All reflex time experiments were made and the records read in ignorance of the results from the intelligence tests. Also fifteen records were selected at random and read by a disinterested person. The agreement between the two readings was practically perfect.

The mean reflex time of the forty-four Otis cases was .0194 seconds. The range was from .0114 to .0268 seconds. The mean reflex time of the forty-three university freshmen was .0197 seconds. The range was from .0154 to .0245 seconds.

Each group gave a fairly normal distribution in reflex time. The great individual differences in reflex time are considered as very important. It varied from 11/1000 to 27/1000 of a second. In other words conduction over a reflex arc in one individual was two and a half times as fast as conduction over the same reflex arc in another individual.

These marked differences in reflex times found in our groups are probably referable to differences in synaptic resistances in the arcs and not to differences in resistance of the nerve trunks. Just how much of the nervous system is involved in the patellar tendon reflex is a debated question, but a recent study by the writer[3] showed that the action current records during the knee-jerk were practically identical with those during voluntary extension of the foot. Both sets of records gave indication of two different rates of discharge, one furnishing the audio or principal frequency of from three hundred to six hundred oscillations per second, and the other, the modulating inaudible frequency of from eight to twelve per second. This slower rate of discharge is probably from the Betz cells in the precentral cortex and would indicate that the higher centers are involved in the knee-jerk. If this is true we are dealing with a considerably greater number of synapses than is commonly thought of in this connection and a larger fraction of the nervous system as well.

Although the individual differences in rate of conduction in the reflex arc we have been studying are great they take on real significance when viewed in connection with the complicated associational paths of the cerebral cortex which probably function in the higher mental processes.

We are here confronted with a new fact—a fact which has become available by the refinement of technique in measurement. It challenges us to reinvestigate all the generally recognized phenomena of this particular reflex. It opens up an unlimited vista of inquiries into the nature of its cause, the conditions under which it varies, and its meaning in psychological and physiological terms. It is conceivable that we are here dealing with a relatively complex reflex arc—perhaps more complex than has been suspected, and it is fair to assume that it is typical of a large number of reflex arcs which constitute an integrated central nervous system. Now, according to the best modern theories of intelligence the cognitive processes may be thought of as hierarchies of reflexes of which the vast majority are perhaps at as low a level in the central nervous system as that of the patellar reflex. If this is true, we have in the type of conduction through the patellar reflex arc a sample of the type of conduction that takes place in all well organized motor life and possibly, as these facts indicate, also the cognitive. Tests of intelligence have always stressed the element of speed and this is perhaps right, because an intelligent response to a complex situation may conceivably be thought of as a prompt response, radiating into a large number of systems. We may think of the central arcs of an individual as having a personal equation, just as we do in a gross way when we observe one man is quick and another is slow in his movements, even in his thought movements.

Whatever the interpretation through further study may prove to be, we have in this concept of the rate of conduction through a central arc, a new approach to the neuro-physiology of intelligence or mental alertness.

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[3] Travis, Tuttle and Hunter. "The Tetanic Nature of the Knee-jerk Response in Man." *Am. J. Physiol.* 81, 1927, 670.

A COMPARISON OF GROWTH CURVES OF MAN AND OTHER ANIMALS

IN connection with investigations on the time relations of growth of domestic animals, several charts have been prepared on the growth of man. The purpose of this article is to present four of the most striking, or the most instructive, charts together with a few comments. For a background to this work and for details of technique the reader is referred to a series of Research Bulletins which are being published by the University of Missouri Agricultural Experiment Station (Columbia, Mo.).

Figure 1 represents an equivalence chart for growth of man and animals. It represents growth equivalence only for the phase of growth following puberty. This chart serves to illustrate the fact that the difference between the growth curve of man and that of any other animal under consideration is infinitely greater than the difference between the curves of widely separated species of animals. The growth curve of man is, quantitatively viewed, in a class by itself, unless it is found to be related to the curves of other primates. This figure suggests the following comments:

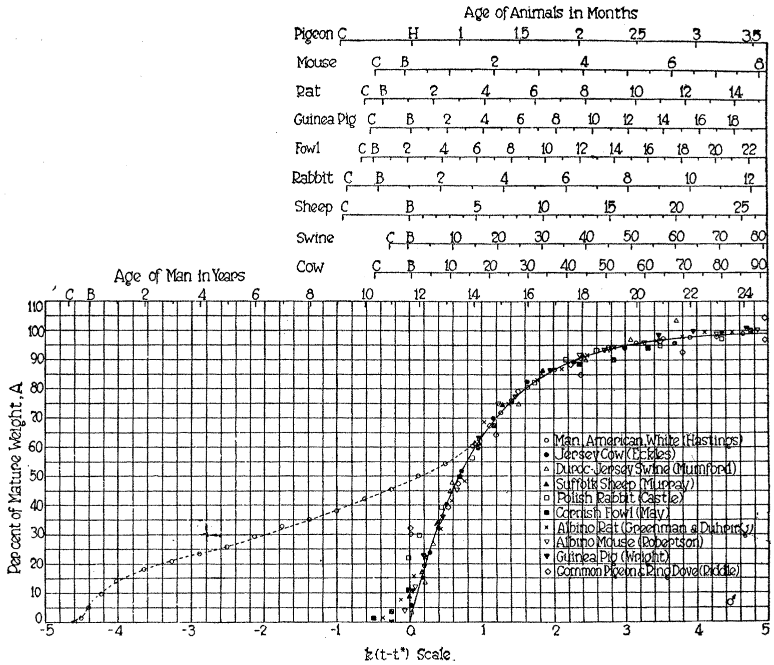

FIG. 1. Growth equivalence during the post-pubertal phase of growth for man and animals. Note that age is counted from birth. For sources of data see Missouri Agricultural Experiment Station Res. Bull. 96 (in press).

1. *The length of the juvenile period.* The length of the juvenile period in man is about 10 years (4 to 14 years). This relatively enormous length of the juvenile period appears to be the most distinguished feature of the growth curve of man.

2. *The position of the pubertal inflection.* In the curve for man, the major inflection (puberty) occurs when the body weight is, roughly, two thirds of the mature weight; in other animals it occurs when the body weight is, roughly, one third of the mature weight.

3. *The post-pubertal phase of growth.* Following the major inflection (puberty) the qualitative course of growth in man and in animals is the same. In both cases the time rates of growth decline by a constant percentage. The numerical value of the percentage decline in the time rates of growth is less, however, in man than in other animals; but the differences are relatively slight. In man it is of the order of 3 per cent. per month; in the sheep, which has the same mature weight as man, it is of the order of 15 per cent. per month. In brief, there are no radical quantitative or qualitative differences between the growth curves for man and other animals during the phase of growth following puberty.

4. *The pre-pubertal phase of growth.* The course of growth during the juvenile, and probably fetal, period of growth is probably qualitatively the same in man and in animals. The time rates of growth tend to increase at a constant percentage rate. There are, however, considerable quantitative differences in this respect. The relatively enormous length of the juvenile period in man as compared to that in animals has

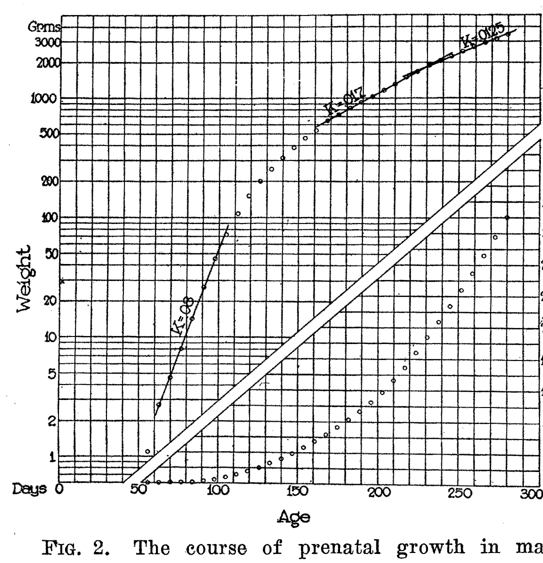

FIG. 2. The course of prenatal growth in man as plotted on arithlog and arithmetic scales. During the third month the rate of growth is about 8 per cent. per day. During the three months preceding birth, the rate of growth varies from 1.7 to 1.3 per cent. per day. The chart was plotted from data published by G. L. Streeter, Carnegie Institution of Washington, Contributions to Embryology, 1920, ix, 143.

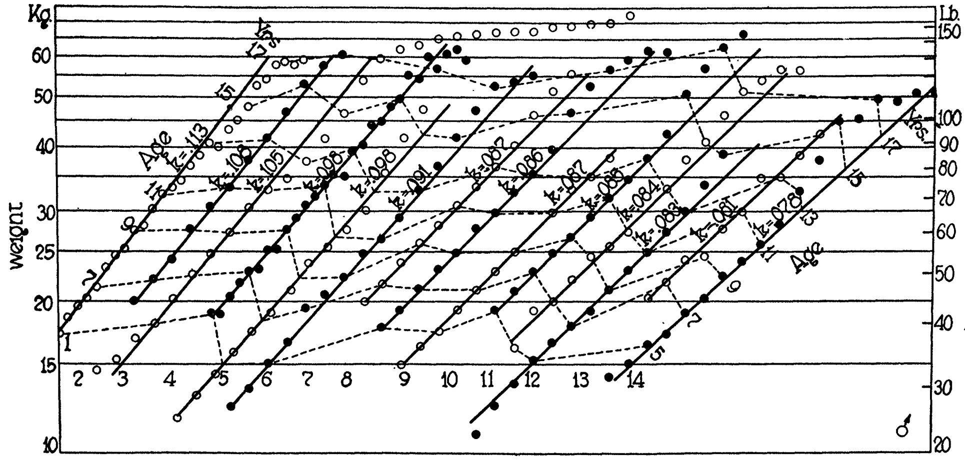

FIG. 3. Chart on an arithlog grid to illustrate the facts that (1) the percentage rate of growth is approximately constant between 4 and 14 years; and (2) that the pubertal acceleration is related to the percentage rate of growth during the earlier phases of the juvenile period. 100 *k* represents the percentage rate of growth per year. The curves are arranged in a descending order of the values of *k*. On the left, where the numerical values of *k* are high, there is no increase in the percentage rate of growth at 12 years; indeed, in curve 1, there is a decrease in the percentage rate at this time. On the right, where the numerical value of *k* is low, there is a very conspicuous pubertal acceleration. The pubertal acceleration may, therefore, be related to the nutritional condition of the child. For the sources of data see Baldwin, B. T., *The Physical Growth of Children from Birth to Maturity,* Univ. of Iowa Studies in Child Welfare, 1921, 1, 188. Curve 1 represents well-to-do American children (column 1 in Baldwin); curve 2, German (column 106); 3, English (c. 54); 4, American (c. 3); 5, French (c. 76); 6, Italian (c. 122); 7, American (c. 39); 9, English (c. 66); 10, German (c. 79); 11, Russian Jews (c. 120); 12, Japanese (c. 127); 13, Russians (c. 115); 14, Japanese (c. 129). The broken lines on the chart connect the points of the same ages.

already been mentioned. Another difference relates to the percentage rates of growth. In man, the percentage rate of growth during the juvenile period (4 to 14 years) is of the order of 0.03 per cent. per day (10 per cent. per year); in other animals, it is of the order of 3.0 per cent. per day (1,000 per cent. per year).

In the fetal period, too, the percentage rate of growth in man is unusually low. Figure 2 shows it to be of the order of 8 per cent. during the three months preceding birth. In the rat, we have found the rate of growth for nine days preceding birth is of the order of 53 per cent. per day. The difference, however, is not so great as for the juvenile period. Again, it is the juvenile period which, quantitatively considered, is the most conspicuous feature of the growth curve of man as contrasted to the growth curve of animals.

5. *The infantile period.* In addition to the juvenile period, the infantile period in man is conspicuous by its differences from the corresponding segment of the growth curve in animals. It appears to show an inflection similar to the pubertal inflection in the curves of animals; but the inflection proves to be abortive. Sometimes between 2 and 4 years after birth the declining time rates of growth are changed into increasing time rates of growth, and practically constant percentage rates of growth. This constant percentage rate of growth often lasts until 15 years. It is this turn of events which principally differentiates the growth curve of man from that of animal.

6. *The pubertal acceleration.* In children there is often an increase in the percentage rate of growth between the age of 12 and 14 or 15 years. Such an acceleration has not been definitely encountered in the growth curves of domestic animals. This acceleration, however, can not be said to constitute a qualitative genetic difference between the growth curves of man and animals, for it is not a universal feature of the growth curve of man. This pubertal acceleration appears to be related to the percentage rate of growth between 4 and 12 years. If the percentage rate of growth for a given group of children is relatively low during the earlier ages, then there is usually an acceleration between 12 and 15 years; if it is high, there is no acceleration. The pubertal acceleration, when present, appears to be in the nature of compensatory growth for an earlier deficiency. Figure 3 illustrates this statement.

It should be said that growth in length takes place at an approximately constant *time* rate when growth in weight takes place at a constant *percentage* rate (Fig. 4). This is evident from geometrical considerations when growth in length is strictly terminal. It is also evident from physiological considerations; con-

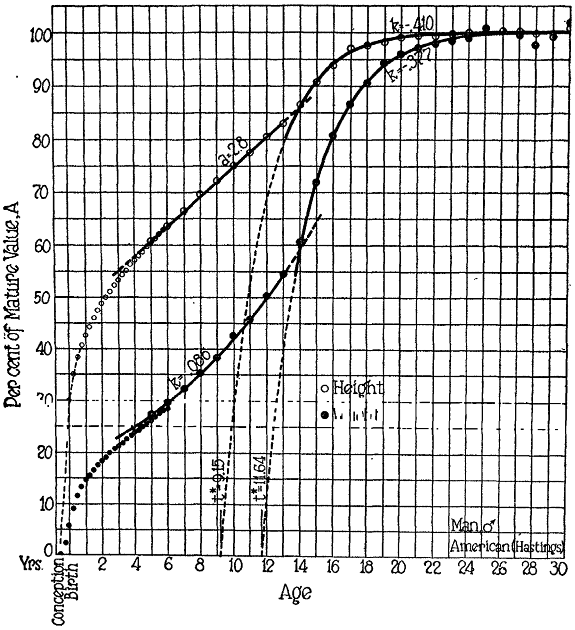

FIG. 4. Weights and heights of man at different ages expressed as percentages of the mature values. While growth in weight between 4 and 14 years takes place at a constant percentage rate (8.6 per cent. per year) growth in height takes place at a constant time rate (2.8 units per year). Data cited by Baldwin.

stant percentage rates of growth in volume and constant time rate of terminal growth both imply that the physiological environment with respect to the growth-limiting process remains constant.

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PROGENIES FROM X-RAYED SEX CELLS OF TOBACCO

IN January of this year two greenhouse plants of *Nicotiana tabacum* var. *purpurea* (U. C. B. G. 27014)[1] in full flower were exposed to moderately hard X-rays. Immediately thereafter all open flowers were removed and the remaining buds trimmed to a series of size classes. Within 48 hours all buds except those in which pollen was formed had fallen. In these larger buds the primordia of female sex cells had been set apart and in the majority the megaspore mother cells were in meiotic prophases or divisions. Seed from 7 capsules produced by selfing the flowers from these larger buds have given some 1,000 plants, which began to flower in July.

At the seedling stages the presence of variant plants was apparent. At maturity over 20 per cent. of the total were striking variants; in one population of some 200 plants there were over 70 per cent. of variant individuals. While it is possible roughly to separate these variants into classes on the basis of total external morphology, no two of them are identical. In estimating individual character contrasts an attempted classification has shown 5 flower color types, 8 flower shape types, 6 habit types, and 10 leaf shape types, with many other less obvious but constant differences in expression as compared with the control. Apart from recessive effects which may appear in subsequent generations, the results of hundreds of larger or smaller changes appear in these progenies. With some marked exceptions, fertility in general parallels extent of total variation—the more abnormal, the more sterile. However, only a very few individuals, if any, fail to produce at least a few viable eggs.

Detailed cytological examination of a number of variant plants indicates (a) that they often are $2n = 48$ as in the control—*i.e.*, that the variants are not solely the result of a disturbance of the meiotic distributional mechanism; (b) at diakinesis, P. M. C. may show lack of ability to pair on the part of one or more pairs of chromosomes, indicating that some decided genetic modification has occurred; (c) that occasional production of 2n pollen grains occurs, possibly as a result of failure of cytokinesis in the archesporium; (d) that their somatic tissues may show nuclear and other abnormalities equivalent to those often described as following irradiation of somatic tissues and thus suggesting that these latter effects may be solely the expression of initial nuclear modification and possibly heritable.

Progenies from these populations and from subsequent X-raying of *tabacum* and other *Nicotiana* species are being grown. Special attention is being given to effects of irradiation on mature pollen, since with such material the X-ray technique may be standardized and simplified. Despite the absence of direct evidence of the heritable nature of the effects produced, the extent and character of the variations in hand, the fertility relations displayed and the cytological information obtained suggest that data, in the case of a plant of economic importance, confirming the results of Muller's X-ray experiments, may be forthcoming.

It is interesting that two similar efforts, one on the animal and the other on the plant side, to accelerate evolutionary processes should have been carried on simultaneously.

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[1] This variety has been grown here in the pure line for many years and has been subjected to genetic and cytological examination in many intra- and interspecific hybrids (*cf. Univ. Calif. Publ. Bot.*, vols. 5 and 11).