AVIAN SPARE YOLK AND ITS ASSIMILATION

BY ALEXIS L. ROMANOFF

IT is well known that at the time of hatching a bird still retains a portion of unassimilated yolk material. About two days before the embryo is ready to be hatched, a rapid growth and unfolding of the tissues at the umbilicus cause that portion of the yolk which has as yet not been absorbed to be enclosed within the abdominal cavity. After enclosure of the yolk, its utilization goes on as before until, under normal conditions, it has been entirely absorbed. Since the yolk sac is actually a diverticulum of the small intestine, its material is absorbed directly from the sac into the blood stream. The spare yolk, in this manner, is able to supply the developing chick with a store of nutriment which enables it to survive for a limited period after hatching without an additional supply of food.

The rate of assimilation of the spare yolk has been studied primarily in the chick (Virchow, 1891; Iljin, 1917; Schilling and Bleecker, 1928; Parker, 1929; Jull and Heywang, 1930; Romanoff and Romanoff, 1933; Romanoff, 1943; and Fronda, Banez, and Monegas, 1937). Very little is known about the absorption of yolk in other species of birds as well as about changes in its chemical composition following hatching. For this reason the work was extended to include several species of birds and chemical changes in the yolk which, it was thought, might indicate preferential absorption of certain food material.

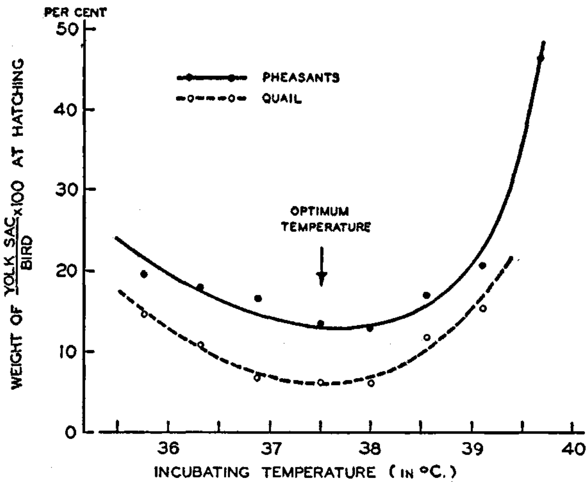
EXPERIMENTAL

Amounts of spare yolk in various species.—In the newly hatched chick the amount of unassimilated yolk material has been variously determined by Iljin (1917) at hatching as 8.19 gms., by Virchow (1891) at 12 hours as 5.34 gms., and by Parker (1929) and Jull and Heywang (1930) at 24 hours as 4.41 gms. and 5.86 gms., respectively. In observations by the author the average yolk-sac weight immediately after hatching was 6.16 gms. in Leghorn and 7.25 gms. in Brahma chicks.

The amount of spare yolk found at hatching in various species of birds is given in Table 1. The weight of the yolk sac varied closely with the weight of the bird. It also varied consistently with the original egg weight; the larger the egg, the heavier the yolk sac. On the other hand, the percentage of yolk weight to bird weight did not show such consistent variation. In general the smaller birds had a lower percentage of yolk weight than the larger birds, the values extending from ten to nearly twenty-five per cent.

The weight of unabsorbed yolk at hatching may vary not only with the species, but also with the idiosyncrasy of the individual, and probably with a number of other factors.

Influence of incubating temperature.—Perhaps the most important external factor influencing the amount of unabsorbed yolk in birds at hatching is temperature. In pheasants and quail (Romanoff, 1934), continued exposure to both high and low incubating temperatures, ranging from 35.5° to 39.5° C., resulted in considerable retention of yolk—the greater the deviation in temperature from the optimum of 37.5° C. the larger the amount of yolk retained (Text-figure 1). At high temperatures

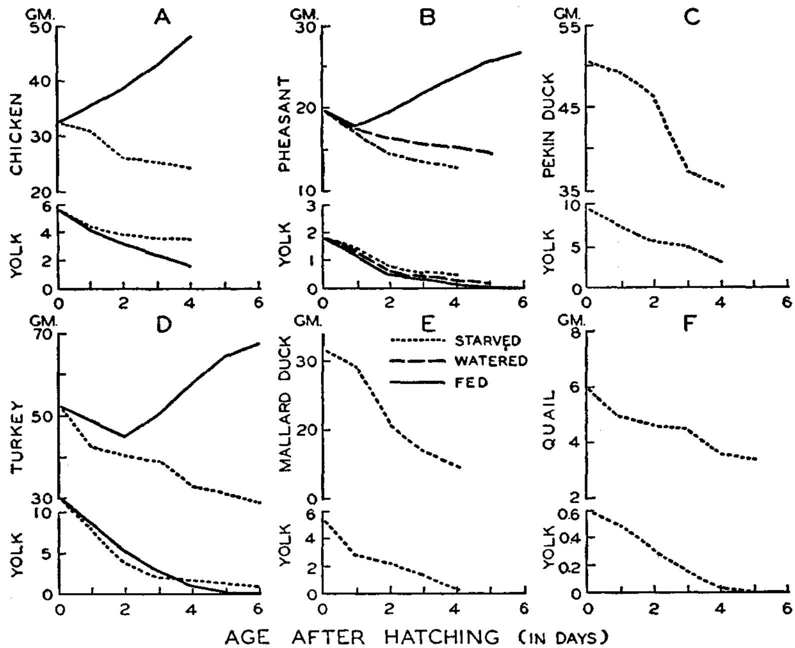


TEXT-FIGURE 1.—Influence of incubating temperature on the amounts of spare yolk at hatching of Ring-necked Pheasants (*Phasianus torquatus*) and Bob-white (*Colinus virginianus*).

the yolk is not efficiently utilized because of the retardation in growth of the embryo and the lowered metabolic rate during the latter part of incubation, while at low temperatures the yolk is large (Romanoff, 1943) owing to an improper physicochemical state of the yolk's contents. The smallest weight of spare yolk undoubtedly is indicative of the greatest metabolic efficiency of the embryo.

Rate of assimilation under feeding and starvation.—Newly hatched birds are known to be able to live for a number of days with neither food nor water, although absorption of yolk material proceeds rapidly after the bird is hatched. The absorption of this yolk is practically complete five days after the bird has hatched, but small remnants of the sac often persist much longer.

None of the birds studied were able to survive the period of starvation in which feed and water were withheld for 120 hours or for five days after removal from the incubator (In practice baby birds are removed from the incubator about 48 hours after hatching in order to allow them to dry off completely). As was expected, the longer the period of starvation, the greater was the loss of body weight.



TEXT-FIGURE 2.—The rate of assimilation of spare yolk after hatching by Leghorn Chickens (*Gallus gallus*), Ring-necked Pheasants (*Phasianus torquatus*), Pekin Ducks (*Anas platyrhynchos*), White Holland Turkeys (*Meleagris gallopavo*), Pekin (*Anas platyrhynchos*), and Bob-whites (*Colinus virginianus*), under feeding and starvation.

In this study the assimilation of the spare yolk was measured in fed and starved birds, including chickens, pheasants, quails, turkeys, and two species of ducks. Fed chicks showed a gain in body weight practically from the time of hatching (Text-figure 2–A), while pheasant chicks and poults showed a slight loss in weight during the first day or two (Text-figure 2–B and D) since they do not take in any food for that period. The weight of starved birds decreased consistently with all species (Text-figure 2–A, B, C, D, E, and F).

The spare yolk was assimilated more rapidly by chicks and pheasant chicks which were fed (Text-figure 2–A and B). In fed poults, the yolk was absorbed more rapidly than in starved birds, only after the third or fourth day (Text-figure 2–D). One group of pheasant chicks, which was supplied with water alone, showed a slow but continual decrease in body weight and spare yolk which was intermediate between the fed and starved birds (Text-figure 2–B).

The yolk of unfed chicks on the fourth day contained a considerable amount of gelatinous material. Also the wings of these chicks resembled long pin feathers while those of fed birds possessed normal wing feathers.

The contents of the yolk sac in the unfed pheasant chicks on the fifth day did not differ from those of previous days. On the other hand, the yolk-sac contents of the fed pheasant chicks became fluid, undergoing a change suggestive of cystic degeneration. With poults, two out of three yolk sacs rotted in unfed birds.

Physicochemical changes with assimilation.—The dry material in the spare yolk decreased more rapidly than the total wet weight, indicating utilization of the actual food material (Table 2). The hydrogen-ion concentration of the spare yolk, in both the chicks and ducklings, gradually changed from neutrality to a slightly acid condition.

Although the actual amount of ether extract decreased after hatching, the percentage weight in relation to the entire yolk did not show any significant change. The refractive index also did not show any appreciable change but the slight increase in iodine number indicates a possible preferential absorption of fatty material by the chick. This agrees with the data of Entenman, Lorenz, and Chaikoff (1940) that show a gradual decrease in percentage of fatty acids in the yolk.

Discussion

It is evident that the amount of the reserve yolk in the bird at hatching may vary according to several different factors. Smaller species of birds have, in general, a lower percentage of yolk weight than larger species (*cf.* Table 1). Also extreme incubation temperatures result in abnormal retention of the yolk (*cf.* Text-figure 1). Jull and Heywang (1930) noted that at hatching time the percentage weight of reserve yolk material varies among different hens as a characteristic of the individual, but it is independent of chick sex.

Studies on the metabolism of the reserve yolk in the chick indicate its completely nutritive function after hatching. There is a rapid absorption of fatty material (*cf.* Table 2) and protein. Entenman, Lorenz, and Chaikoff (1940) determined that at hatching the yolk sac had about 0.5 gm. of fatty acids, while on the fifth day it retained only 0.03 gm. Phospholipid and cholesterol were also absorbed, but in lesser amounts. According to Romenski (1919) the protein in the yolk is rapidly utilized during the 36 hours of starvation after hatching. He showed that during this period the yolk lost 160 mgs. of nitrogen, while the chick's body gained 35 gms.

During five to seven days of starvation, the total loss was from one-third to one-half of the original body weight. It is interesting to note that according to Iljin (1917) there is no change in dry weight of starved chicks. This would indicate that during starvation the bird lives entirely on spare yolk without the destruction of the constitution of the organism. This makes it possible for the bird to maintain normal body functions after a prolonged starvation, without detrimental effects on later life.

There is apparently very little effect of starvation on the rate of absorption of the reserve yolk in the species studied (*cf.* Text-figure 2). Similarly in work by Parker (1929), poisons and extreme brooding temperatures did not change appreciably the absorption rate of the yolk nor the further growth rate of the chick. She also found no correlation between the yolk-absorption rate and the general vigor of the chick. The assimilation is not materially affected either by the quantity of food consumed (Schillinger and Bleecker, 1928, and Parker, 1929) or by cold drinking water (Heywang, 1940).

Although it is apparent that assimilation of the yolk is a fairly regular process despite starvation or feeding, yet in practice, early feeding should not be harmful. In fact, feeding may induce a slightly more rapid rate of yolk assimilation (*cf.* Text-figure 2). Also, starvation may result in high mortality during the brooding period as has been shown by Fronda, Benetz, and Monegas (1937)—the longer the period of starvation, the higher the rate of mortality. This is presumably due to inadequacy of spare yolk in some chicks which early reach a critical stage of starvation. It is not advisable, therefore, to withhold feed and water from newly hatched birds longer than necessary after removal from the incubator.

CONCLUSIONS

From the study of several species of birds it was found that the relative amount of spare yolk at hatching varies with the size of the egg, being smallest in species laying small eggs and much larger in birds laying large eggs.

Much greater amounts of spare yolk were retained in birds hatched under extreme temperatures.

The average rate of assimilation after hatching was fairly identical in both fed and starved birds, although the individual variation was high.

Physical and chemical studies of spare yolk during assimilation show some changes in fats, indicating their preferential absorption.

TABLE 1

AMOUNTS OF SPARE YOLK FOUND AT HATCHING IN VARIOUS SPECIES OF BIRDS

Species of Birds	*Birds observed*	*Original egg weight*	*Weight of bird without yolk sac*	*Weight of yolk sac*	*Yolk sac / Bird × 100*
	number	*grams*	*grams*	*grams*	%
Bob-whites (*Colinus virginianus*)	6	9.0	4.95	0.49	9.9
Ruffed Grouse (*Bonasa umbellus*)	189	18.0	11.40	1.56	13.7
Ring-necked Pheasants (*Phasianus torquatus*)	11	32.0	14.10	1.84	12.7
Jungle Fowl (*Gallus gallus*)	5	35.0	21.07	2.59	12.3
Guinea Fowls (*Numida meleagris*)	2	40.0	27.91	4.00	14.3
Mallards (*Anas platyrhynchos*)	8	58.0	30.81	5.66	14.6
Leghorn Chickens (*Gallus gallus*)	67	60.0	32.34	6.16	19.0
Brahma Chickens (*Gallus gallus*)	4	64.0	41.63	7.25	14.9
Runner Ducks (*Anas platyrhynchos*)	14	65.0	37.50	8.47	23.9
Pekin Ducks (*Anas platyrhynchos*)	6	80.0	50.99	9.18	18.0
White Holland Turkeys (*Meleagris gallopavo*)	7	80.0	45.48	11.26	24.8
Bourbon Red Turkeys (*Meleagris gallopavo*)	11	85.0	52.47	12.18	23.2
Embden Geese (*Anser anser*)	3	198.0	98.83	21.24	21.5

TABLE 2

PHYSICOCHEMICAL CHANGES IN SPARE YOLK OF THE CHICK

Age after hatching	*Amount*			*Hydrogen-ion concentration*		*Ether extract*				*Fatty acids*†
	Wet	*Dry*		*Chick*	*Duckling**	*Amount*		*Iodine number*	*Refractive index*	
days	*grams*	*grams*	%	*pH*	*pH*	*grams*	%	*value*	$^{n}(D)$	%
0	7.62	4.38	57.4	7.29	7.05	1.33	17.5	73.89	1.468	11.9
1	6.02	3.40	56.5	6.81	6.84	0.89	14.8	77.28	1.471	9.1
2	4.09	2.30	56.2	6.59	6.45	0.67	16.4	79.41	1.471	8.0
3	2.38	1.27	53.4	6.53	6.27	0.38	15.9	85.89	1.473	7.0
4	1.43	0.75	52.4	6.60	6.40	0.21	14.7	88.55	1.475	6.1
5	1.16	0.62	53.4	6.63	6.28	0.22	19.0	85.19	1.475	5.3

* The data on the duckling are included here for comparison with that of the chick.
† The data of Entenman, Lorenz and Chaikoff (1940).

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HISTOLOGICAL STUDY OF THE DIGESTIVE SYSTEM OF THE ENGLISH SPARROW

BY L. J. GIER AND OTTIS GROUNDS

Plate 9

THE available literature shows that little histological work has been done on the digestive systems of birds. The most extensive single piece of literature is that of Calhoun (Calhoun, M. Lois. The microscopic anatomy of the digestive tract of *Gallus domesticus*. Iowa St. Col. Jour. Sci., 7: 261–382, 1933). This paper gives a good review of the previous work.

In the study described below, digestive tracts of ten English Spar-