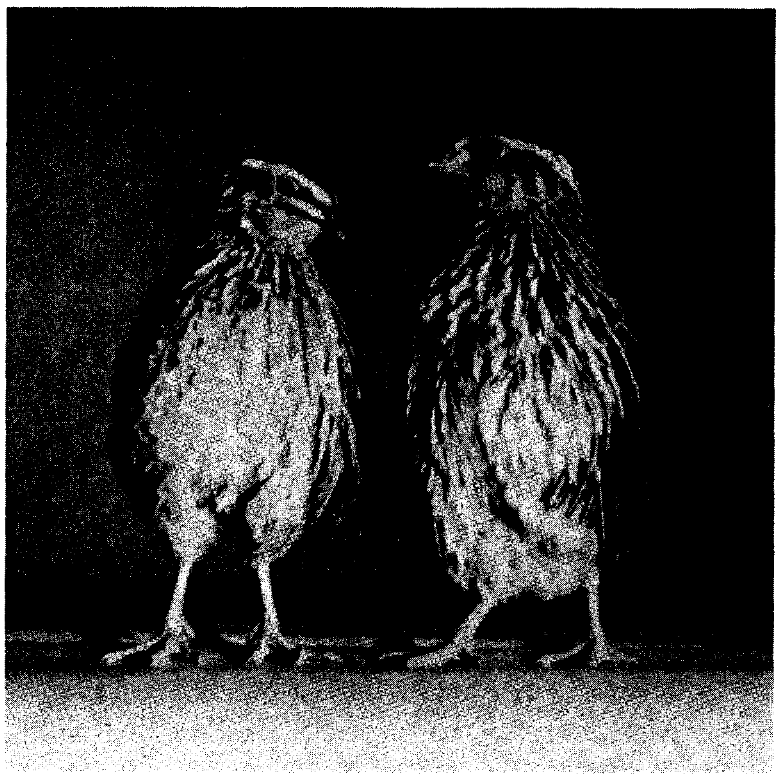
JAPANESE QUAIL HUSBANDRY IN THE LABORATORY

(Coturnix coturnix japonica)



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Feb. 1973

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I. INTRODUCTION

Species or subspecies of the genus Coturnix are native to all continents except the Americas. One of them, Coturnix coturnix japonica, was introduced into the United States by bird fanciers around 1870. This subspecies is called Japanese quail but is also known by other names: Common quail, Stubble quail, Pharoah's quail, Eastern quail, Astiatic quail, Japanese Grey quail, Red-throat quail, Japanese migratory quail, King quail, and Japanese King quail. Use of the term 'coturnix' herein refers specifically to this japonica subspecies, the subject of this manual. Our North American quail belongs to different genera: Bob White quail (Colinus virginianus) and California quail (Lophortyx California).

Interest in the common coturnix as a game bird experienced an upsurge in about 1955 when many state game commissions attempted to establish this species. These projects met with difficulty in many areas because of the migratory behavior of the bird.

Certain properties of coturnix, such as its ability to produce 3 to 4 generations per year, make it an interesting laboratory animal (Padgett and Ivey, 1959; Wilson et al., 1961; Howes and Ivey, 1961; Reese and Reese, 1962). Depending on the day length, some females start laying at 35 days of age (average 40 days) and are in full production by 50 days of age. Under favorable environments they produce for long periods, averaging 250 eggs per year. Coturnix are relatively inexpensive to maintain and some 8 to 10 quail can occupy the same space as one chicken.

In 1957 researchers of the Poultry Department of the University of California hatched several hundred coturnix eggs and have since maintained thousands in experimental populations. It has been established that the coturnix is similar in numerous physiological characteristics to chicken and turkey while differing from those species in ways that may throw light on heretofore unresolved problems. Thus, coturnix is proving to be a valuable animal for avian research.

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II. DESCRIPTION

A. Sex Differences

Adult Male: The two sexes can be distinguished outwardly at. about 3 weeks of age. The-adult male is identified readily by the cinnamon-colored feathers on the upper throat and lower breast region. Sanford (1957) wrote of the voice of the male as a loud, castanet-like crow, describing sound as "pick-per'awick" or "ko-turro-neex". Young birds begin to crow at 5 to 6 weeks old. During the height of the normal breeding season, coturnix males will crow through out the night.

Adult Female: The female is similar to the male in coloration except that the feathers on the throat and upper breast are long, pointed, and much lighter cinnamon. Also, the tan breast feathers are characteristically black-stippled.

B. Migratory Behavior

In the wild, coturnix is a migratory bird. Sanford (1957) compares the migratory behavior of coturnix to that of our native Mallard duck. Coturnix releases made in Missouri indicate that in mild winters the bird has a tendency to remain scattered in portions of its summer range. In colder weather the birds tend to congregate in a limited area. Weatherbee and Jacobs (1961) reported that of 171,865 banded coturnix released in 14 Midwest and Western states only 143 banded birds were recovered approximately 60 days after release. Those workers suggested, however, that the species could possibly display an orthodox north-south migratory behavior on this continent if natural breeding populations could be established.

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III. EGGS

A. Egg Pigmentation and Patterns

Coturnix eggs are characterized by a variety of color patterns (Fig. I), ranging from dark brown, blue, and white to buff, each heavily mottled with black, brown, and blue. The egg shell pigments of the coturnix egg were found to be ooporphyrin and biliverdin (Poole, 1965). According to Poole (1965), ooporphyrin alone seems responsible for the slight pigmentation of eggs in the white-shell mutant. The deposition of superficial pigment begins between the

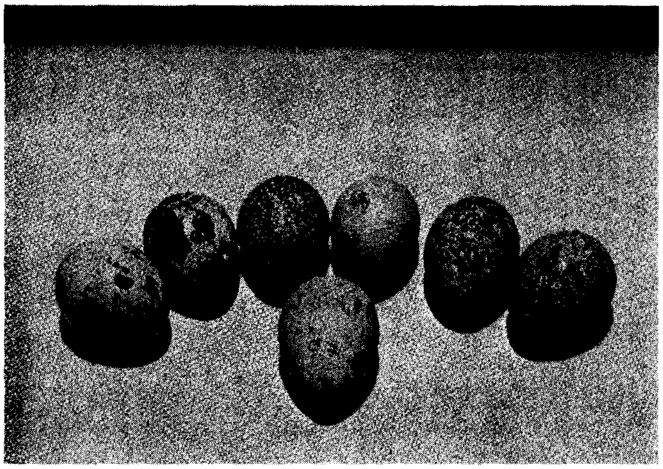

Figure 1. Color pattern of coturnix eggs.

second and third hours prior to oviposition and is accompanied by an abrupt reduction of ooporphyrin content in uterine tissue extracts. Woodard and Mather (1964) found that pigmentation of the shell occurs approximately 3 1/2 hours before oviposition in coturnix laying on a 25-hour rhythm.

It has been observed at our laboratory that an individual hen lays eggs of a shape, size, and color pattern characteristic of that hen. Jones _et al._ (1964) suggested that by sorting eggs on the basis of color pattern it would be possible to distinguish the eggs of individuals in mixed clutches of coturnix eggs with a high degree of accuracy.

B. Egg Composition

Mohmond and Coleman (1967) reported the relative proportions of the coturnix egg to be: 47.4% albumen, 31.9% yolk, and 20.7% shell and membranes. Mohmond and Coleman (1967) reported the thickness of shell and shell membrane to be respectively 0.197 and 0.063 mm.

C. Egg Weight

Average weight of a coturnix egg is approximately 10 grams (about 8% of the hen's body weight). This compares with approximately 3 and 1 percent, respectively, for the chicken and turkey. Average weights of yolk, egg, and shell vary with relation to position in egg sequences, according to Woodard and Wilson (1963). Those workers reported that the first coturnix egg of a sequence is smaller than succeeding eggs (Table I), in contrast to the case for chickens and turkeys.

Table 1. The relation of position in sequence to weights of egg, shell, and yolk. The first eggs and terminal eggs of the sequences are respectively designated C_1 and C_t.

Egg sequence		Av. egg weight (gm)			Av. shell weight (gm)			Av. yolk weight (gm)		
Length	No. of sequences	C_1	C_t	Intra-sequences	C_1	C_t	Intra-sequences	C_1	C_t	Intra-sequences
3	9	9.55	9.56		.748	.757		2.919	2.991	
4	16	9.61	19.46	9.61 9.66	.744	.775	.771	2.964	2.933	2.980
						.788			3.142	3.002
5		[illegible]	9.75	9.66	.765		.775		2.681	3.044
6	8	9.31	9.22	9.43	.754	.796	.773	2.053 2.709	2.747	2.863
7	5	8.45	8.90	[illegible]	.674				2.719	2.762
8	2	9.08	8.76	[illegible]	.761	.734	.745	2.602 2.961	2.758	2.688
9	2	9.98	9.90	9.80	.807	.771	.785	3.160	3.211	3.206
10	2	8.10	7.99	8.59	.646	.660	.701	2.288	2.172	2.472
11	1	10.29	10.58	10.36	.815	.829	.840	3.428	3.363	3.323
12	2	8.87	8.76	8.81	.730			2.761	2.713	2.724
13	1	9.38	8.98	9.23	.736	.675	.771	2.757	2.790	2.801
20	1	9.13	9.57	9.59	.664	.723	.680	2.672	2.884	2.831
21	2	9.36	9.21	9.33	.709	.837	.768	2.932	2.930	2.807
29	1	10.23	10.83	10.37	.778		.830	3.226	2.467	3.291
30	1	8.15	9.85	9.11	.610	.755	.725	2.628	3.285	2.973
33	1	9.80	9.59	9.55	.661	.750	.743	2.891	2.969	2.934
34	1	9.21	8.96	9.41	.671	.683	.733	2.878	2.469	2.819
45	1	8.95	9.44	8.82	.750	.766	.744	2.471	2.689	2.476
$\bar{x}$		9.30	9.44	9.41	.724	.741	.759**	2.858	2.890	2.889
$S\bar{x}$		+.139	+.165	+.129	±.011	±.014	±.010	+.067	±.070	±.013

*Significant at the 1 percent level for comparison between C_1 and intra-sequence eggs.

D. Egg and Meat Products

For centuries the meat or flesh of coturnix has been a food in Asia and Europe. Prior to 1939 Egypt exported as many as 3 million captured live quail per year to European markets (Meinertzhagen, 1954). San Francisco imported many birds from Japan during the period 1895 to 1904 (Grinnell and Miller, 1944).

In parts of the United States the dark breast and leg muscle of coturnix are considered a delicacy. The eggs are sometimes hard-cooked, pickled, and colored with various shades of food coloring.

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IV. INCUBATION

A. Care of Eggs

Special care must be taken in collecting and handling quail eggs for they are thin-shelled, break more easily than chicken and turkey eggs, and dehydrate more rapidly. Eggs should be of a uniform size, with clean shells. They should not be held-for more than 7 days before being placed in the incubator. Eggs to be incubated should not be washed; if cleaning is required, it should be done with a clean abrasive (e.g., fine sanding paper). Eggs should be collected several times a day and stored where the temperature can be maintained at about 13°C.

B. Artificial Incubation

Coturnix eggs can be incubated successfully in most commercial single-stage incubators. However, trays must be modified by adding 1/2" x 1" strips of welded wire to the chicken egg tray holders, as shown in Figure 2. The machine should have a fan to provide adequate air circulation and should be equipped to allow automatic turning of all eggs through an angle of 90 at least 4-6 times per 24 hours. Turning is particularly critical in early incubation. Lack of turning during the first 3 to 4 days will produce some malformed embryos as well as other minor defects. Used successfully at the Universitv of California., Davis. is the following schedule of forced-air incubating temperature and humidity (wet bulb).

Days after setting	Temperature (dry bulb) °F	°C	Humidity (wet bulb) °F	°C
0-12	99.5	37.5	87	30.6
13-15	99.0	37.2	85	29.5
16 (for 10 hr)	98.5	37.0	82	27.8
16-17	99.5	37.5	90	32.3

On this schedule, coturnix eggs average 380 hours (15.8 days)-from setting-to pipping, 10 hours from pipping to hatch, and an additional 5 hours for drying the chick. Time of hatch varies among strains, and inbred lines may take as long as 18 days to hatch. Weak chicks should not be helped from the egg, for they generally then become "picking bait" for healthy chicks.

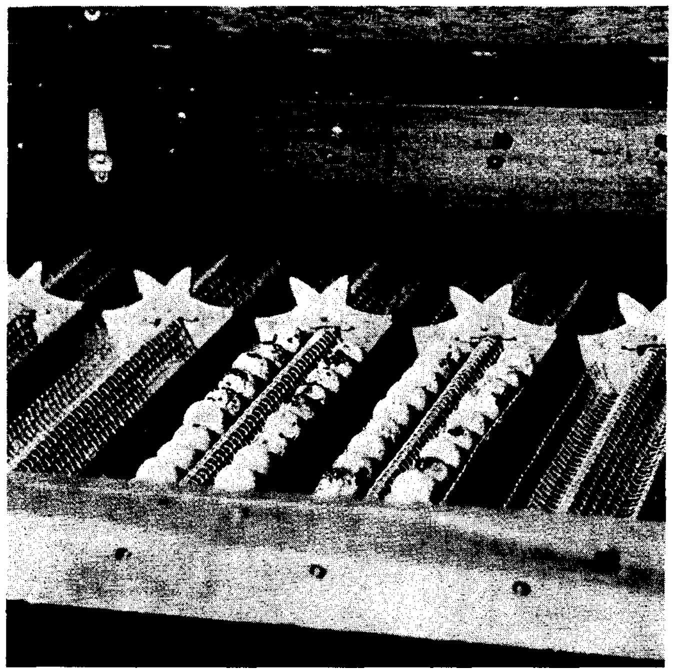

Figure 2. Modification of a commercial chicken incubator tray for setting coturnix eggs.

C. Embryo Mortality

Most embryonic deaths occur during one of two periods, during the first 3 days of incubation and just prior to hatching (Fig. 3). Most eggs removed at the first candling (8 days of incubation) are infertiles and

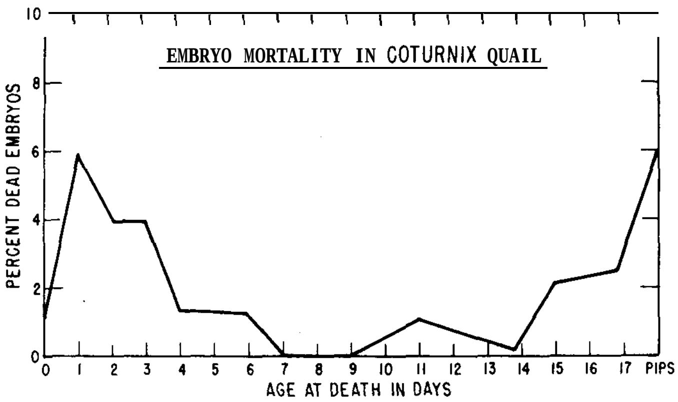

Figure 3. Embryonic mortality of coturnix.

early embryo deaths. The terminal peak in mortality is generally due to the inability of the developing embryo to form a vital organ or a malfunction of its development. Such critical functions include: change in position of the embryo prior to pipping, utilization of the remaining albumen, absorption of the yolk sack, and change from allantoic to pulmonary respiration. In addition, there is indication of a. slight mid-incubation peak of mortality reminiscent of that in chickens formally associated with a variety of dietary deficiencies.

Normal quail embryo development has been described in detail by Padgett and Ivey (1960) and Abbott (1967). Figure 4 shows their development.

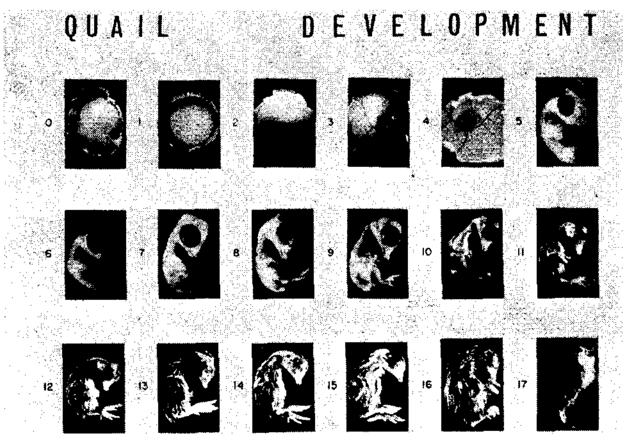

Figure 4. Coturnix embryo development.

D. Natural Incubation

Only limited information is available on natural incubation in the Japanese quail. Stevens (1961) reported the natural hatching success of 29 scantily built nests to be 67.1 percent. He further reported that nesting by young birds was not evident but that 4 adult birds produced 2 broods each and 2 other birds produced 3 broods during the same season. Rothstein (1967) reported that a group of 5 females and 2 males failed to establish a nest although eggs were laid in abundance. He attributed this to a high degree of domestication and lack of any sign of broody behavior.

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V. REPRODUCTION

A. Hatchability

Experiments in our laboratory indicate that hatchability decreases in storage at a fairly constant rate of about 3 percent per day (Table 2).

Table 2. Fertility and hatchability of coturnix eggs held for various periods before incubation.

Holding period (days)	2-8	9-15	16-22	23-29
No. eggs set	667	584	499	521
% fertility	79	73	65	45
% hatch of fertile eggs	69	53	26	10

Age of parent stock has a pronounced effect on hatchability (Table 3). Maximum hatchability occurs with eggs from 8-to-24-week-old birds. The reason for poor hatchability beyond 24 weeks of age is not known.

Table 3. Effect of age of parents on hatchability and fertility.

Female Age (weeks)	Female Number	Male Age (weeks)	No. of eggs set	Percent fertile eggs	Percent fertile eggs hatched
77	5	48	37	27.0	0.0
62	11	18	93	46.2	28.2
34	7	48	61	44.3	52.0
22	15	18	165	56.4	57.5

Turning eggs daily prior to incubation has no beneficial effect on hatchability (Table 4).

B. Fertility

Our experiments indicate that optimum fertility comes from a mating ratio of 1 male to 1 or 2 females (Table 4). Lower fertility with higher mating ratios may be due to preferential mating behavior (Woodard and Abplanalp, 1967).

Table 4. Effect of mating ratio (male to female) on fertility and hatchability when mass mated.

	Period 1				Period 2[1/]		
Group	Mating ratio males to females	No. eggs set	Fertility (%)	Hatchability (%)	No. eggs set	Fertility (%)	Hatchability (%)
1	1:1	307	76.5	86.4	247	87.0	81.9
2	1:2	408	82.1	82.4	434	82.7	92.5
3	1:3	497	61.0	79.9	430	64.0	87.3
4	1:4	525	44.4	77.7	472	51.9	86.1
5	1:5	684	64.5	78.2	605	67.4	87.3
6	1:6	603	71.5	79.6	521	12.7	84.8

[1/] New males mated with females.

Fertility in mass-mated females continues for approximately 10 to 12 days after males are removed (Table 5). Fertility remains at optimum, however, only if males are left continuously in cages with the females. Sittmann and Abplanalp (1965) found that fertility continued for approximately 11 days after coturnix were placed singly in individual cages. Persistence of fertility appears to be slightly shorter in coturnix than in ducks and geese, about one-half that in chickens, and about one-fourth that in turkeys (Fig. 5). Wentworth and Mellen (1963) report that the mean duration of fertility of coturnix females was 4.6 days with artificial insemination (single insemination) and 5.1 days with natural mating (male with female for 16 hours).

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Table 5. Duration of fertility of coturnix eggs as affected by length of the mating period. Fifteen females were mated to 5 males in each group. Each group was replicated, and males removed after 1 to 5 days.

Length of mating period (days)	Av. fertility (%)															
	1	2	3	4	5	6	7	8	9	10	11	12.	13	14	15	16
2	0	0	48	59	54	39	22	33	16	15	6	0	0	0	0	0
3	0 0	0	44	68 57	64 57	60	46	56	29	30	13	12	8		11	0
		0	33				67	65	45	46	33	25		0		
4	0	0	38	50	65	48	66	57	37	33	37	23	10	3	0	0
5	0	0	13	52	59	79	54	72	56	45	42	44	11	10	7	0

VI. BROODING AND REARING

A. Brooding Facilities

1. Battery Brooding

Coturnix chicks can be brooded successfully in several types of commercial or game-bird battery brooders. When commercial chick battery brooders are used they must be modified: Openings in the wire floor must be covered with a rough-surfaced paper during the first week. Also, the sides and ends must be blocked off with 1/4" hardware cloth to prevent coturnix chicks from escaping through the feeders and

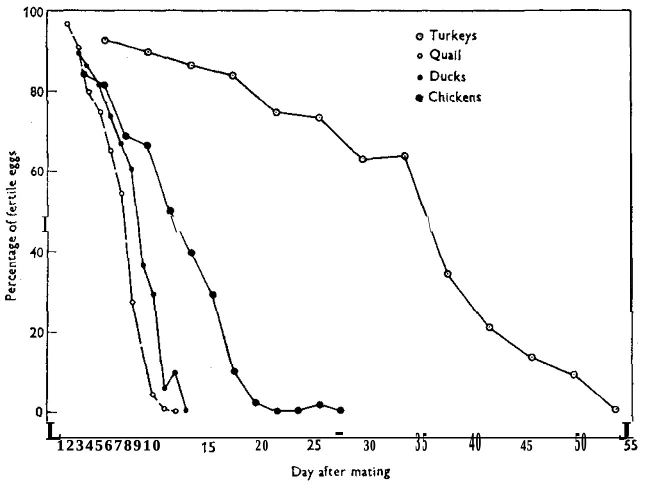

Figure 5. Duration of fertility following termination of mating 0 in different species of birds. Coturnix trials I and II of present data; ducks, percentages from two graphs of Ash **(1962)** averaged without weighting, starting with 2nd day after natural mating; chickens, two-day unweighted means calculated from graph of Parker et al. (1942), starting with 3d day after artificial insemination; turkeys, four-day unweighted means calculated from Lorenz's data used by Parker (1949), starting with 4th day following artificial insemination.

waterers. In a successful system at our laboratory, coturnix chicks are started in commercial game-bird batteries (needing no modifications) and transferred to commercial chick batteries at 2 weeks old. Flat paper plates are used as feeders for the first few days. Later, a 2" x 2" galvanized feeder with a 1/2" x 1/2" welded wire grill is placed over the opening to prevent feed wastage.

Waterers for the first 2 weeks are pint-size Mason jars with shallow drinking founts (bases). Drowning is prevented by covering the water founts with a 1/8" hardware grill. Colored marbles or pebbles in the founts attract the chicks to drink.

Other waterers used with varying success are "dew drops" and commercial rat waterers. Results with rat waterers are best with the type that uses a polyethylene jar inverted into a steel funnel. The stalk of the funnel terminates in a small basin or cup which maintains a constant water level.

Coturnix chicks can be brooded under the same starting temperature used for chickens and turkeys. Start chicks at 95°F and drop the temperature 5°F each week thereafter up to 5 weeks of age. Then the chicks should be well feathered and ready to move into laying cages or pens.

2. Preparations for Brooding

(a) Test the brooding facilities and have the equipment operating well before chick arrival.

(b) Provide clean fresh water and feed daily.

(c) Avoid overcrowding; reccommended floor space per chick is **36** square inches.

(d) Avoid unnecessary handling and disturbances. Coturnix chicks are easily frightened.

(e) Brood chicks under 24 hours light for the first 2 weeks and under **12** hours of daily light thereafter. If early maturity is desirable, brood chicks under 24-hour light for **6** weeks.

(f) Avoid chilling of chicks.

B. Banding

For pedigree matings, chicks can be banded at hatch with a wing band of game bird size; larger wing bands (chicken size) can be used at **3** weeks of age, when sexes are identified easily. Leg bands or tagged gum labels have also been used, with varying success.

C. Cannibalism

Coturnix being cannibalistic, they should be debeaked at the first sign of picking or debeaked routinely when-transferred from the battery or floor pens into colony mating cages. Equipment for debeaking chickens is adequate for quail. Several factors can contribute to cannibalism, including: 1) overcrowding; 2) inadequate diet; **3)** unusual amount of disturbance; and 4) excessive handling.

D. Handling and Care

Frequent handling of coturnix may result in deaths. Avoid moving the birds once they have reached maturity, for handling at that time may cause a pause in egg production. Laying hens should be housed in an area where outside disturbances are at a minimum.

E. Predators

Cages or pens in which birds are kept should be enclosed to provide adequate protection against invasion by rodents, cats, and predatory birds. Disturbances created by such invasions not only cause serious drops in egg production but frequently result in deaths. Blue jays, woodpeckers, magpies, crows, and rats will destroy or pack off large numbers of eggs. Predators not only are destructive but also are a source of disease (ornithosis, psittacosis, tuberculosis, and paratyphoid) and external parasites (fowl mite, lice, and ticks).

VII HOUSING ADULT BIRDS

A. Cages

Coturnix can be housed successfully in individual or colony wire-floor cages. Most cage houses designed for chickens are adequate for coturnix, but protection from cold and wind must be better than that of an open chicken house. The house should provide maximum protection from direct sunlight and wind, with adequate ventilation. It is also desirable that the structure be bird- and -rodent-proof. Cooling systems are advisable where summer temperatures are high, though quail can tolerate hotter environments than the chicken can.

Cage sizes designed for specific use at this research station are:

1) Pedigree matings: a 6" x 10" x 6" cage can be used for individual matings. Cages can be hung in single or double (back-to-back) rows, depending on the apace available (Figs. 6, 7). Batteries of single cages can be decked for efficient use of space (Fig. 8). Hart et al. (1969) reported a design for a bird carousel to accommodate quail in small controlled-environment chambers (Fig. 9).

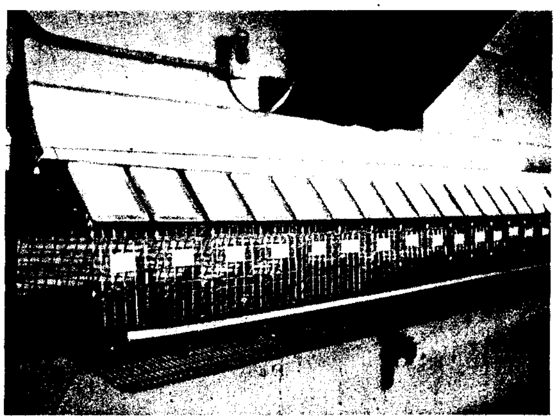

Figure 6. Individual coturnix mating cages, single row.

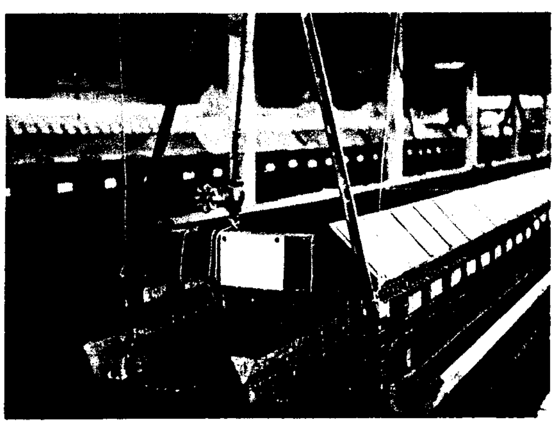

Figure 7. Individual coturnix mating cages in back-to-back installation. Continuous water trough services both sections.

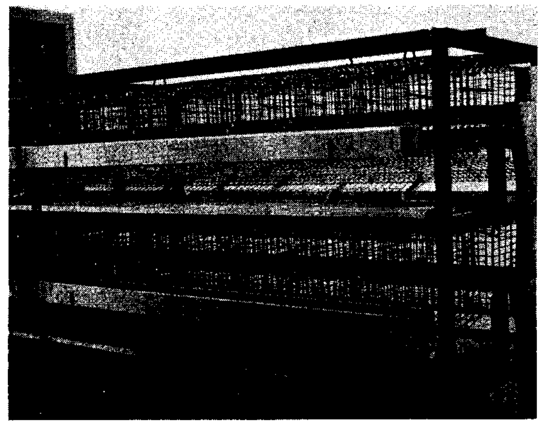

Figure 8. Back-to-back individual mating cages in j-deck battery.

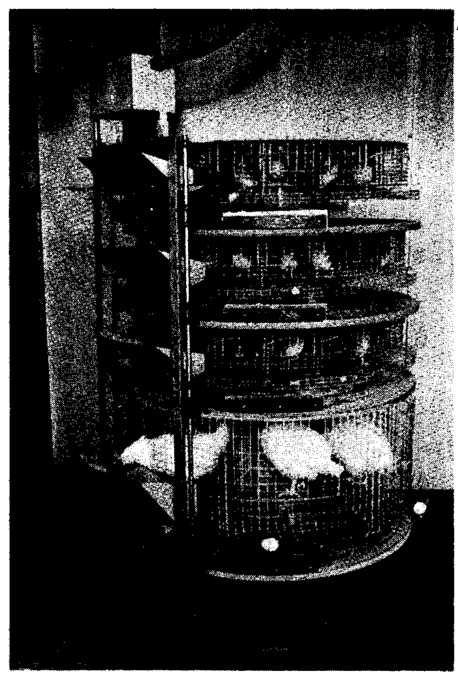

Figure 9. Bird carousel. Decks for chickens and quail are interchangeable. Turntable rotates at 3/4 revolution per hour.

This unit is designed so that the decks are interchangeable and any combination of chickens or quail decks is possible on each carousel. The turntable rotates at 3/4 revolutions per hour, thus giving the birds equal opportunity to eat and drink at a fixed station and equalizing exposure to light.

2) Small group matings: A 12" x 12" colony cage can serve this purpose (Fig. 10). A ratio of 1 male to 1 or 2 females is considered optimum for high fertility.

3) Large mass matings: Several cage sizes can be used satisfactorily. Cage sizes of 2' x 2' x 12" and 2' x 4' x 12" will respectively accommodate 25 and 50 birds (Fig. 11). To discourage jumping (with possible injury), cage height should be 12" or less.

A suitable material for construction of

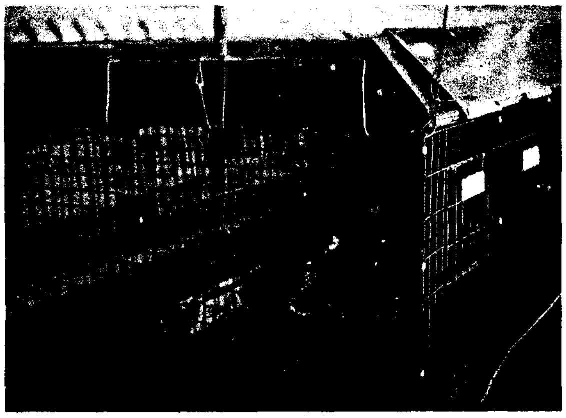

Figure 10. Colony mating and laying cages. 12" x 12" x 18" back-to-back sections.

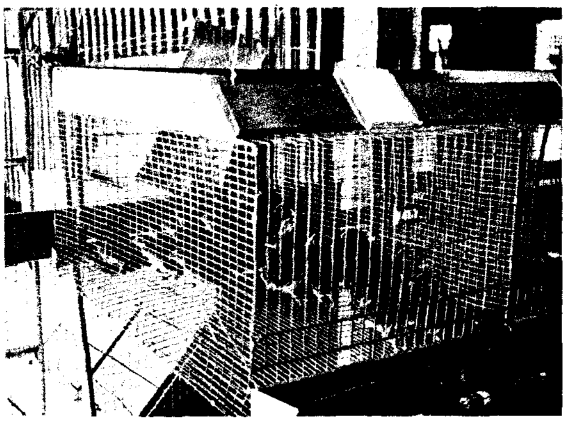

Figure 11. Colony mating cages. 18" x 24" x 12" high.

individual or colony quail cages is 18-gauge welded wire. The wire forms a rigid framework that can be supported from the cage-house rafters, facilitating mechanical removal of droppings. The floor section is made of 1/2" x 1" welded wire and permits roll-out of eggs. The back, top, and front sections can be shaped from one piece of 1" x 2" material. The 1" x 2" openings allow ample room for the quail to eat and drink. Two-inch galvanized iron "V" troughs mounted to the lower back edge of the cage can serve either a single cage or a back-to-back section of cages.

Egg card holders are tacked to a 1" x 6" board secured to a semi-upright position at the top front edge of the cages (Fig. 5). The egg record cards are protected from dirt, water stains, and fly specks by sheet-metal covers of 26-gauge, 6" wide x 6' long.

B. Experimental Units for Temperature and Light Control

Special box-units designed to control temperature and light have been designed in our laboratory. The units are constructed of 4"-thick polystyrene foam strips (an excellent insulating material) cemented together with Weldwood glue. Each unit is 36" wide, 48" long, and 22" high. For convenience, it is separated into two parts: a 32" x 32" brooding area in front; and a 14" x 32" area that contains a portable heating unit in the rear. A pegboard Masonite partition separating the heating area from the brooding area allows hot air to circulate throughout the box. The brooding area accommodates 50 chicks to 2 weeks of age or 30 chicks to 5 weeks of age. Then the brooding floor and pegboard partition are removed and replaced with two seven-cage sections mounted on sliding tracks. This arrangement permits the caretaker to slide the racks of cages to the outside of the unit (Figs. 12, 13).

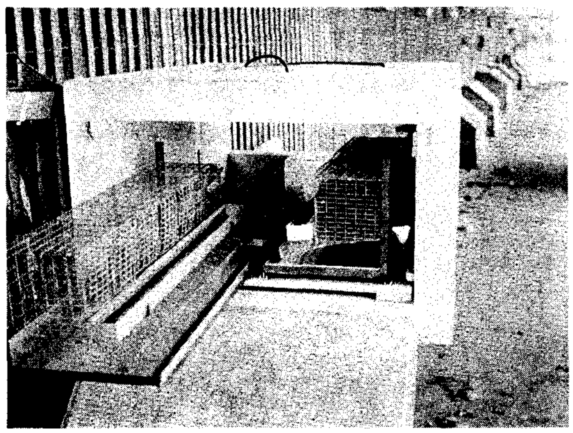

Figure 12. Experimental coturnix brooding units for controlling light and temperature. Sides, top, and bottom are constructed of 4"-thick styrafoam.

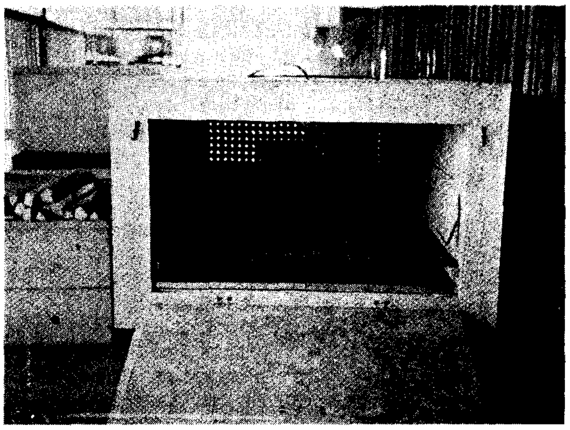

Figure 13. Experimental brooding unit converted to laying cages.

Thermostatically controlled fans near the back of the unit exhaust excess heat. The pressure deficit created within the box causes cool air to be sucked into the unit through two light-trapped vent openings near the top front of the unit.

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VIII. EGG PRODUCTION

A. General

Studies of the effects of light on chickens made it clear that a chicken's response to light is influenced greatly by the light regimen in the growing period. We therefore chose the coturnix to study the effects of photoperiod on sexual maturity since it matures in 5 to **6** weeks rather than 5 to **6** months.

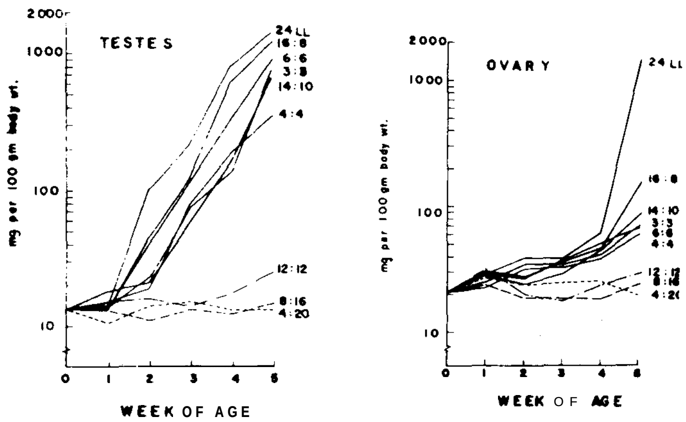

Figure 14. Mean ratios of testes and ovary weights to body weight of coturnix raised under various light regimens from hatch to 5 weeks old. The numerals on right of each graph are hours of light and dark per cycle.

Coturnix are similar in sexual development and egg production to high-producing strains of chickens. For example, age at first egg, testicular development, and egg production can all be altered dramatically by manipulating the length of the daily photoperiod (Fig. **14).**

Our studies have shown that optimum egg production of coturnix requires 14-18 hours of light daily. Figure 15 shows egg production of coturnix in single cages in a chamber with controlled light **(14** hours per day) and constant temperatures (with noted exceptions). The birds were fed a turkey starter ration up to **14** weeks of age and then received an experimental diet containing a high percentage of cottonseed meal. On two occasions during the experiment the temperature rose from 75° to 90° F. The data indicate that coturnix egg production can be maintained at a rather high rate under optimum conditions but is very sensitive to dietary or environmental changes.

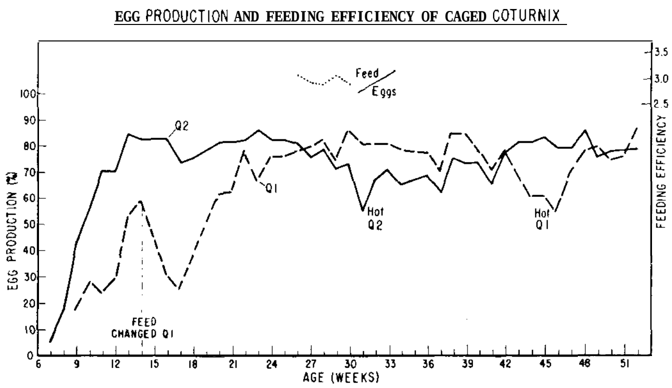

Figure 15. Egg production and feeding efficiency of coturnix kept in individual cages. Group Q1 was fed a standard turkey starter ration to **14** weeks of age, and then a diet containing a high percent of cottonseed meal was substituted. Group Q2 was fed a standard turkey starter crumble throughout the test.

B. Time of Lay

Figure **16** compares chickens and coturnix as to the distribution of time of lay. Approximately 75% of all chicken eggs are laid in the morning, whereas coturnix lay 75% of all eggs between **3** and **6** p.m. (Wilson and Huang, **1962).** About 20% of coturnix eggs are laid in darkness.

C. Time Interval and Clutch Length

Under continuous light, coturnix lay their eggs relatively uniformly over the 24-hour day, according to Arrington et al. **(1962).** Those workers also found that both

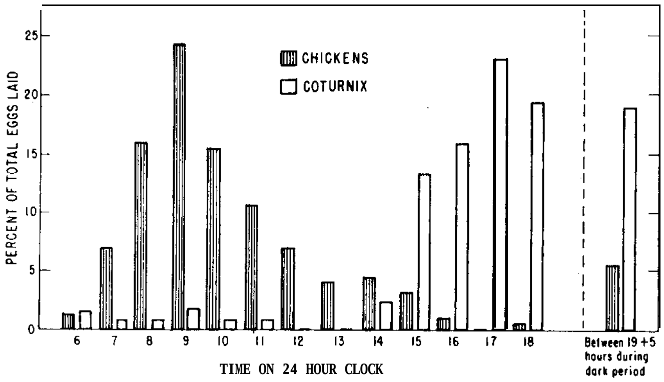

Figure 16. Time-of-lay distributions for the chicken and coturnix.

sequence length (clutch length) and time interval between successive ovipositions were thereby increased. They concluded that hens under continuous lighting changed from uniform laying to a cyclic pattern of oviposition if fed only during the daytime but continued to lay at a uniform rate throughout the 24-hour day if fed only at night. A possible factor in preventing this **group** from reflecting response to controlled night feeding could be the daytime activities of maintenance work.

D. Lighting for Early Maturity

Preliminary studies indicate that gonadal response is maximum under continuous lighting (Table 6).

Table 6. Testicular weights of S-week-old coturnix and average age at first egg of females exposed to various artificial day lengths between 1 and 5 weeks of ane.

Hours of light per day	Average weight of testes (mg)	Median age at first egg (days)
12	10.5	74
		46
14 / 16	159.9 / 288.6	44
24	454.4	42

Mather and Wilson (1964) reported the post-natal testicular development in the coturnix subjected to 16 hours of light and 8 hours of darkness per day. They found that the relationship between age and weight of the testes approximates a logarithmic growth curve until the combined testicular weights reach about 500 mg. Spermatozoa were observed in the testes at 26 days of age.

E. Unnatural Day Lengths

Abplanalp et al. (1962) studied the relation of maturation and egg production in coturnix to unnatural day lengths. Total length of day was held at 14, 16, 18, 20, 22, 24, 26, 28, 30, 36, 40, or 44 hours. In each cycle, light was given continuously for two thirds of the time and darkness for one third, thus holding constant the total light energy in all tests.

The results showed that artificial days of 16 to 18 hours retarded the maturation of both males and females and reduced production. The physiological mechanisms for reproduction seem to function best when stimulated by external cycles of about 24 hours.

F. Quality of Light

The quality of light has a pronounced effect on the rate of growth of female coturnix (Table 7). According to Woodard et al. (1969), hens kept under green or blue light weigh less at 5 weeks old than birds given red or white light of comparable intensity. Testicular development is stimulated by the longer wave lengths (red) at both high (10 lux) and low (3.5 lux) intensity. Five-week-old males brooded under red light of low intensity develop testes that are 11 times as heavy as those of males kept under blue light of comparable intensity.

Preliminary studies concluded at this research facility indicate that although red light hastens sexual maturity in the female coturnix, there is evidence (Fig. 17) that laying hens produce at about the same rate under red light as under incandescent light.

Table 7. Average body testicular weight and feed efficiency of S-week-old coturnix brooded under various wavelengths of 1 ght.

Light intensity (lux)	Color treatment	Body weight (gm)		Weight of testes[2] (gm)	Ratio of feed consumption to weight gained
		Males	Females		
17.0	Incandescent[1]	106.2	111.5 a	0.984 a	3.9
12.0	Red	104.0	112.5 a	1.145 a	3.8
12.7	Green	104.0	107.2 b	0.520 b[1]	4:o
40.0	Blue	101.5	107.2 b	0.354 b[1]	3.4
3.5	Red	103.2	111.6 a	1.144 a	3.6
3.5	Blue	103.7	110.3 a	0.119 c	3.5

1/Control.

/Combined data of two replicates. Values in columns 4 and 5 having different subscripts are significantly different (P<.01). Values b[1] and c are significantly different from each other (P<.05).

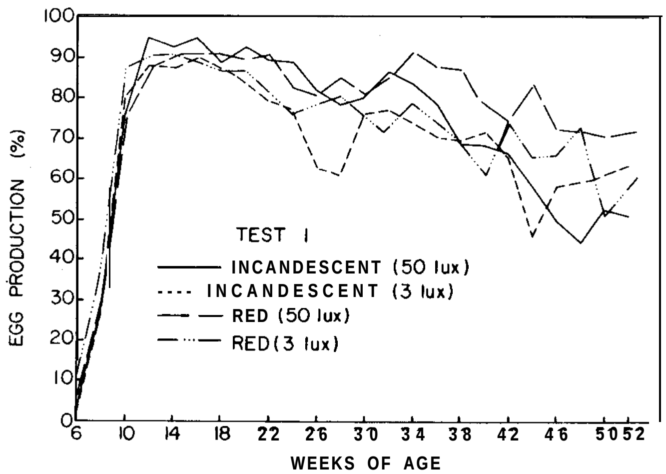

Figure 17. Average monthly rate-of-lay for coturnix maintained under red and incandescent light of differing intensities.

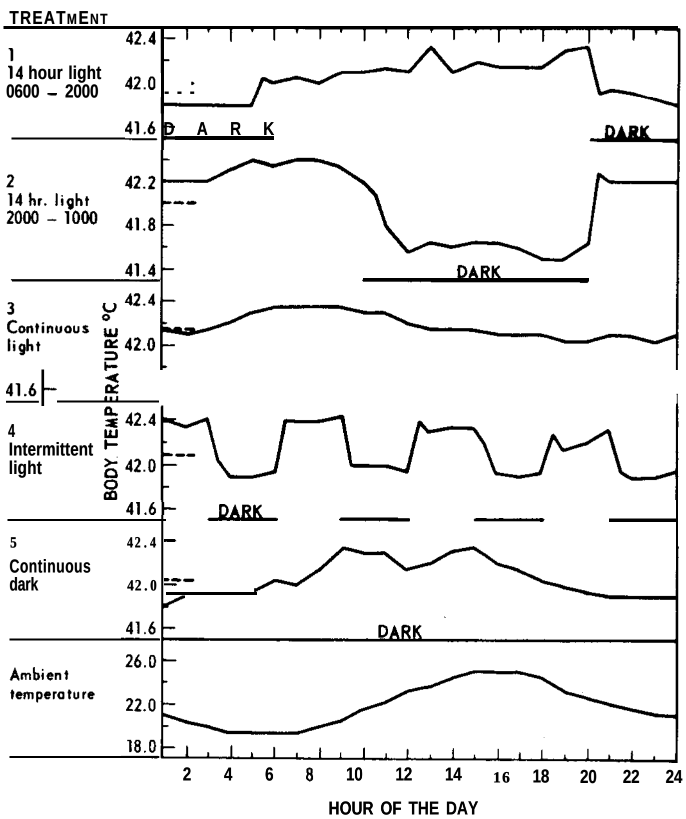

Figure 18. Mean hourly body temperature of coturnix exposed to different photoperiods. Broken lines represent mean temperatures for the 24-hour period.

G. Photoperiod, Body Temperature, and Time of Lay

According to Woodard and Mather (1964) the mean body temperature of the coturnix female fluctuates between 41.8° and $42.4^{\circ}C$ over a 24-hour period. Normal cyclic fluctuations in body temperature of coturnix kept in moderate environments are associated with physical activity and (usually) with the light period (Fig. 18). Woodard and Wilson (1971) reported a substantial increase in body temperature of about $1^{\circ}F$ at or near oviposition (Fig. 19).

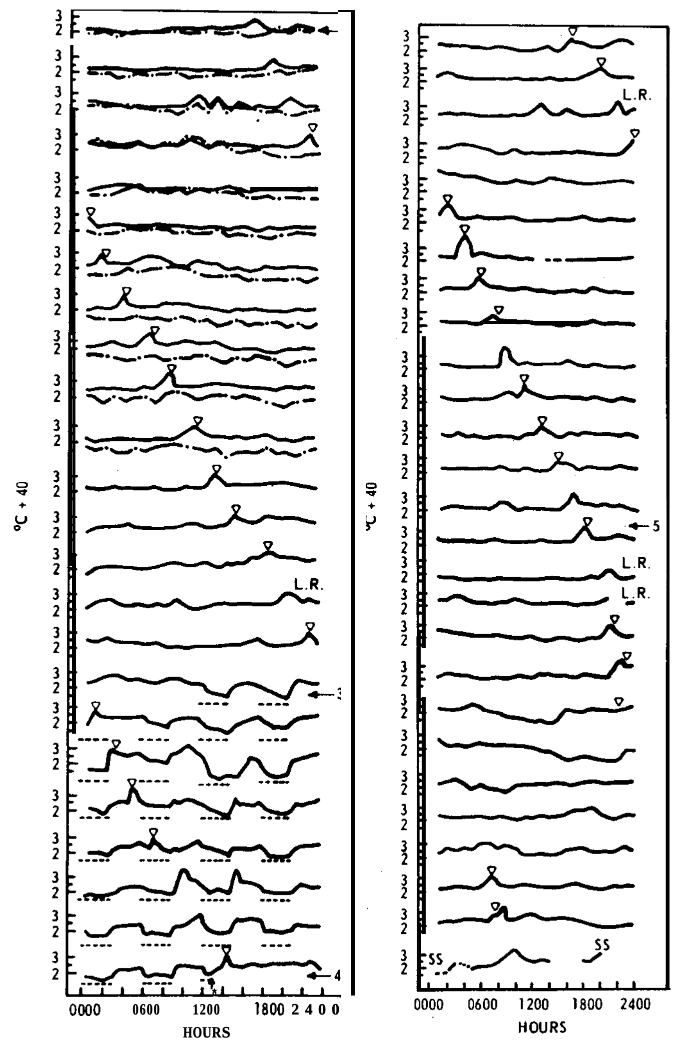

Figure 19. Synchronization of peaks in body temperature to time of lay in coturnix. Records start in period 2 (upper right side of left column) and run consecutively for 51 days through light period 2, 24LL, 55 lux; period 3, (3L:3D), 55 lux (dark periods are indicated by dashed lines); period 4, 24LL, 1.1 lux; period 5, 24LL, 1000 lux (see Table 1 for duration). Body temperature curves for a nonlayer, as shown by the dash and dot line, is compared with that of a layer for the first 11 days. Time of oviposition is indicated with a (v) delta. Body temperatures shown on the ordinate are in Celsius + 40, i.e., 2 + $42^{\circ}C$. LR = late recorded eggs; SS = soft shell eggs.

H. Senescence and Egg Production

The effect of aging- on egg production was determined for 3 generations of coturnix by Woodard and Abplanalp (1971). According to those investigators, rate of lay decreases sharply after the hens are 26 weeks old (Fig. 20). Cessation of lay occurred at 134, 110, and 138 weeks in 3 groups of hens kept under 14 hours light per

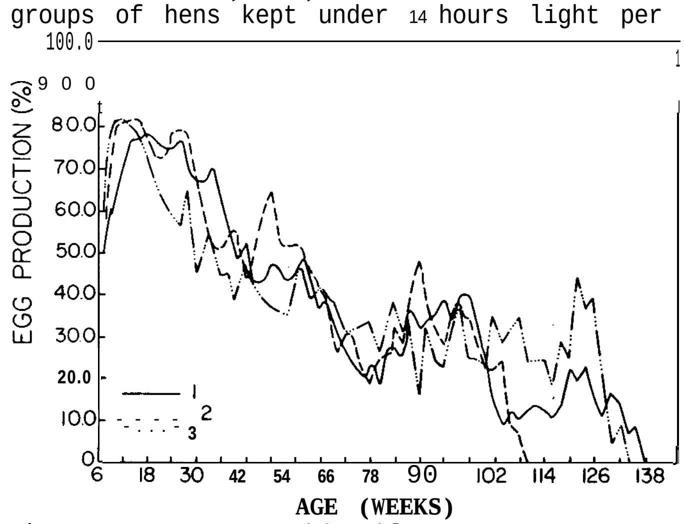

Figure 20. Average biweekly percent egg production in 3 generations of coturnix maintained under constant stimulatory light.

day. Figure 21 compares the average number of eggs produced during the approximate 2 1/2 years of lay by coturnix, chickens (Zander et al., 1942), and turkeys (Marsden and Martin, 1955). Second-year production as a percent of first year for combined groups of coturnix was 48.3 percent. In contrast, second-year production for chickens and turkeys was respectively 68 and 65 percent. This observation again demonstrates that coturnix age more rapidly than the larger gallinaceous species.

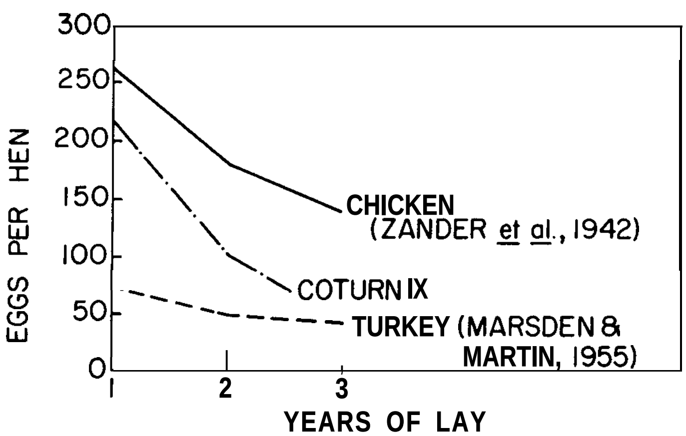

Figure 23. First-year and second-year egg production in the chicken, turkey, and coturnix.

I. Senescence and Mortality

The effect of aging on livability in 3 generations of coturnix of mixed sexes kept under a constant stimulatory light (14L:10D) was determined at the Davis Facility. Woodard and Abplanalp (1971) reported that females die much younger than males, with their mortality rising uniformly with age to about 100 weeks (Fig. 22). The regression line for this period was calculated to be Y = 0.93 x. Thus, approximately 1% of the females would be expected to die with each 1 week of life. The last females in the 3 generation groups died at respective ages of 1311, 1192, and 1382 days.

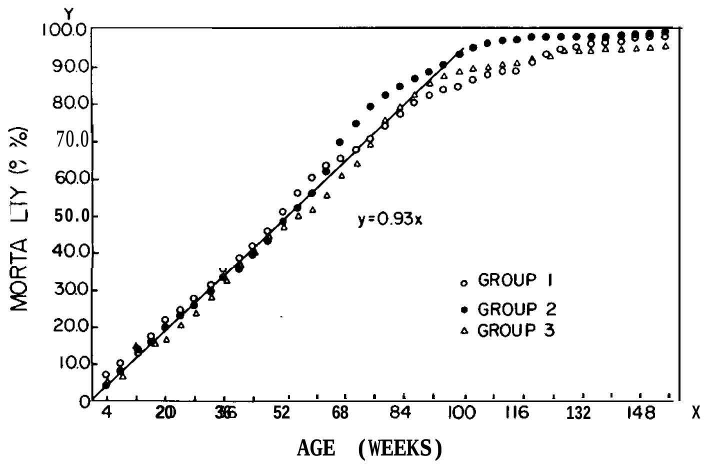

Figure 22. Cumulative mortality in 3 generations of coturnix females. The regression Y = 0.93 X applies to mortality to 100 weeks of age.

Male coturnix live much longer rate than females (Fig. 23). Fifty percent were alive at 90 weeks of age, compared with only 16% of the females. At least one male in each group is still living, and the oldest is now 1915 days old.

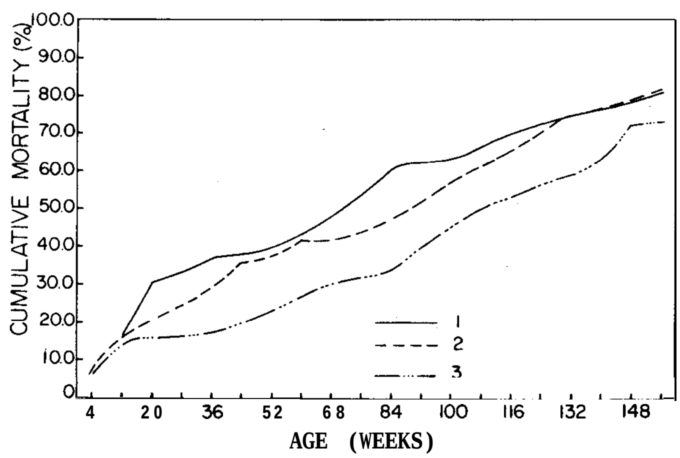

Figure 23. Cumulative mortality in 3 generations of coturnix males.

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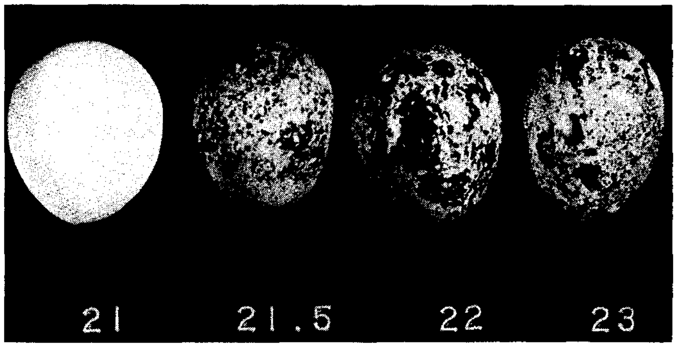
IX. EGG FORMATION

The interval between gonadotropin release and ovulation in coturnix is usually 4 to 6 hours, similar to that of chickens (Opel, 1967). Ovulation is usually within 15 to 30 minutes of oviposition, comparable to the interval in chicken and turkey (Woodard and Mather, 1964). Our data indicate that the ovum traverses the various parts of the oviduct in the following times: infundibulum, 1/2 hour; magnum, 2 to 2 1/2 hours; and isthmus, 1 1/2 to 2 hours. The egg stays in the uterus 19 to 20 hours. Table 8 compares, for coturnix, turkey, and chicken, the size of the oviduct and rate of movement of the ova in each part of the oviduct. These data indicate that the upper areas make up a largerpercent of total oviduct in the coturnix than in the chicken and turkey.

Figure 24 is a representative series of eggs indicating degree of pigmentation with time of development.



HOURS AFTER OVULATION

Figure 24. A representative series of eggs showing period of pigmentation in the coturnix.

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Table 8. Size of oviduct and rate of movement of the ova in each component of the oviduct of turkey, chicken, and coturnix.

Species	Percent total length of each component of the oviduct: Infund.	Magnum	Isthmus	Uterus	Vagina	Reference
Turkey	14.8	42.6	15.3	13.5	13.6	Asmundson (1939)
Chicken	9.6	45.0	13.4	16.0	16.0	Warren and Scott (1935)
Coturnix	18.2	46.9	20.1	9.9	4.9	Woodard and Mather (1964)
"Time Spent in the Oviduct (Hours)"						
Turkey	1/4 - 1/2	2 1/2-3	1-1 1/2	22-24		Wolford et al. (1964)
Chicken	1/4 - 1/2	2-3	1 1/4	18-20		Warren and Scott (1935)
Coturnix	1/4 - 1/2	2-2 1/2	1 1/2-2	19-20		Woodard and Mather (1964)

X. GENETICS AND BREEDING

A. Origin of Coturnix

The domesticated coturnix first used in laboratory work in this country were a postwar importation from Japan. Selection for a high production rate in these domesticated birds is believed to go back perhaps 200 years or more. The earlier breeding work on coturnix in Japan was devoted to developing them as song birds or for fighting qualities. Domesticated coturnix populations are also known to exist in Southeast Asia, including Taiwan, and imports from the latter country have been used to supplement the genetic basis of our breeding populations at U.C. Davis (line 908).

The genetic improvement of wild Japanese quail under domestication has been confirmed in a study at the National Institute of Genetics, at Mishima, Japan (Kawahara and Tita, 1969). A population of wild coturnix collected at the foot of Mount Fujiyama was compared with a domesticated strain. The wild birds were smaller than the domestic birds, laid some 14 percent fewer eggs, and matured at 117 days of age, compared with 48 days for domestic coturnix. Almost half of the wild coturnix failed to lay in cages. F_1 hybrids between wild and domestic coturnix were backcrossed successfully to either parent line, proving the close genetic relationship.

B. Hybridization

Coturnix can be hybridized with chickens, as demonstrated in early attempts at this laboratory and exhibited at the 1960 Annual Meeting of the Poultry Science Association and later by Wilcox and Clark (1961) and Haley et al. (1966). An average of about 7 percent fertility was obtained from weekly inseminations on quail hens with chicken semen. Less than 1 percent of all fertile eggs hatched. Fertility and hatchability in cross inseminations can be doubled by inseminating more often, and results at our laboratory indicate that fertility with chicken semen is higher in old coturnix hens than in young ones. Reciprocal recurrent selection of lines of coturnix and chickens for high fertility with chicken sperm has been successful at our laboratory to the point where the selected lines produce over 90 percent fertile eggs (Haley et al., 1966).

In the chicken-coturnix hybridization, no fertility has resulted in chickens inseminated with coturnix sperm. Also, surviving hybrid embryos are all males, in accordance with Haldane's rule that the homogametic sex among hybrids of all kinds is the male viable. Female hybrids do occur but die at early stages, according to chromosome studies by Bammi et al. (1966a,b).

Upon insemination with chicken semen, coturnix hens show an initial rise in hybrid fertility that drops again after five or six weeks; studies at our laboratory indicate the decline to result from the production by the coturnix hen of antibodies against chicken sperm (Haley and Abplanalp, 1970). This view is supported by the failure to obtain hybrids in the reciprocal cross (coturnix x chicken).

Japanese quail hens inseminated semiweekly with turkey semen have shown about 15-20 percent hybrid fertility. One turkey-coturnix hybrid hatched at our laboratory but died two days later. Hybridization of coturnix with the chukar partridge has failed completely. Sarvella (1971) obtained and raised hybrids between pheasant and coturnix

Cytologically the Japanese quail closely resembles the chicken and turkey (Bammi et al., 1966a). They have probably 38 pairs of autosomes and two sex chromosomes.

C. Inbreeding Sensitivity

Studies using the Japanese quail in breeding experiments were started at our laboratory in 1959. They have demonstrated that this species offers scientists several advantages in exploring breeding systems and certain applied problems of poultry breeding. Its rapid maturation, very high rate of egg production and growth, and close genetic relation to other poultry make the Japanese quail an excellent pilot animal. The most distinctive genetic property of Japanese quail populations appears to be their pronounced sensitivity to inbreeding. Adverse effects of inbreeding on hatchability, viability, and egg production were found to be almost twice as severe in coturnix as in chickens or turkeys. Under a system of inbreeding by brother x sister mating, about 150 inbred 'lines were started at our laboratory, but none survived past 3 generations of continued sibbing. Table 9 shows some of the more important results of that study by Sittmann et al. (1966a). Similar results have been reported by Boesiger (1969) and Shinjo et al. (1971).

Several practical consequences must be drawn from these findings. First, it should be obvious that the breeding of highly inbred (homozygous) lines of coturnix may be difficult and would have to be carried out with a breeding system of less intensive inbreeding than brother x sister matings. Half-sib matings or sib matings followed by generations without close matings and with selection for good reproduction might be successful. Secondly, selection experiments with coturnix should be planned with large enough populations to avoid inbreeding effects of appreciable magnitude. This means that populations should be propagated with a minimum of about 25-40 mated pairs. In mass matings, no fewer than 20 males and 40-60 females should be used to propagate control strains used for the production of experimental animals.

The pronounced inbreeding effects suggest that coturnix populations carry many harmful recessive genes. The discovery and description in this species of large numbers of distinct major genes can therefore be

Table 9. Effects of inbreeding on the percentage mortality of quail to 16 weeks, nonlayers among hens, the percentage fertility of eggs incubated, and other traits of adult birds.

	Inbreeding (F, in percent) and mating type					
	0(R_0)	0(R_1)	25(S_1)	37.5(S_2)	50(S_3)	10% inbreeding
Number of chicks banded	2659	499	1391	326	26	....
Mortality: 0 to 5 weeks	17.2	23.1	25.8	40.9	71.4	+4.2
5 to 16 weeks:						
males	5.9	6.4	7.5	11.5	....	+1.0
females	11.5	5.2	16.1	18.9	....	+3.0
Number of surviving females	793	128	350	61	0	....
Nonlaying females among survivors	5.0	5.0	8.7	14.6	....	+2.1
Total eggs incubated	10,863	1241	2775	741	....	....
Age at first egg (days)	56.7	57.3	59.6	65.1	....	+1.7
Number of eggs to 16 weeks of age	47.7	49.1	42.4	35.1	....	+3.0
Egg weight (gm) at 12 weeks	10.26	10.27	9.83	9.56	....	-0.2
Body weight (gm) at 6 weeks:						
males	107.9	104.3	102.7	98.9	....	-1.7
females	121.1	112.7	110.0	108.2	....	-2.4
Percent fertility of all eggs set	79.5	76.4	50.3	33.0	....	-11.0
Percent hatchability of fertile eggs (Inbreeding is that of the embryo)	73.0	63.0	53.0	40.0	26.0	-3 for hen -7 for embryo

R_0 = non-inbred controls; R_1 = crosses between inbred lines;
S_1, S_2, S_3 = inbreds from 1, 2, and 3 generations of sib-matings.

only a matter of time. Several have in fact already been described in the course of the work reported here. Among them have been recessive autosomal lethals causing micromelia (Hill et al., 1963), congenital loco (Sittmann et al., 1965a), and white plumage (Sittmann and Abplanalp, 1965b). A non-lethal gene causing differential migration of serum albumin under starch gel electrophoresis has been found by Haley (1965), and a gene for white egg shell color was reported by Poole (1964). A sex-linked gene causing buff plumage and pink eyes (pk) has been described by Sittmann et al. (1966b). Those workers also demonstrated that both of the albino genes caused a marked reduction in reproductive fitness when homozygous. Unpublished data from this laboratory further suggest abundant single-gene variation in egg proteins and blood serum proteins (also, Lepore and Marks, 1965), as well as additional embryonic lethals. Japanese quail should therefore be considered favorable genetic material for problems related to developmental and biochemical genetics.

D. Selection Studies

Long-term selection studies for growth rate are in progress at several laboratories. Our own lines at Davis are now in their 29th generation of selection for high 6-week body weight. Birds belonging to these lines are now some 70 percent larger than those of unselected populations and the hens reach 210 grams at 6 weeks old (Fig. 25). Along with increased growth the selected lines show many of the undesirable changes known to occur also in meat-type chicken populations. Thus, hens of the selected lines lay larger eggs but tend to

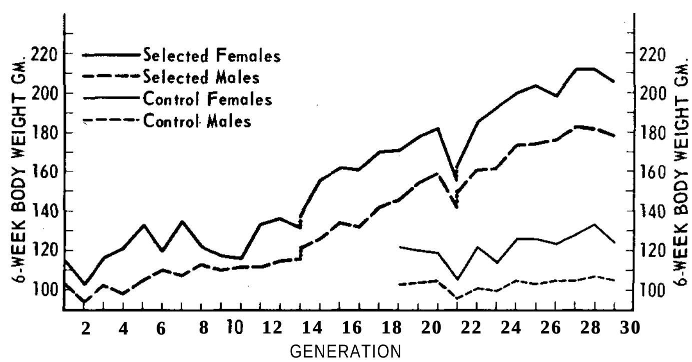

Figure 25. Selection for 6-week body size for 29 generations.

have reduced fertility and hatchability of eggs, as shown in Table 10. These adverse effects of large body size seem to become more pronounced as the hen ages.

Marks and Lepore (1967), using a population selected for rapid growth to 4 weeks of age on a diet containing thiouracil, made the interesting observation that coturnix chicks fed a diet containing 0.2 of thiouracil show reduced growth, as expected, but have improved fertility as adults when switched to a normal diet. Marks (1970) also demonstrated that selection of growth

Table 10. Comparison of the average performance of 2 lines selected for high 6-week body weight with the control population in the 16th generation of selection.

Trait		Control line Males	Control line Females	Average of two selected lines Males	Average of two selected lines Females
Body weight (gm) at:	6 weeks	109.04	130.9	132.3	167.1
	18 weeks	123.8	155.2	149.0	182.6
Egg weight (gm) at:	16 weeks		10.7		11.0
	20 weeks		10.7		11.1
Percent fertile eggs at:	9 weeks		75.7		60.5
	25 weeks		73.4		57.5
	41 weeks		62.8		42.9
Percent hatchability of fertile eggs at:	9 weeks		74.7		57.8
	25 weeks		79.6		62.5
	41 weeks		75.3		50.5
Egg production to 16 weeks			43.0		44.3

under the inhibiting diet is capable of causing specific adaptation of selected birds to overcome the specific thiouracil effect, while showing less selective improvement under normal diets than population selected under control conditions. The beneficial effects of thiouracil inhibition of early growth on subsequent fertility has also been demonstrated in selected population at Davis, as shown in Table 11.

	Selected line (Gen 23) Control diet	Thiouracil (0.21% to 4 weeks)	Control line (unselected) Control diet	Thiouracil (0.21% to 4 weeks)
Body weight at 6 weeks (gm)	175 males	167	121 males	112
	155 females	150	96 females	98
Eggs laid to 16 weeks	34.7	33.1	39.2	29.8
Fertility of eggs set	70.0	93.0	90.8	94.3
Hatchability of fertiles	65.0	77.5	60.3	72.2

Several selection experiments for increased egg production have been conducted at our laboratory (Abplanalp, 1966) under normal management conditions. An increase in eggs laid between 6 and 16 weeks of age appears difficult to realize, as demonstrated by a 15-generation selection experiment shown in Figure 26. Although crossing of selected lines showed improvement in egg production, further selection following such crosses failed to increase egg production. Selected lines did, however, advance their sexual maturity by a few days while rate of lay remained unchanged.

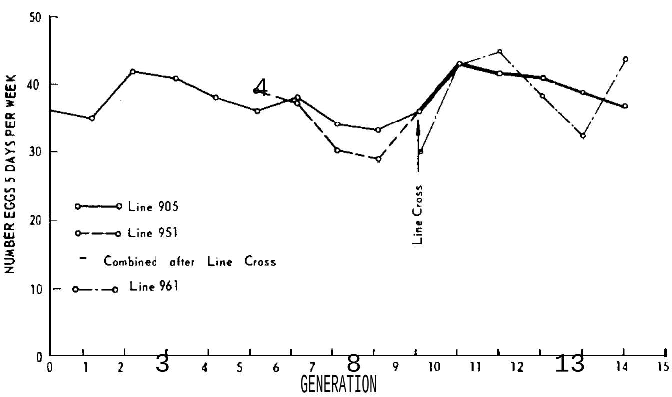

Figure 26. Selection for egg production to 16 weeks under 14L:10D. Line 905' selected 9 generations, then combined with 951 and selected for 4 generations. Combined lines were selected for another 5 generations compared with a new line (961) selected for 5 generations.

Our studies of the genetics of egg production in quail thus suggest that this species may be an excellent animal for this purpose, since it exhibits many of the genetic difficulties encountered in further improvement of today's highly productive chickens.

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XI. PHYSIOLOGY

Physiological investigations of coturnix have been mostly on the effect of environment on reproduction. The physiological parameters have been compiled by the National Academy of Sciences (1969). Physiological studies with coturnix have been reviewed by Wilson (1972).

A. Hypophysis

Several reports have been published on the role of the hypophysis in sexual development of the coturnix. The technique for hypophysectomizing coturnix has been published by Opel (1967). According to Opel approximately sixty percent of coturnix hyposectomized at 4 weeks of age remained alive, compared with total mortality of adult chickens. The anatomy of the blood suwwly to the oituitarv and basal hypothalamus was reported by Opel to be similar in coturnix to that in other avian species.

As determined with a coturnix bioassay, the gonadotropic potency of the adenophypophysis in mature coturnix exposed to continuous light did not differ significantly at any time during the 24-hour light period (Tanaka et al., 1966). When coturnix were maintained on differing light schedules of either 16L:8D, 14L:10D, or (6L:6D)[2], however, the potency level was higher at the end of the light period than 3 or 4 hours after the beginning of darkness. No significant difference in potencies during darkness has been observed. The results indicate that the gonadotropin content in the adenohypophyses from immature male coturnix reared under certain light regimens changes with the daily light-dark rhythms (Tanaka et al., 1966).

The cytology of the adenophypophysis of the male has been studied extensively by Trixier-Vidal et al. (1967). These workers have identified several types of cells in the adenohypophysis: beta- and gamma-gonadotropic cells, thyrotropic delta cells. and corticotropic ceils. The significance of the orangeophilic alpha (STH?) cells and the erythrosinophilic eta (prolactin?) cells remains hypothetical. The cell type kappa has been identified in other species of birds and may be related to the secretion of MSH.

B. Hypothalamus

In the hypothalamus of coturnix neurosecretory cells occur in two areas, the supraoptic nucleus and the paraventricular nucleus. These nuclear areas consist of a series of extended groups of cell (divisions) that are interconnected through irregular chains of neurosecretory cells. The paraventricular nucleus is large and well developed (Oksche et al., 1964).

Morphologically the neurosecretors cells vary extensively even in normal birds. There may be small indistinct cells with very little stainable neurosecretory material, or relatively large cells filled with homogeneous neurosecretory material. In the latter the initial sections of axons are frequently conspicuous because of the presence of neurosecretory granules. The large paraventricular nucleus is striking because of its very intense neurosecretory activity. The initial part of the neurosecretory tract is clearly evident because the neurosecretory substance is stainable.

In addition to the accumulation of neurosecretory material in the neural lobe of the hypothalamus there is a second storage site in the zona externa of the median eminence.

Rhythmic changes of the concentration of nourosecretory material in the median eminence were found to be inversely related to the volume of the stainable portion of the median eminence. These rhythms in the median eminence as well as the morphological observation of neurosecretory material in the supraoptic nuclei suggest that the onset of light and dark periods activates the hypothalamic neurosecretory system, initiating synthesis and release of neurosecretory material (Konishi and Kato, 1967).

Sharp and Follett (1969) investigated the influence of hypothalamic lesions in the basal hypothalamus on gonadotropin release. They concluded that the AF-positive neurosecretory was not related to gonadal growth. Lesions that destroyed either the nucleus hypothalamicus posterior medialis, tubero hypophysial system, or the median eminence completely blocked testicular development that would otherwise have been induced photoperiodically. Coturnix differ from other species in that lesions made in the posterior hypothalamic nucleus, leaving the tubero-hypophysial intact, still block gonadotropic secretions.

C. Neuroendocrine Control of Behavior and Plumage

According to Reese and Reese (1962), coturnix appear well suited for behavioral studies. Farris (1967) reported that male coturnix could be classically conditioned to display courting behavior at the sound of a buzzer, a previously neutral stimulus.

Castration of male coturnix destroyed their aggressiveness as measured by paired encounters, whereas injection of testosterone into submissive birds changed the established dominance relations (Selinger and Bermant, 1967).

Warner (1970) reported interesting effects of gonadal steroids and pituitary gonadotropins on plumage colorations. He used normal and castrated males (capons) and females (poulards) as well as hypophysectomized coturnix. Plumage was darker in poulards than in intact males, and breast spots (characteristic of female plumage) were typically absent. Injections of estradiob resulted in lighter plumage color in poulards. Exogenous testosterone resulted in lighter-colored plumage of capons. In poulards a daily dose of 225 mgm testosterone resulted in plumage most like that of intact males and showed a greater change in the plumage of capons treated similarly.

D. Physiological Values

	Value	Reference
Metabolism		
Body temperature	42.2°C	Woodard and Mather, 1964a
Respiratory rate per min		
Restrained, unanesthetized M.	56(40-85)	McFarland and Lacy, 1968
Restrained, unanesthetized F	71 (45-93)	McFarland and Lacy, 1968
Clearance of ingesta	1-1 1/2 hr	McFarland and Freedland, 1965
Skin temperature (21 °C ambient)	39.0°C	McFarland et al., 1966
Reproduction		
Puberty egg, F	42 days	Wilson et al., 1961
Sperm,-M ---	36 days	Mather and Wilson, 1964
Production rate	80%	Wilson et al., 1961
Timefbr egg formation	24 hr	Woodard and Mather, 1964b
Testes weight	2500 mg	Wilson et al., 1962
Testes wt at first spermatozoa	551 mg	Mather and Wilson, 1964
Semen concentration	5.9 million/mm^3	Wentworth and Mellen, 1963
Semen volume	10 ul/bird	Wentworth and Mellen, 1963
Hatching time	394 hr	Abbott and Craig, 1960
Number of developing ova (16L:8D)	3.17	Homma et al., 1965;
Ovary, laying	6.2 g	Wilson et al., 1962
Oviduct, during lay	4.9 g	Wilson et al., 1962
Cloacal gland, with sexually active M	2 mm	McFarland and Lacy, 1968
Cloacal gland, with sexually active F	0.65 mm	McFarland and Lacy, 1968
Blood values		
Hematocrit. M	43%[a]	Atwal et al., 1964
Hematocrit; F	40%[a]	Atwal et al., 1964
Hemoglobin, M	14.5 g%[a]	Atwal et al., 1964
Hemoglobin, F	12.9 g%[a]	Atwal et al., 1964

	Value	Reference
Blood values (continued)		
Red blood cells, M	5.1 million/mm^3 [a]	Atwal *et al.*, 1964
Red blood cells, F	4.3 million/mm^3 [a]	Atwal *et al.*, 1964
Total leucocytes, M	24,000/mm^3	Atwal *et al.*, 1964
Total leucocytes, F	25,000/mm^3	Atwal *et al.*, 1964
Plasma osmotic pressure	320 mOsm/kg of H20	Koike, 1964 (personal communication)
Plasma refractive index, M	1.3423	McFarland and Lacy, 1968
Plasma refractive index, F	1.3468	McFarland and Lacy, 1968
Blood volume	6.5% of body wt	McFarland, 1968 (personal communication)
Plasma electrolytes, Na	180 meg/1	McFarland, 1968 (personal communication)
Plasma electrolytes, K	1.4 meg/1	McFarland, 1968 (personal communication)
Plasma electrolytes, Cl	124 meg/1	McFarland, 1968 (personal communication)
Percentage distribution in blood		
Heterophils, M	50%	Atwal *et al.*, 1964
Heterophils, F	52%	Atwal *et al.*, 1964
Lymphocytes, M	46%	Atwal *et al.*, 1964
Lymphocytes, F	40%	Atwal *et al.*, 1964
Monocyctes, M	2%	Atwal *et al.*, 1964
Monocyctes, F	1%	Atwal *et al.*, 1964
Eosinophils, M	1%	Atwal *et al.*, 1964
Eosinonhils, F	4%	Atwal *et al.*, 1964
Basophils, M	1%	Atwal *et al.*, 1964
Basophils, F	3%	Atwal *et al.*, 1964
Plasma protein, M	3.4 g%	Atwal *et al.*, 1964
Plasma protein, F	3.6 g%	Atwal *et al.*, 1964
Cardiovascular		
Heart weight	1.18 g	Freedland *et al.*, 1966
Heart rate per min		
Restrained, unanesthetized M	369(249-494)	McFarland and Lacy, 1968 (personal communication)
Restrained, unanesthetized F	432(265-531)	McFarland and Lacy, 1968 (personal communication)
Systolic blood pressure	152(120-165) mm Hg	McFarland and Lacy, 1968 (personal communication

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XII. NUTRITION

The nutrient requirements of coturnix has been reviewed extensively by Vohra (1971).

The standard metabolic rate of adult coturnix of both sexes can be reasonably predicted by the following equation:

$$\text{Heat production (kcal/hour)} = 70\ (\text{kg body weight})^{2/3}$$

A. Energy Requirements

Coturnix can utilize diets containing 2200 to 3400 kcal/kg metabolizable energy (ME) equally well if the protein level is about 25%.

B. Protein Requirements

Coturnix chicks weigh about 7 gm at hatching. Table 12 gives the body weights of coturnix raised on diets containing 20, 25, 30, and 35% protein.

The body weight of coturnix fed 20% dietary protein level was not different statistically from those fed 25%, but was far lower than those fed 30% protein by the 5th week of age. No significant differences were observed in the body weights of coturnix fed **30** or 35% protein. By the 6th week, the body weights on all the four protein levels were of the same magnitude. A level of 25% dietary protein is recommended for optimal growth.

Recommended for egg production is a dietary protein level of 20%. Coturnix were raised to sexual maturity on a diet containing 25% protein and then fed diets containing 15, 20, 25, or 35% protein. The average body weight and egg weight of females was lower with 15% protein than with the other diets. Average egg weights on the respective diets were 8.5, 9.5, 9.8, and 9.9 gm.

A dietary level of 20% protein gave optimal production, fertility, and hatchability of eggs.

Table 12. The body weights (gm) of quail chicks fed diets containing 4 different levels of protein.

% protein in diet ME, Kcal/kg (Calc)	**20** **2990**	25 **2880**	30 **2770**	**35** **2660**
Age (weeks)	Body weights (gm)			
0	**6.8**	**6.8**	**6.8**	**6.8**
2	14.8	17.2	40.4	30.1
3		32.0	69.0	44.7
	27.4		[illegible]	67.1
5	[illegible]	**87.2**	96.4	94.7
6	118 99.3	102.6 117.6	113.5 123.3	**111.2**
				115.5

Vohra and Roudybush, **1971**. Poultry Sci. 50: **1081-1084**.

C. Calcium and Phosphorus Requirements

Growth, feed efficiency, and bone ash did not differ significantly when calcium level varied from 0.44 to 2.3% and calcium/phosphorus ratio varied from 0.7 to 2.9%. It has been suggested that breeders should have a higher level of calcium (2.5-3%) and 0.8% phosphorus in their diet.

D. Trace Elements Required

Coturnix requirements have been estabblished for some trace elements: zinc, selenium, and magnesium. They can tolerate 203 ppm fluoride ion in drinking water without adverse effect, whereas 500 ppm was lethal. Coturnix need potassium for survival, and sodium for growth and egg shell formation.

E. Vitamin Requirements

A deficiency of choline in growing coturnix is reflected in an increase of lipid content of liver. No perosis-like condition has been observed to result from choline deficiency, although the requirement for choline is much higher in breeder coturnix than in chickens.

Table 13 summarizes the current information on the nutrient requirements of coturnix. The 1971 edition of N.R.C.'s Nutrient Requirement of Poultry gives some data on only a few nutrients.

Table 13. Nutrient requirements of coturnix.

	Growing quail		Breeder quail
	0-3 weeks	3-5 weeks	Adult
Metabolizable energy, kcal/kg			2600
Protein, % diet[1]	2925	2600	20
Lysine, % diet[2]	1.3	1.2	?
Methionine, % diet[2]	0.74	0.71	?
Glycine, %[2]	1.28	1.28	?
Calcium, % diet	1[3]	1[3]	3[4]
Phosphorus, % diet	0.8[3]	0.8[3]	0.8[4]
Zinc; mg/kg diet[5]	75	75	75
Selenium, mg/kg diet[6]	1	1	1
Magnesium, mg/kg diet[7] / Sodium, % diet[8]	150	150	?
Potassium, % diet[8]	0.28 0.11	0.28 0.11	0.11
Vitamin A, I.U./kg diet[9]	3300	3300	3303
Vitamin D3, I.C.U./kg diet[10]	1200	1200	1200
Vitamin E, I.U./kg diet[11]	40	40	40
Pantothenic acid? mg/kg diet[12]	40	40	?
Choline, mg/kg diet	2500-3500	2500-3500[13]	1045-2090[14]
Linoleic acid			needed

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13. Vogt, 1970. Arch Geflugelk. 34:41-44
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Table 14. The composition of the commercial and purified diets for quail.

	gm/kg		
	Commercial-type diet		Purified
Ingredients	Growing	Breeding	diet
Ground milo	286.1	386.1	----
Ground corn	200.0	200.0	----
Corn starch	----	----	415.1
Soybean meal, 44% protein	300.0	230.0	----
Isolated soybean protein	----	----	
Fish meal, 62% protein	110.0	70.0	400.0
Alfalfa meal, 20% protein	40.0	40.0	----
Solkafloc (cellulose)	----	----	70.0
Soybean oil	25.0	25.0	37.5
$CaCO_3$	10.0	20.0	10.0[4]
$CaHPO_4 \cdot 2H_2O$	15.0	15.0	
NaCl, iodized	3.0	3.0	[illegible]
$MnSO_4 \cdot H_2O$	0.3	0.3	----
ZnO	0.6	0.6	----
Vitamin mix	10.0[1]	10.0[1]	10.0[2]
Mineral mix[3]			22.9
DL-Methionine	----	----	4.5

[1] Vitamin mix supplied (in mg): menadione, 2; riboflavin, 6; niacin, 40; calcium pantothenate, 10; folic acid, 0.5; vitamin B_{12} 10 pg; choline chloride 800; BHT, 1000; vitamin A, 4000 I.U.; vitamin D_3, 1500 I.C.U., vitamin E, 40; balance starch.

[2] Supplied (in mg): menadione, 10; riboflavin, IO; thiamin HCl, 10; pyridoxine HCl, 10; calcium pantothenate, 30; niacin, 120; folic acid, 5; biotin, 0.4; BHT, 1000; choline chloride, 2500; vitamin B_{12}, 10 pg; vitamin A, 5000 I.U.; vitamin D3, 4500 I.C.U.; vitamin E, 88; the balance starch.

[3] The mineral mix supplied (in mg): NaCl, 9.9; K_2HPO_4, 4.95; $MgSO_4 \cdot 7H_2O$, 3.97; KCl, 3.97; $FeSO_4 \cdot 7H_2O$, 0.644; $MnSO_4 \cdot H_2O$, 0.297; ZnO, 0.12; $CuSO_4 \cdot 5H_2O$, 0.097; $Co(CH_3COO)_2 \cdot 4H_2O$, 0.02; KIO_3, 0.009; $Na_2MoO_4 \cdot 2H_2O$, 0.009; $Na_2SeO_3 \cdot 5H_2O$, 0.00066.

[4] Add 30 gm $CaCO_3$ instead of 10 gm for breeder hens substituting an equivalent amount of starch.

This information has formed the basis for the formulation of diets of a commercial type as well as a purified type that have been used successfully in nutritional studies. Their composition is given in Table 14.

When facilities are lacking for mixing diets, coturnix can be raised successfully on commercial turkey starters. Table 15 gives the body weights of male and female coturnix on this type of a diet up to age 52 weeks.

Table 15. Average body weight of coturnix females and males to 52 weeks of age.

Age (weeks)	Body weight (gm)	
	Female	Male
	7.0	7.0
2	43.3	43.0
6	95.2	91.2
8	130.1	111.2
	142.3	116.5
12	152.0	120.8
20	155.2	122.2
24	161.6	123.8
	[illegible]	127.0
28	158.4	125.3
32	152.8	123.9
36	152.0	124.6
40		
44	1559.5	125.7 125.1
48	163.0	125.8
52	.	128.6

Data based on approximately 100 females and males at start of test.

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XIII. DISEASES

Coturnix have been reported to be susceptible to some of the common poultry diseases. Hill and Raymond (1962) reported a natural infection, avian encephalomyelitis, caused by a virus, in adult coturnix. Coturnix have also been found susceptible to fowl pox, Newcastle disease (B. and Grumbles-Boney strains), and infectious bronchitis viruses, according to Edgar et al. (1964). Those workers also reported that coturnix are susceptible to the following bacterial pathogens- Salmonella pullorum, S. gallinarum, S. typhimurium, Pasteurella multocida, and one pathogenic strain of Escherichia coli. Coturnix are also subject to fungus infections by Aspergillus fumigatus.

Wight (1963) reported that both leukosis and fowl paralysis have been observed in coturnix. Various manifestations of the leukosis complex have been diagnosed in the strain of coturnix at this laboratory (Bigland et al., 1965). A diagnostic survey of 400 individuals at this laboratory showed the coturnix to be subject to many ailments common to other fowl (Table 16).

Table 16. A summary of common ailments and frequency of occurrence in 400 individual coturnix necropsied.

Diagnosis	Frequency
Abscesses	43
Ascites	7
Aspergillosis	2
Candidinsis	11
Coli-granuloma	3
Enteritis	5
Fibrosis	9
Hemorrhage	31
Hepatitis	3
Injury, cannibalism	43
Impaction. emaciation	12
Leukosis .	39
Lymphomatosis	3
Mucopurulent airsacculitis	3
Nephritis	74
Pericarditis	8
Peritonitis	36
Reproductive disorders	39
Salmonella[1/]	30
Sinusitis	8
Staph. infections	10
Salpingitis	8
Tape worms	1
'Tumors	13
Ulcers	1

1/ Salmonella species:

	Reported cases
give	14
anatum	13
infantis	1
london	1
kentucky	1

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