doubt is partly responsible, as well as the long time required for a thorough course.

The number of scientific students is still on the increase. In most of the other faculties there have been no consistent gains or losses, the decrease in certain universities being made up by a corresponding increase in others. Columbia University still has the largest enrolment in the graduate schools, with Chicago second, Harvard third and Yale fourth. The University of Michigan continues to head the list in the number of law students, followed by Harvard, Minnesota and Columbia in the order named. Although the attendance at the Columbia medical school has suffered a loss of over 100, this university still has the largest enrolment of any of the medical schools enumerated, but is closely followed by Illinois, with Northwestern and Pennsylvania occupying third and fourth places respectively.* As to the scientific schools, Cornell is in the lead, with Yale second, California third and Michigan fourth. Harvard has by far the largest collegiate enrolment and also had the largest summer session last year. As to the relative ranking of the teaching force in the largest institutions, Columbia now occupies first place, with Harvard second, Cornell third and Illinois fourth.

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* The table credits Columbia and Illinois with 669 students each, but in the case of Columbia there are a number of fourth-year college students enrolled in the medical school who do not appear among the 669, but in the primary registration under the college.

VARIATIONS INDUCED IN LARVAL, PUPAL AND IMAGINAL STAGES OF BOMBYX MORI BY CONTROLLED VARYING FOOD SUPPLY.

ONE of the races of the mulberry silkworm, *Bombyx mori,* has been the subject of experiments directed toward a determination of the exact quantitative relation which quantity and quality of food bear to the development and variations of the individual insect and its progeny. Such an experiment, on the face of it, might seem to be a laborious task having no further justification than the superfluous, though specific, demonstration of the axiom that the well-nourished are the well-developed. The writers will not hesitate, however, to put on record authentically determined data showing just how definite and constant is the relation for one animal species between varying nutrition and variations. As a matter of fact the experimental breeding and rearing and the accumulation of quantitatively determined data refer to several problems besides the few discussed in this paper. The successive years of breeding have left us at the present moment with a large number, several thousand, of eggs, due to hatch next March, which are the results of selected mating, and of which the ancestors for two or three generations are known, quantitatively described, and preserved for reexamination, if necessary. In addition to the knowledge of the structural and physiological characters (duration of various life-stages, etc.) of these ancestors, the quantitatively determined life-conditions, normal and experimentally varied, are known. These thousands of the fourth generation should afford us exact evidence, for this animal species, touching the prepotency of sex, of sports, of particular characters and of vigor, as well as evidence regarding fertility in relation to age, and evidence concerning genetic and physiological selection.

The present statement is limited to an outline of the results of only those experiments relating directly to the influence exerted by varying conditions of food supply.

The insect, *Bombyx mori,* has a complete metamorphosis, taking no food as an adult, so that the experimental control of the feeding has been necessary only during the larval or 'silkworm' stage. The larval life is subdivided into five stages clearly set off from one another by the intervening moults, of which there are normally four, and these substages have been useful when an alteration of food conditions during a sharply defined shorter time than the entire larval life was desirable.

The change in quality of food has consisted in a substitution of lettuce for the silkworm's proverbial mulberry diet. The change in quantity of food has consisted in altering the amount of mulberry served to the larvæ, the control of which has been secured as follows: It has been determined through experience with normal larvæ that each will consume a certain amount of food in a certain number of hours (increasing in amount with the increasing age and size of the larva), this amount representing the optimum amount of food for the normal individual and necessitating as many daily meals as are required to keep any but the moulting larva constantly supplied with fresh food. This amount determined, a tolerably definite small proportion of the optimum amount has been allotted the individuals which were sentenced to short rations, which, roughly speaking, might be listed as one quarter the optimum amount during earlier stages and one eighth during the late larval stages. This one fourth, one eighth or whatever it may have been numerically, was, at any rate, as small an amount of food as was compatible with mere life. Our object was not that any of the larvæ should die of starvation, but that they should live to tell the tale of the results of diminished nourishment. This difference in feeding was not regulated by lengthening the intervals between meals, but by giving the under-fed but a scanty share of the quantity afforded the well-fed individuals at each meal. There were no intervals between the meals of the well-fed, whereas there were lengthy intervals between the meals of the under-fed, because the under-fed very promptly ate their allotments and were, therefore, without food during the remainder of the interval preceding the next feeding time.

These experiments have extended over a period of three years, covering as many generations of the insect. The data gathered (being the measurements, weight and duration of each larva in each of its five stages; the time of spinning, weight of silk and weight and duration of each pupa; and the weight, size, pattern and fertility of female of each imago) furnish material, then, for a study of the effects of underfeeding upon individuals during a single generation (the 1903 generation or that of 1902 or 1901), during two successive generations (1901–02 or 1902–03), and two alternating generations (1901, 1903) and during three generations (1901–03), a control lot having been carried for each experimental lot so that what is modified may confidently be distinguished from what is normal.

The practice of isolating the larvæ individually has been observed for some of the lots of 1901 and for all the individuals in all the lots of 1902 and 1903. The necessity for such an arrangement will be appreciated by making comparison of a lot of isolated individuals with a lot of individuals getting a living in a single tray where competition became a factor, the amount of food per capita being identical for the two lots.

In 1901, two lots, each consisting of twenty larvæ, were reared on very short rations, the first lot having its individuals isolated, the second having all of its individuals in a single tray. The amount of food per capita allowed these two lots was identical—an amount calculated to produce dwarfs. After the second moult, when the larvæ were about nineteen days old, we found the first lot very uniform and the second very unequal in size, the difference between the heaviest and lightest in the first lot being 19 mg. as against 45 mg. in the second. To the second lot belonged the smallest individual among the season's entire generation of worms, while, on the other hand, this competitive lot boasted one precocious individual weighing more than the average among other lots of well-fed worms, holding, indeed, third place among the 'heavy weights' of the season.

The records of size, when these larvæ had finished feeding and were ready to spin, show the final results of the competitive and non-competitive life of the under-fed lots: in the first lot, with the individuals isolated, the difference in weight between the largest and smallest was 229 mg., in length 8 mm.; in the second, with the individuals together and competing, the difference in weight was 901 mg., in length 22 mm. These figures speak for themselves and offer a pretty illustration of the non-combative but equally strenuous struggle for existence which occurs when an inadequate food supply results in a struggle between closely allied and hence competing forms, to the prosperity of some and the decline of other members of the species thus divided against itself.

A second reason for isolating the larvæ individually is that individual records extending over long periods of time are not otherwise possible. The data consist of individual records concerning Characters, in part enumerated below, of 630 individuals of *Bombyx mori* belonging to three generations (1901–03).

The studied characters which are pertinent to the present discussion may be listed as follows:

1. Those relating to *size* as indicated by weight of larva, of the cocooned pupa, of the cocoon or pupa alone and of the adult upon emergence.

2. Those relating to the prompt performance and normal occurrence of physiological functions such as the moulting and spinning of the larva and the emergence of the adult.

3. Fertility in so far as it is indicated by the number of eggs laid.

4. Mortality among the variously nourished lots as indicated by the death rate.

Some generalizations already reached through the study of the data may be briefly summarized as follows:

1. As to the substitution of lettuce for mulberry as silkworm food, the experiment has been tried only with the generation of 1903, and that on a rather small scale. The 'worms' have adapted themselves to this change of diet to the extent of living successful individual lives and of producing eggs which bear all the earmarks of fertility, that is, have gone through the normal change of color from yellow to gray, the result of beginning development. The eggs will not hatch until March, 1904. The young larvæ adopted the unusual diet very reluctantly, but in later life these same larvæ, 'educated' to its use, ate lettuce with a relish which would rival that displayed by the normal larva with its mulberry leaf.

The most striking variation induced by this lettuce regimen was that the time consumed by the metamorphosis was double the time appointed for that of the normal mulberry-fed larva—being three months as compared with six weeks for the latter. In the commercial world this fact would offset the advantage of the lettuce, as a cheaper food and as one available at all seasons, by demanding twice the labor that is required to rear to spinning time larvæ fed on mulberry. Thus it appears that the lettuce experiment can not be of economic value to sericulture unless it should prove that lettuce-made silk is worth the cost of double labor.

The other variations noted among the lettuce-fed 'worms' have to do with the larva and cocoon. All of the lettuce-fed larvæ appeared to be unusually 'thin skinned,' the body wall being stretched and shiny. The larvæ were at all stages characteristically heavier than mulberry-fed larvæ, each of them weighing at spinning time as much as, and two of them weighing 400 mg. more than the heaviest of the mulberry-fed. The weights of the cocooned pupæ were somewhat above the average among the mulberry-fed, a fact due to the large pupa rather than to the amount of silk in the cocoon, as was demonstrated by weighing cocoon and pupa separately, whereupon it was found that the cocoon was, on the average, but one half as heavy as that of the average among the mulberry-fed, in some cases falling as low as two fifths of the mulberry cocoon's average weight, and in no case rising above three fifths. The silk appears to be less strong and elastic than that of the mulberry-made cocoon.

2. In the mulberry-fed worms there exists a very definite and constant relation between amount of food and size as indicated by weight, the starveling individuals being consistently smaller than the well-nourished, the lingering effects of this dwarfing being handed down even unto the third generation, although the progeny of the famine generation be fed the optimum amount of food; in case the diminished nourishment is imposed upon three or even two successive generations there is produced a diminutive, but still fertile, race of Lilliputian silkworms whose moths, as regards wing expanse, might join the ranks of the micro-Lepidoptera almost unremarked.

In illustration may be quoted the typical or modal larval weights for each of the lots of 1903 at the time of readiness to spin, which marks the completion of the feeding and is, therefore, an advantageous point for a summary of the results of the three years' experimental feeding.

The history of the eight lots referred to may be gathered from an examination of the accompanying table, in which 'O' means optimum amount of food and 'S' means short rations. The column to the right indicates the relative rank of the various lots as judged by the modes of frequency polygons erected to include all the individual weights for each lot at spinning time.

Lot Number.	History of Lots.			Modal Rank. 1903.
	1901. Grandparents.	1902. Parents.	1903.	
1	O	O	O	1
2	O	O	S	6
3	O	S	O	3
4	O	S	S	7
5	S	O	O	2
6	S	O	S	5
7	S	S	O	4
8	S	S	S	8

We find that control lot 1, consisting of normally fed individuals of normal ancestry, holds first rank in weight, as was to be expected. Second comes lot 5, whose grandparents experienced a famine but whose parents as well as themselves enjoyed years of plenty. Lots 2 and 3 have likewise had one ancestral generation on short rations, and the fact that they are lighter in weight than lot 5 illustrates a general rule which obtains throughout the entire company of experimental worms, namely, that the effects of famine grow less evident the further removed the individuals are from its occurrence in their ancestral history. Thus lot 5 is two generations removed from the famine of 1901, while lot 3 has had but one generation in which to recover its ancestral loss. Lot 2, which has had a total of but one famine year—the current year—nevertheless ranks below lot 7, which has had two famine years in its ancestry succeeded by plenty during the current year. Lot 2 also ranks below lot 6, a fact which appears strange, considering that lot 6 has suffered two generation of famine, including the current year, which is the only famine year experienced by lot 2. In explanation of this anomalous condition it is suggested that possibly the larvæ of lot 6 were better fitted for enduring and making the best of hard conditions than were the individuals of lot 2, the ancestors of the former lot having been selected two years ago on a food-scarcity basis. This suggestion gathers support from an inspection of the mortality notes, from which it appears that the number of deaths —for which the famine was probably a contributing and not a primary cause—in each lot which is for the first time subjected to short rations is almost doubly greater than the number of deaths in lots which are descended from starved ancestors, whether these ancestral famines occurred in successive or alternate years. The figures indicate that a reduction of food is almost twice as destructive upon the first generation which is subjected to it as it is when visited on a second generation. Lot 4 follows lot 2 as the seventh in rank and its position is in accord with the rule above noted, its latest ancestral generation which enjoyed an optimum amount of food having been grandparental, whereas the ancestors of all the other lots except lot 8 have had the optimum amount of food during 1902 or 1903. Lot 8 holds lowest rank, it and its ancestors having been subject to trying conditions throughout the entire three years, during some one or two of which all the other lots have enjoyed the best of food conditions. Thus it appears that a generation of famine leaves its impression upon at least the three generations which succeed it, yet the power of recovery through generous feeding exhibited by the progeny of individuals subjected to famine is so extensive (witness lot 5) that it appears probable that every trace left by the famine upon the race would eventually disappear. It is even conceivable that the ultimate result of the famine would be a strengthening of the race, the famine having acted the part of a selective agent, preserving only the strong.

But although there is a large difference between the well-fed and the poorly fed, there persists, more obviously in late than in early life, a very considerable discrepancy as to size among the individuals of each single lot whose environment, in so far as food, temperature, room, humidity, etc., constitute it, is identical.

For example, referring again to the weights at spinning time of the larvæ of 1903, it is true that although each lot has a modal class of weights to which the majority of its individuals belong and about which the rest of the lot distributes itself rather symmetrically, the extremes are surprisingly distant from one another. Thus in lot 1 (the normal control lot) the extremes are 1,540 and 2,530 mg.; in lot 2,* 800 and 1,402 mg.; in lot 3, 1,180 and 2,170 mg.; in lot 4, 690 and 1,204 mg.; in lot 5, 1,370 and 2,100 mg.

That is to say, identical feeding has not made identical full-grown larvæ out of individuals which undoubtedly varied *congenitally* at the start, those variations—in embryo—standing at birth in the same relation to one another that they stand in the adults, having merely been *smaller* and less readily discernible in early life, although manifestly present in delicately measurable degree in the earliest records made upon normal individuals. For example, weight measurements taken immediately after the second moult range in one lot from 21 to 39 mg., or 60 per cent. of the modal weight, while the weights in this same lot at spinning time,

* See table, page 746, for the history of each lot.

some five weeks later, range from 534 to 2,080 mg., or 85 per cent. of the mode for the lot. These embryonic but potentially large variations have simply 'grown up' along with the insect and are as truly congenital in the adult as they were in the newly hatched larva. This would seem to place quite conclusively in the category of congenital variations some part of those variations (in size and proportions of parts) which are commonly, and properly to some degree, called acquired.

while the third lot was twenty-four hours behind the second. All the individuals of the first lot had finished moulting on April 20, all of the second on April 24, while the moulting in the third lot continued until April 29.

As in the matter of weight, this retarding of the functions, by means of a reduced food supply, affects not only the immediate generation which is subjected to the famine, but the lingering effects of it may be traced in the progeny of the dwarfed individuals

Lot Number.	History of Lots.			Rank of 1903 Lots as to Promptness in Spinning.			
					When Two-thirds of Each Lot were Spinning.		
	1901. Grandparents.	1902. Parents.	1903.	Earliest Spinner.	Date.	In Order of Rank.	Latest Spinner.
1	O	O	O	1	May 12	1	1
2	O	O	S	5	" 25	4	4
3	O	S	O	2	" 13	2	3
4	O	S	S	4	" 26	5	5
5	S	O	O	3	" 13	2	2
6	S	O	S	6	" 29	6	7
7	S	S	O	6	" 22	3	5
8	S	S	S	7	" 30	7	6

3. That conditions of alimentation bear a directive relation to functional activity may be demonstrated by reference to the records of the physiological functions of moulting, spinning, pupating and emerging, of the individuals of the experimental lots.

An abnormal extension of the time needed for the metamorphosis follows upon a reduction of the food supply. The degree of extension depends with the utmost nicety upon the amount of food given the larvæ. For example, among the 1901 generation of silkworms, one control lot of twenty larvæ was given the optimum amount of food, a second lot of twenty larvæ one half this amount, and a third lot of twenty larvæ one quarter of the amount. To take the time of the fourth moulting as an illustration, the moulting was begun by the first lot, which led the way by two and a half days, at the end of which the second lot began to moult,

at least unto the third generation, even though two years of plenty follow the one year of famine. The conditions which obtain in each lot of individuals of the 1903 generation at spinning time are shown in the accompanying table, which is based upon polygons erected to include all the individuals in each lot.

This period in the life of the silkworms is particularly advantageous for consideration here because it marks the completion of the feeding, so that the individuals of under-fed ancestry have been given the best chance to recover, while those subject to altered food conditions have had the benefit of the alteration during the entire food-taking period of life.

In the table 'O' means optimum amount of food and 'S' means short rations. To the right of the history of the lots is a section showing the rank of the lots as to the extreme time limits of the spinning time (emphasized congenital differences again), with a safer criterion, as to their relative promptness, in the column between the extremes—a column of figures intended to show the relative promptness with which a two thirds majority of the larvæ in each lot arrives at the spinning time, this proportion being taken to represent the typical condition for the lot. The order in which the lots are arranged in this column corresponds in a general way with that prevalent for the weights at spinning time, and the generalizations indulged in there may with few exceptions be applied here. The lots which were well fed during the 1903 generation are ahead of all of those given short rations in 1903, whatever ancestry they may have had. Lot 1 leads here as in the matter of weight. Lots 3 and 5 tie for second place, having held second and third places in weight. Lots 2 and 4 stand in the same relation to one another that they held as to weight. Contrary to the weight relation, lot 6 follows lot 2 at the spinning—a fact which illustrates again the general rule that two generations of famine are more disastrous than one, but does not lend support to the notion of natural selection on a food scarcity basis as previously suggested. Lot 8, which has had no relief from famine during the entire three years, brings up the rear at the spinning, as might be expected.

This check upon functional activity exercised by diminished nourishment affects the moulting, the time for the commencement of spinning and the issuing time for the adults, but the time spent in the spinning of the cocoon, from its beginnings in the threads of the supporting net to its apparent completion when the cocoon becomes opaque, is practically identical for under-fed and well-fed individuals. A reason for this exception to the tardy habits of the under-fed is to be found in the fact that the under-fed larvæ produce less silk (less in size, thickness and weight) than the well-fed, thus accomplishing more meager results in the same amount of time. That the individuals sentenced to short rations should produce less silk than their well-fed neighbors is certainly to be expected, silk not being made without leaves any more readily than bricks without straw.

4. Not only do short rations protract the time appointed for the spinning, moulting, etc., but they appear to have a more striking effect upon the actual occurrence of the moulting. The normal number of moults for the silkworm larva is four. Five moults have occurred for most of the individuals belonging to the under-fed lots of 1902 and 1903, whereas none of the well-fed individuals has undergone a fifth moult. It would seem, therefore, that the occurrence of a fifth moult may be fairly ascribed to a reduction of food; at least a fifth moult very frequently accompanies it and has suggested the possibility that the enforced fasting of the under-fed larva—in the intervals between meals—may have the same physiological effect as the normal fasting which precedes the normal moulting, during which time the so-called 'moulting fluid' is secreted. That this effect may accumulate throughout the lifetime of the larva until the larva is actually forced to indulge in the extravagance (of strength, feeding time and body wall material) of an additional moult is conceivable and will justify a further test.

5. As to the life and death selection due to famine, it may be said, in addition to the previous discussion of mortality among the experimental silkworms, that while lots subjected to two years of famine (themselves in one year, their parents in the year before) were fertile in so far as number of young hatched is concerned, it was found to be exceedingly difficult to rear from them a 1903 generation. Indeed, at the time of the second moulting there were but

nineteen individuals (and tolerably vigorous larvæ they were) alive in the lot which had experienced two years of famine, although every individual of the 149 hatched was carefully preserved and royally fed —a fact which goes to prove that the equipment at birth of many of these larvæ was inadequate.

The fact that some larvæ of starved ancestry have exhibited a superiority over their fellows, in surviving and recovering from hard conditions, is testimony for the existence of individual variations which can not be defined anatomically, and yet which serve as 'handles' for natural selective agents. Such variations might be called physiological variations, since it seems that the surviving larvæ must be those which are in best trim physiologically. These larvæ are able to make the most of the food offered to them. If competition were allowed, they would probably be the individuals which would cover the area most rapidly, securing whatever food there might be. But under our experimental conditions there was no competition allowed and yet certain precocious individuals made more grams of flesh and more yards of silk, than other larvæ furnished with the same amount of raw material under like conditions; that this was due to the possession by the former of certain congenital qualities of adaptability can scarcely be doubted.

6. As to the fertility of the variously fed lots; in so far as number of eggs produced is a measure of fertility, our records already demonstrate the fact that the better nourished are the more fertile. Furthermore, the economy in this matter practised by the starvelings is not merely numerical, quality as well as quantity of eggs being affected. In witness of this point may be recalled the story of the dying 1903 generation, produced from eggs of the starvelings of 1901 and 1902, which would seem to offer conclusive evidence that a famine suffered by the parents works its way into the germ cells so that most of their progeny have but a poor birthright.

A more exhaustive study of silkworm fertility and its correlation with anatomical variations and physiological vigor has been begun, and when it is carried to the point of indicating not only how many eggs are laid but how many eggs develop through larval and pupal stages into fertile adults, some clear light may be thrown upon such questions as that which arises concerning the precise ancestry of the survivors of our induced famine and the part these survivors will play in race history.

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SCIENTIFIC BOOKS.

RECENT PSYCHOLOGICAL LITERATURE.

The lack of an adequate history of the remarkable developments in psychology during the last quarter century has been keenly felt in many directions and not least by the psychologists themselves. The task of supplying this need is peculiarly difficult. For its successful accomplishment one must possess not only the rare gift of lucid and accurate exposition, but one must also be a competent philosophical scholar, with a considerable knowledge of biology in addition to a wide and exact acquaintance with the many phases of psychology itself. The fulfillment of these trying requirements has been in effect essayed by Guido Villa, of the University of Rome.* His book is not entitled a history, but in substance it is such, being an effort to give, in connection with comments upon the work of various authors, a correct impression of the general drift of contemporary psychology.

It must be admitted that the book is superior to anything else at the moment available. It represents an immense amount of patient en-

* 'Contemporary Psychology by Guido Villa' (translation by Harold Manacorda), Swan Sonnenschein & Co., London, 1903, pp. xv + 396.