparent fluid) in the sample. The use of excessive force on the cloaca during collection can cause a surplus of lymph in the semen. These watery fluids, like fecal and urate contaminants, adversely affect spermatozoa, especially if the semen is held for some time before insemination (Smyth 1968, Lake 1971, Fujihara and Nishiyama 1976).

Small representative portions, taken from the semen before insemination can be examined in the laboratory for sperm number, motility, morphology, and larger samples for metabolic rate and semen composition. Perhaps the simplest measures of semen quality are sperm number and motility. Sperm number can be estimated from a semen score for density, spermatocrit, counting in a hemocytometer or in an automated density, spermatocrit, counting in a hemocytometer or in an automated counter. Sperm concentration can be evaluated in semen mounted on a hanging drop slide, under a cover slip on a slide, or in a capillary tube. This is a useful way to distinguish semen quality in species with low sperm concentrations like cranes (Putnam 1982); however, semen from species with higher sperm concentrations first require dilution. The scores can be calibrated by comparing them to actual sperm counts. The spermatocrit, a simple measure of sperm concentration, is useful in characterizing semen produced in quantity (>0.1 ml) and containing a large number of sperm per ml (>3×10⁹) (Arscott and Kuhns 1969). The semen sample is loaded into the standard microhematocrit capillaries and centrifuged. The percent by volume is determined in several ways. The semen is diluted (if necessary), fixed, and the sperm counted in a hemocytometer or in an automated counter (Jones and Wilson, 1967). Optical density of a diluted semen sample can be measured and sperm number determined from a previously established standard curve (Kosin and Wheeler 1956, Carson et al. 1955). A reasonable estimate of sperm concentration is important in determining if the insemination dose will contain an adequate number of sperm.

Sperm progressive motility is an estimate, based on a scale from 0 to 100, of the percentage of spermatozoa moving in a forward motion. This is another quick indicator of semen quality. A drop of semen is placed on a clean microscope slide under a cover slip and several areas examined at a 430 magnification. Since some live cells are inactive, it is not an estimate of all live cells.

Examining sperm morphology using conventional microscopes can provide information of the percentage of live cells in the semen, the
percentage of abnormalities, and the size of cells. One of the easiest
determinations, a live-dead count from an eosin-nigrosin stained
slide, makes it possible to evaluate the number of live sperm
inseminated (Gee and Sexton 1979). It is a more time consuming
determination than progressive motility, but it can be determined in
the laboratory long after the insemination, usually without a
significant loss in accuracy. However, there are confounding factors
such as excessive moisture in the atmosphere that can make the
staining process less definitive (Ogasawara et al. 1976).
Abnormalities can be determined from a variety of preparations
including the eosin-nigrosin stained slide. Good slide staining
techniques aid in delineating parts of the spermatozoa such as the
head from the acrosomal cap and mid-piece (Sharlin et al. 1979).
Abnormalities in sperm can be used to evaluate semen from
individual males and to determine effects of diluents and storage.
Sperm head size determined from properly stained slides can be
used to distinguish between subspecies (Sharlin et al. 1979,
Russman and Harrison 1982) and to predict fecundity within
subspecies (Sharlin et al. 1979). Electron microscopy is useful in
detecting membrane and fine structure abnormalities in
spermatozoa, but its usefulness is generally confined to research.

Metabolic rate in semen samples can be determined using a variety
of tests such as methylene blue reduction and oxygen consumption
(Smyth 1968). The effects of various diluents, environmental factors,
and individual differences can be evaluated. Determinations require
precise laboratory control and may require very specialized
equipment.

The chemical composition of semen from most avian nondomestic
species is unknown and even in the domestic fowl it is not very
useful in distinguishing between good and bad semen samples
(Mann 1964, Burt and Chalovich 1978). Semen pH and osmolality
are two factors that vary from species to species and should be
considered when diluting semen. In our laboratory, we have
recorded semen pH in a range from 6.0 for a duck to 8.0 for a crane.
Laboratory tests can be used to evaluate differences between new
diluents or techniques, but eventually the semen must be
inseminated and fertile eggs produced to prove its value.
Satisfactory fertility has been obtained from semen that scored
poorly in laboratory tests, especially frozen-thawed semen (Sexton
1976b). Cryoprotectants and freezing can affect sperm motility and
morphology without destroying the ability of the frozen-thawed
semen to produce fertile eggs.

Equipment and Supplies
The basic equipment used to collect and inseminate semen is
relatively simple and inexpensive (Corten 1973). Semen collecting
devices include those used to hold the bird (cones, stands, and
jackets) and those used to catch the semen (cups, funnels, test tubes,
capillary tubes, pipettes) (Smyth 1968). Electroejaculation requires
special equipment and devices capable of delivering measured
electrical charges and appropriate probes adaptable to the species.
Containers of semen can be held in a small rack and case until they
are needed for insemination. If the sample is held for more than a
few minutes, the case provides protection from temperature shock,
direct sunlight, and contamination. A thermometer is useful in
determining the case temperature.
Inseminating equipment includes syringes, pipettes, straws, or eye droppers and devices to hold or add diluents. A flexible tube attached to a mouthpiece at one end and a semen straw at the other is a useful method for inseminating large numbers of birds (Smyth 1968).

The animal facilities should be free of obstructions to reduce the chances of injury and to accommodate a quick, less stressful capture. Also, clean facilities reduce the risk of semen contamination and soiling of the bird during capture.

A few pieces of laboratory equipment like the microscope are all that are needed for the routine examination of semen. Progressive motility estimates require only a clean slide and coverslip, but a hanging drop slide is useful for lengthy microscopic studies of living samples. A variety of stains are needed for live-dead counts and to perform special morphological studies. A balance is needed to weigh out chemicals, and to prepare stains and other supplies. Other supporting pieces of equipment and supplies include cell counters, slide trays, record books, and photographic attachments. Semen and diluent pH determinations require pH paper or a pH meter. Osmolality can be determined from small samples using a vapor point osmometer. Tests of semen metabolic activity may require respirometers or spectrophotometers.

Storage and Preservation
Although the best fertility rates are obtained from inseminating semen immediately following collection, fresh semen can be stored for several hours or more (more than a day in chickens) without destroying fertility. A rate of thirty-seven percent fertility after 36-37 hours storage is possible in chickens (Lake et al. 1959). Semen storage for an hour or more requires temperature control and protection from contamination and drying. Sperm of most species’ survive best at near freezing temperatures (Gee and Temple 1978, Sexton 1979). Since bacterial contamination can cause a rapid destruction of sperm cells in storage, sources of contamination must be avoided. Diluents can be used to introduce antibacterial agents, stabilize pH and osmolality, and in other ways extend the viable life of a semen sample (Smyth 1968, Gee and Temple 1978, Sexton et al. 1980).

Semen preservation in the frozen state has been demonstrated in a few birds and makes it possible to store semen for many years (Sexton 1979, Gee and Sexton 1979, Watanabe and Terada 1980, Watanabe et al. 1981). Fertility rates with frozen-thawed semen can be improved using intrauterine (Watanabe and Terada 1976, Marquez and Ogaswara 1977) and intraperitoneal (Harris 1968) inseminations, but good fertility has been obtained using the conventional methods described earlier (Sexton 1976).

There are four critical steps in cryopreservation of semen: pre-freeze, freeze, storage, and thawing (for a recent review see Mazur 1980). Important pre-freeze considerations are time held, dilution rate, contamination, diluent, and pH of the semen. The time a sample should be held before it is frozen depends on the conditions of storage and are species specific (Sexton and Gee 1978). The number of good quality semen samples (90% or more of live motile sperm) decrease with time held before freezing. However, if the samples
that deteriorate are discarded and only good samples are frozen, fertility rates from AI with frozen-thawed semen held before freezing are similar to those frozen soon after collection.

cryoprotectant, cryoprotectant level, equilibration time, and freeze rates are the most critical variables in the successful preservation of semen. The cryoprotectant level required to provide protection against freeze damage is dependent on the diluent, pH, equilibration time, and varies between species (Watson 1978). Of the two most common cryoprotectants, glycerol and dimethylsulphoxide (DMSO), only glycerol has to be removed before insemination since it has an antifertility effect in birds (Nevelle et al. 1971, Sexton, 1979, Lake et al. 1980). Levels of glycerol that provide good protection against freeze damage range from 8% to 15% (Brown and Harris (1963, Neville et al. 1971), and for DMSO, from 4% to 10% (Sexton 1979, Gee unpublished). Freeze rates are different for each cryoprotectant as are the mechanics for sample freezing. Glycerol preserved samples can be frozen in a variety of successful schemes (Hawk 1979). DMSO rate seems to require a precise freeze rate of VC per minute from 5°C to –20°C, 50°C per minute from –20°C to –80°C, and 160°C per minute from –80°C to –196°C (Sexton 1980). New successful DMSO schemes may be possible when a greater number of experimenters adopt the use of DMSO.

Storage and thawing conditions are important in the recovery of viable sperm from frozen-thawed semen. Deterioration of the sample is prevented if it is stored at liquid nitrogen temperatures (-196°C), but some deterioration has been recorded at higher temperatures (-80°C) (Graham 1975). Most techniques thaw samples at room temperature or in a crushed ice bath; however, the effect of thawing rates on sperm survival needs more study (Gee and Sexton 1979).

Frozen-thawed semen should be inseminated by the most effective route and at the most advantageous time during the reproductive cycles. Frozen-thawed semen has less energy reserve that a fresh sample due to storage while preparing it for freezing and the cells may be less active due to this and inhibition as soon as possible after it is prepared for insemination and all adverse environmental conditions avoided.

Summary
Artificial insemination is a practical propagation tool that has been successful with a variety of birds. Cooperative, massage, and electroejaculation and modifications of these three basic methods of semen collection are described for a variety of birds. Semen color and consistency and sperm number, motility, and morphology, as discussed, are useful indicators of semen quality, but the most reliable test of semen quality is the production of fertile eggs. Successful cryogenic preservation of avian semen with DMSO or glycerol as the cryoprotectant has been possible. Although the methods for preservation require special equipment, use of frozen semen requires only simple insemination supplies.

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In artificial incubation, we are attempting to reproduce an environment which is similar to that of the parent bird, in order to properly hatch a healthy chick. Failure to provide this proper environment will result in poor hatches.

A number of reasons can be cited for poor hatches and some of the more common ones are listed below:
1. Weak Parent stock, unhealthy or fed a nutritionally deficient diet.
2. Infertile eggs
3. Inbred stock
4. Egg shell contamination
5. Eggs too old when set
6. Improper care of eggs prior to incubation
7. Improper incubator ventilation, oxygen starvation
8. Eggs not turned often enough
9. Incubator temperatures too high, too low, or too variable during incubation.
10. Too little or too much humidity in the incubator

The above list is not all inclusive, but does point out a significant number of variables which must be controlled if high percentage hatches are desired. Neglect in any of these areas will result in failure. You will note that the last four reasons for poor hatches are directly related to the incubator or the operation of it.

In order to hatch an egg it must be a good fertile egg. This egg must come from well mated parent (unrelated preferred) stock and they must be fed a proper nutritional diet. Assuming this is the case and you wish to hatch the egg by artificial means, an incubator will be required.

The primary purpose of this paper will be to focus on the four latter reasons for poor hatches as they are associated with the incubator. Perhaps, at this point it would be wise to point out something about incubators that most people are not aware of. Most incubators, and this is particularly true if you have one which is more than 5-6 years old, were originally designed for the poultry industry. Many of them do a fine job of hatching chickens and turkeys but can be very disappointing when used to incubate gamebird or more exotic types.
of bird eggs. The reason for this is that poultry eggs have been bred for decades in incubators to such an extent that we have conditioned the eggs to withstand large environmental variations such as temperature without significantly reducing the percentage of hatch. Many incubators in use today do not have the capability to minimize these variables without modification to the incubator. Many incubator manufacturers sell their product (with an instruction booklet) with little if any first-hand knowledge of some of the types of rare and semi-rare bird eggs we are putting into them. To illustrate this point a little better, I would like to refer you to Figure 1.1 do not claim any accuracy to the graph shown as it is provided simply to illustrate the importance of providing the optimum temperature to insure a high percentage hatch. The graph depicts the optimum temperature of 99.5°F for pheasants as an example. A good deal of literature exists which states 99.75° to be the optimum temperature for pheasants, however. Note the difference between the curves for pheasants and poultry. The significance of this figure is to illustrate that proper temperature measurement and control (regardless of egg type) is vital to a large percentage hatch. Mother Nature also has different ranges of permissible temperature variation for various eggs, however. It is known that egg size, shell thickness, clutch size, temperature environment, bird characteristics and other parameters determine the degree of permissible environmental variation allowed before hatchability is significantly affected.

The numbers of bird breeders are increasing all of the time. The unfortunate part of many novice and experienced breeders is that many will purchase incubators, follow the instructions, and suffer the invariable learning curve we all must take before achieving a high percentage of successful hatch. I might add that many never achieve a high percentage hatch. Some get discouraged and give up, others will blame the incubator, incubator manufacturer, incubator instructions or themselves. In reality, it may be only one or a combination of all the above.

Let's discuss the incubator and the problems associated with it in sufficient detail that it will improve your percentage of success. The incubator in reality is a simple device. Its function is to control the environmental conditions (temperature, humidity, oxygen supply and egg rotation if required) of a good fertile egg. Incubators vary in type (still air or forced air), construction, material, size, reliability and cost. The still air incubator remains in use today, but is not nearly as common as the forced air type. It is the device closest to duplicating the setting hen, however. The heat is transmitted to the egg from above and moisture from the bottom similar to a setting hen. This type of incubator permits a thermal gradient to exist across the egg. This can be difficult to control as drafts around the incubator can cause large variations in the egg temperature. Additionally, it is difficult to make an accurate humidity measurement in a still-air thermal gradient environment. Over 40 years ago, the forced air incubator was introduced. It needs less space, holds more eggs and generally will, in principle, outperform the still air incubator. The discussion which follows assumes the use of this type of incubator.

Before you set an egg in an incubator you must know the ideal or optimum conditions for a successful hatch. A good deal of printed
information (temperature, humidity and turning frequency) is available for some types of semi-rare and rare eggs, but for others there is none. For these eggs, you may need to contact other successful breeders, avian department personnel of universities, avian department personnel of zoos or use your own trial and error method. For rare eggs, curves similar to that shown in Figure 1 do not exist because eggs would have to be sacrificed to develop such a curve. Because some eggs may be so precious, each breeder must guess at the ideal environmental conditions for the egg.

Next, I would like to discuss what I believe is the parameter which is responsible for most incubator related hatch failures. Temperature measurement and control leaves a great deal to be desired in many incubators in use today. Most commercially sold incubators today contain a thermometer which is satisfactory for poultry perhaps, but not for more exotic types of eggs. To illustrate this point, Figure 2 has been provided to show a comparison between glass thermometers. The two thermometers on the left are typical of those found in incubators. You will observe that the smallest increments are 2.0°F apart, although some employ thermometers of 1.0°F increments. This severely reduces your ability to discriminate fractions of a degree, assuming the thermometer is truly accurate to begin with. Another important fact which most people are unaware of is that a general rule of thumb is used in the manufacture of thermometers. The general rule is that the accuracy of the thermometer is only as good as the smallest incremental division. In simple terms, your reading of 100°F on these types of thermometers may be 98 or 102°F in reality. These types of thermometers are mass produced at very low cost and are not inherently designed to be highly accurate devices. The thermometers identified as models 18F and 28F (Figure 2) are A.S.T.M. (American Society of Testing and Materials) thermometers. These thermometers are manufactured by a number of thermometer manufacturers (generally located in Eastern United States) to a rigid ASTM specification. They must meet or exceed the accuracy requirements of the specification. The 18F model must be accurate to within 0.2°F and the 28F model with 0.1 °F. This author has tested a number of these thermometers in a secondary standards laboratory which is traceable to the National Bureau of Standards Laboratory and found three different manufactured thermometers to meet or generally exceed the ASTM accuracy requirements. These thermometers are more expensive of
course but not prohibitively so. These thermometers are readily available and can be purchased from chemical supply distributors or directly from thermometer manufacturers. Perhaps you would be reluctant to use this type of thermometer because it will not fit into your incubator. The solution would be simply to drill a hole into the side or top of your incubator in order to place the bulb portion of the thermometer in close proximity to the eggs. The bulb portion should not touch the egg or tray or an error in the temperature measurement will result.

For some incubators, even a more accurate thermometer will not help if it is placed in a position significantly removed from the eggs. Some incubators mount the thermometer behind a glass or clear plastic window in order to provide readability. The problem which may arise here is that without careful and proper incubator design the temperature of the air near the thermometer and the temperature around the eggs maybe significantly different. The air temperature around the egg is the desired measurement to be controlled.

Another advantage of the ASTM thermometer is that it lets you observe the temperature cycling or fluctuation which are a result of the temperature control systems. Other methods of temperature measurement exist and will be discussed briefly. Figure 3 has been provided to show another temperature measuring device. These dial thermostats can be found in 1°F increments but again lack the accuracy of the ASTM thermometers. The reason is that these devices employ a bimetallic coil or spring which effectively rotates a pointer directly related to temperature. The coil does not have the temperature sensitivity to accurately respond to temperature variations of less than 1 degree F.
Thermocouples are another form of temperature sensor. These devices are two dissimilar metals such as chromel and alumel which when welded together (in wire form) produce a small voltage which varies directly with temperature. However, thermocouple outputs drift with time and age; thermocouples should not be used to make temperature measurements which require better than 1 degree F accuracy.

Thermistors are similar to thermocouples in size and are relatively inexpensive. A thermistor is simply a resistor which varies resistance (generally orders of magnitude) with relatively small changes in temperature. However, thermistors too are unstable and will drift (in resistance) with time. Both of these types of sensors are sold in large quantities today. Usually they are connected to an electronic hand held box which has a digital display of the temperature reading. The display will often be capable of indicating temperature in tenths of one degree. However, you must read the accuracy specifications of these types of devices and they generally will not be accurate to better than 2.0°F.

Another device used to measure temperature is called an RTD (Resistive Temperature Device). These sensors are generally made from pure platinum wire. They can be very stable and very accurate temperature measuring sensors but can be fairly expensive when coupled with quality signal conditioning equipment. The biggest advantage with thermocouples, thermistors and RTD’s is that they can be remotely mounted from the readout device.

After temperature measurement in importance is temperature control. In order to control temperature, you must first be able to read it accurately. Temperature control systems have been improved in some types of incubators being manufactured today. Temperature controllers as a whole have been greatly improved in the past ten years largely due to new electronic components. Probably the most common temperature control system still used in incubators today is the thermal bellows and micro-switch. By today’s standards, this is an archaic method of fine temperature control. Please do not misunderstand this previous statement; with careful attention this type of control can work but it is not the most sensitive, or most reliable type of controller. It is one of the least expensive, however. Since it is a very common type of temperature
controller, it will be discussed in great detail with answers as to why yours does not work very well.

Refer to Figure 4 and you will find an illustration of a typical incubator temperature control system. You should recognize the temperature sensor as a metal bellows generally made from rolled brass sheet. The sheet brass is pressed in a die to form convolutions into the disks. This strengthens and stiffens the bellow walls. The fours shaped disks and buttons are soft-soldered together. Ethyl Ether is added to the interior of the cavity and the injection hole is soldered closed. Now whenever this bellows is subjected to a warm temperature the wafer will expand linearly with temperature. It is designed so that the internal pressure will cause the greatest expansion to occur between the two center buttons. In Figure 4, the wafer is shown to actuate a microswitch. This switch allows the voltage to be impressed across the heater until the thermal wafer depresses the actuator pin of the switch in order to remove the power to the heater. The amount of expansion that the wafer must incur is directly related to the differential travel of the microswitch pin between the on and off positions. During the course of a breeding season the bellows will expand and contract thousands if not millions of times. This action, especially true if it must expand several thousandths of an inch, will cause eventual work hardening of the brass.

To illustrate this point Figure 5 shows a portion of the thermal wafer cross section. The section was taken from an area of greatest stress. It was polished, etched and photographed at 230X magnification. Review of Figure 5 shows a new or unused waferwall cross section. Here the grains of the brass are randomly distributed, but the wafer on the left which was used for one entire breeding season and accumulated approximately 100,000 cycles, shows a much different grain structure. Note the preferential alignment of the grains. This is indicative of twinning or work hardening. This study was conducted on additional wafers from other incubators as well. The results were similar. These wafers were removed during the startup of attempting to use them for a second year’s breeding season. The temperature control was erratic and unstable. The poor temperature control was caused by the failure of the wafer to expand and contract linearly with temperature. Replacement of the bellows rectified the temperature instability problem. Therefore, it is strongly recommended that new thermal wafers be placed into
Where you store your thermal wafers is very important as well. If you store them in an attic or garage where temperature is unusually warm the wafer will expand and be actually working without your knowledge. Another way to ruin a new thermal wafer is to screw it onto the adjusting bolt and leave it a significant distance from the microswitch pin before energizing the incubator. The incubator may reach an excessive temperature such as 110 degrees or above. At this point the internal pressure will nearly double, and most likely cause the wafer to expand beyond its yield limit. This will stretch the brass and render it useless as it will no longer expand and contract linearly with temperature changes. The solution is to slowly allow the temperature to rise in the incubator by slowly backing the wafer from the microswitch.

Another significant point about this type of temperature sensor is its susceptibility to error produced by barometric pressure changes. As an example, if the barometric pressure decreases the wafer will expand more readily because of its internal pressure. The additional expansion will cause a net result of lowering of the temperature set point of the incubator because the heater will be shut off due to a decrease in ambient pressure instead of a high temperature condition. Thus the thermal wafer becomes a barometer as well and will necessitate an adjustment to the adjustment bolt to rectify the problem.

Another bit of advice is to leave the incubator power on once you have started to use it for the breeding season. Intermittent significant periods of time which allow the thermal wafer to cool will allow it to take a set or again reduce its sensitivity to temperature changes. It will work best if you use it continuously throughout the hatching season.

Next, how can you tell if the thermal wafer is in satisfactory condition? There are several ways. One way is to shake the wafer at ambient temperature. You should be able to hear the liquid ether. If not, the liquid has escaped in the form of gas thru a small crack in one of the solder joints. This renders the wafer useless as it will no longer expand. Examine the edges where the solder is located. Cracks found here may cause a future failure at a most inopportune time. Another method is to examine the wafer for bulging. Refer to Figure 6. A cross section of a new unused thermal wafer is on the left. Note the flat characteristics. The wafer in the center was used for 3 months or one short season. The wafer to the right was used for several years for an unknown number of cycles but the temperature control using this thermal wafer was extremely poor (variations of ±5 to 6°F). The thermal wafer may be effectively worn out as a reliable temperature sensor if significant temperature variations occur. Work hardening or twinning of the material is not a visible characteristic without destructive testing.
The other important part of this type of temperature control system
is the microswitch. These are mechanically actuated electrical switches (refer to Figure 2). As such, they have a useful life expectancy. Generally the mechanical life is 20 million cycles but the contact electrical life is 5 million cycles at rated current. Excessive force to the mechanical pin as well as excessive current through the contacts will severely reduce the useful life. In summary, if your microswitch is approaching to total of 5 million cycles it would be prudent to replace it. The number of cumulative cycles can be calculated readily by counting the number of actuations (heater power lamp on) the switch undergoes in a 5 min. period. Multiply by 288 to give you the number per day and then you can predict how long the switch should be used without significant danger of exceeding its normal life. They are generally reliable for years.

In addition to the reliability of the switch, the force and differential travel of the actuator pin are very important characteristics of the switch. Many microswitches found in incubators require a force of 9 to 13 ounces (2.5-3.61 newtons) and have a differential travel of 0.002 inches (0.05 MM) or more. This differential travel has a great bearing on the minimum and maximum temperature extremes during a typical on-off temperature cycle. The more sensitive the microswitch is, the less the thermal wafer has on expand and contract due to temperature variations. Microswitches are readily available which only require 4 ounces (1.11 newtons) of force to actuate them and have a differential travel of 0.0002 to 0.0005 inches (0.005-0.013 MM). These characteristics will significantly reduce the minimum and maximum temperature extremes during a typical thermal cycle.

The placement of the thermal sensor within the incubator is also very important. It must not be randomly located within the incubator. It is best to place the sensor between the heat source and eggs or in close proximity to the heater if thermal lag effects are to be minimized. If the temperature sensor is not near the direct heated air but placed near the eggs a thermal lag or poor response time will result. This will in turn cause significant temperature variations to occur. If your temperature control is poor, you may want to consider changing the components or installing a newer more reliable type temperature controller.

There are a number of better and more reliable temperature controllers on the market. One type uses a thermistor as the temperature sensor. It is a small bead which is very responsive to temperature change when coupled to a reliable electronic circuit. The power is turned on and off through a transistor which acts as an electronic switch. In principle, this type of temperature control is superior to the thermal wafer and microswitch which are mechanical devices with a shorter life. The thermistor temperature sensor is not affected by barometric pressure changes as well.

A similar type of temperature controller uses a small RTD (Resistive Temperature Device generally made from platinum wire) as the temperature sensor. These are generally a little more expensive but can be very reliable controllers when used with a well-designed circuit using quality electronic components.

Another temperature controller used in incubators utilizes a fixed contact thermometer. The thermometer is manufactured to place
one of the contacts at a point where the mercury will touch the contact at a specific temperature. The thermometer is used in conjunction with a mechanical relay which is connected in a normally closed position. In this manner the power to the heater is on until the mercury column touches the fixed contact, allowing current to flow and open the relay contacts, shutting off the heat supply. As temperature starts to decrease and the mercury column touches the fixed contact, allowing current to flow and open the relay contacts, shutting off the heat supply. As temperature starts to decrease and the mercury falls away from the contact the heater power is reactivated. This operation continues in a on-off cycle fashion to maintain the proper temperature. No adjustments to the temperature setpoint can be made unless another fixed temperature contact thermometer or adjustable type contact thermometer is used. This type of temperature control system can work very well, but an accurate contact thermometer must be used, with a reliable relay. Its location within the incubator is important as well.

Proportional type temperature controllers are also available. This controller when properly matched to an incubator supplies only partial power to the heater in order to maintain a predetermined temperature. These devices can be excellent temperature controllers, but can be tricky to operate and are generally more expensive than the others.

In all of the temperature control systems discussed there remains room for error which most users are unaware of. If you want to maintain an ideal constant internal incubator temperature you must control a delicate heat balance of the system. The best temperature control system ever invented cannot take into account all of the variables that require control. As an example, suppose you have a small plastic type incubator and have reached excellent temperature equilibrium with six eggs inside and a constant ambient temperature of 70°F. Next let us suppose the ambient temperature decreases 10 to 15°F. This will undoubtedly increase the heat loss thru the plastic and cause a decreased internal temperature within the incubator. It will necessitate readjustment of the temperature control to rectify the problem. However, when the ambient temperature returns to 70°F the heat loss will decrease and the internal temperature will rise.

Another common method of upsetting the delicate heat balance is to add a significant amount of mass (several dozen cool eggs) to the incubator. This will cause the heat load to be significantly different. The average internal temperature will decrease immediately and probably will not achieve the original setpoint temperature after a substantial amount of time. an adjustment to the temperature controller will be required to acquire the original setpoint temperature. There are a significant number of variables which can affect the delicate heat balance of an incubator. Voltage dips caused by power companies can effectively reduce the power to your heater, resulting in a reduced heat output.

Another troublesome area of concern for breeders who operate incubators is the measurement and control of humidity. There are a number of ways to measure humidity, but only the wet and dry bulb method will be discussed in detail because it is the most common
method used in incubators today. Humidity measurements (wet-dry psychrometry) are indirect in nature – they must rely on the two temperature measurements and the use of a psychrometric chart. The basic principle is the depression in temperature caused by the thermal energy required to evaporate water from a moistened wick surrounding a thermometer bulb (wet bulb). The air to be measured must flow around the wick (minimum air flow velocity should be 2-3 meters/second) and must be adiabatically saturated. The resulting temperature drop on the wet bulb thermometer depends on the degree of saturation of the air. A measurement of the ambient temperature (dry bulb) allows determination of the moisture condition of the air by use of Mollier’s diagram, a psychrometric chart, or special tables.

Although this method can theoretically be accurate (±2% R.H. is realistic) and is superficially simple, it does require attention to details. The following factors are all sources of possible error:
1. Temperature difference between the 2 thermometers when dry.
2. Accuracy and resolution of both thermometers.
3. Insufficient and irregular air flow velocity.
4. Loose fitting wick.
5. Radiant heat effects.
6. On the continuously wetted wick, heat transfer from wet-bulb reservoir.
7. Impurities in the water.
8. Presence of dust or chemicals in the air (diagrams are based on clean air).
9. Barometric pressure (diagrams are established at a standard pressure).
10. Accuracy of interpretation of the diagrams and charts.

Each type of egg requires different humidity conditions in order to optimize the weight loss or increase of air cell size within the egg. Periodic weighing or candling of the egg during the incubation period are the best methods of determining if the humidity is correct for a given egg. If you have various species of bird eggs which require the same temperature but different humidity requirements, you will be forced to use another incubator to obtain the proper environmental conditions.

If you know the ideal temperature and relative humidity requirements (specific values, not broad ranges) for a given type of egg, the correct wet bulb temperature can be determined from a psychrometric chart as shown in Figure 7.

Humidity control within an incubator is generally controlled by slowly adding water to containment areas in the bottom of the incubator. The amount of water surface area, incubator internal temperature, barometric pressure, the airflow (in and out) and the ambient air humidity will all have a significant effect on the humidity within the incubator. Assuming all are relatively constant, most regulation is done by increasing or decreasing the water surface area and/or regulating the amount of air into and out of the incubator. Although precision humidity control is not required for most eggs, reasonable control of ±4% R.H. is not difficult to attain.
Two other minor incubator-related problem areas are adequate ventilation (oxygen starvation) and egg tipping or turning. Most incubators have been designed to ensure adequate ventilation provided the operator does not severely restrict the air vents. A power loss to the incubator will not only inhibit the proper temperature environment but oxygen starvation will result (no air flow when the fan is not operating) if the incubator is not opened adequately to increase oxygen supply.

Egg turning is very critical to most eggs to promote proper embryo development. Incubators with automatic turning mechanisms are very desirable. Most incubators rotate or tip the eggs on a frequency of once an hour or one half hour. If you are required to turn the eggs manually, your ability to keep a rigid frequent turning schedule will be severely taxed. Infrequent or irregular egg turning will generally produce deformed birds.

Another area of concern for breeders who desire high percentage hatches is the number of incubators that will be required. One incubator should be dedicated to hatching the eggs. When the chick has pipped it should be immediately transferred to another incubator which has a higher humidity and slightly decreased temperature. At this stage of the bird’s young life it is producing heat and can tolerate a slight lower temperature. The increased humidity will assist in softening of the egg in shell and permit easier hatching to occur. The hatching process leaves a messy residue which can provide breeding areas for bacteria. Once the hatching is completed the incubator should be thoroughly cleaned in preparation for the next batch of eggs. If hatching occurs in the primary incubator, these bacteria could ruin the remainder of the eggs within it.
In summary, I have tried to discuss incubator-related problem areas with practical solutions. I hope some of this advice will be of benefit to those who would like to be more successful breeders. The successful breeders have already learned most of the pitfalls discussed and have overcome them. Although many breeders have difficulties with incubators, prudent attention to quality instrumentation (thermometers), temperature control, and incubator care and operation will improve their hatching success. It is a most joyous reward to know you have played a vital role in the birth of one of god’s beautiful feathered treasures.
Ultimate factors are sometimes called root causes because they are realized only when examining deeper layers of proximate factors. Proximate factors are grouped together to form a set of proximate causes that represent a hypothesis. Yet, proximate and ultimate causes deal with questions of how and why and both have applications in other fields. Wikipedia notes that in biology, ultimate causation deals with evolutionary forces that affect traits, and proximate causation deals with biological functions as a product of environmental and physiological factors. According to Ohio State University, Factors Affecting Farmers’ Adaptation Strategies to Environmental Degradation and Climate Change Effects: A Farm Level Study in Bangladesh. Mohammed Nasir Uddin 1., Wolfgang Bokelmann 2. The ranking of different adaptation strategies to climate change, as identified by the surveyed farmers, are presented in Table 3. Out of 14 adaptation strategies, increased use of irrigation was ranked first and thus most important, among farmers’ adaptive strategies to climate change. Irrigation increases the yield of production [30,31], improving nutrient availability to the plants but also leading to increased soil salinity [32,33]. Practicing crop diversification was identified as the second-ranked adaption strategy.