GENETICS

AN INTRODUCTION TO THE STUDY OF HEREDITY

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WITH 72 FIGURES AND DIAGRAMS

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THIS VOLUME

IS AFFECTIONATELY DEDICATED

TO

MY MOTHER

PREFACE

THE following pages had their origin in a course of lectures upon Heredity, given at Brown University during the winter of 1911–1912, which were amplified and repeated in part the following summer at Cold Spring Harbor, Long Island, before the biological summer school of the Brooklyn Institute of Arts and Sciences.

An attempt has been made to summarize for the intelligent, but uninitiated, reader some of the more recent phases of the questions of heredity which are at present agitating the biological world. It is hoped that this summary will not only be of interest to the general reader, but that it will also be of service in college courses dealing with evolution and heredity.

The subject of heredity concerns every one, but many of those who wish to become better informed regarding it are either too busily engaged or lack the opportunity to study the matter out for themselves. The recent literature in this field is already very large, with every indication that much more is about to follow, which is a further discouragement to non-technical readers.

It may not be a thankless task, therefore, out of the jargon of many tongues to raise a single voice

which shall attempt to tell the tale of heredity. There may be a certain advantage in having as spokesman one who is not at present immersed in the arduous technical investigations that are making the tale worth telling. The difficulties in understanding this complicated subject may possibly be realized better by one who is himself still struggling with them, than by the seasoned expert who has long since forgotten that such difficulties exist.

Among others I am particularly indebted to Dr. C. B. Davenport for many helpful suggestions, to my colleague, Professor A. D. Mead, for reading the manuscript critically, to Dr. S. I. Kornhauser who gave valuable aid in connection with the chapter on the Determination of Sex, and to my wife for assistance in final preparation for the press.

I wish to thank Professor H. S. Jennings and Dr. H. H. Goddard, who have given generous permission to copy certain diagrams, as well as The Outlook Company and The Macmillan Company for the use of figures 24 and 66, respectively.

The fact that all the suggestions which were at various times offered by my kindly critics have not been incorporated in the text, absolves them from responsibility for whatever remains.

H. E. W.

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CHAPTER I

INTRODUCTION

1. The Triangle of Life

Within a generation the center of biological interest has gradually been swinging from the origin of species to the origin of the individual. The nineteenth century was Darwin's century. His monumental work "On the Origin of Species by Means of Natural Selection," which appeared in 1859, not only dominated the biological sciences but also influenced profoundly many other realms of thought, particularly those of philosophy and theology.

Now, at the beginning of the twentieth century, a particular emphasis is being laid upon the study of heredity. The interpretation of investigations along this line of research has been made possible through the cumulative discoveries of many things that were not known in Darwin's day. Trained students have been patiently and persistently bending over improved microscopes, untangling the mysteries of the cell, while an increasing host of investigators, inspired by the Austrian monk Mendel, have been industriously devoting their energies to

breeding animals and plants with an insight denied to breeders of preceding centuries.

The study of the origin of the individual, which has grown out of the more general consideration of the origin of species, forms the subject-matter of heredity, or, to use the more definitive word of Bateson, of *genetics*.

It is not with the individual as a whole that

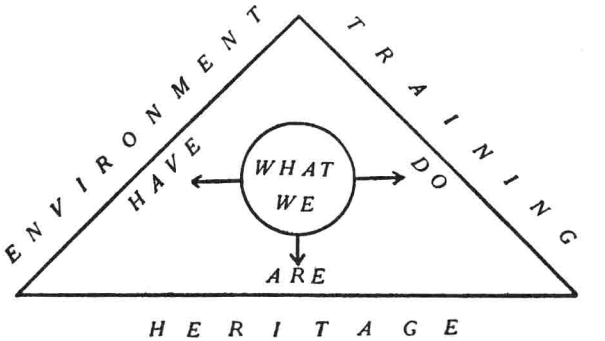

FIG. 1. — The triangle of life.

genetics is chiefly concerned, but rather with *characteristics* of the individual.

Three factors determine the characteristics of an individual, namely, *environment*, *training*, and *heritage* as expressed diagrammatically in Figure 1. It may indeed be said that an individual is the result of the interaction of these three factors since he may be modified by changing any one of them. Although no one factor can possibly be omitted, the student of genetics places the emphasis upon heritage as the factor of greatest importance. Heritage, or

"blood," expresses the innate equipment of the individual. It is what he actually *is* even before birth. It is his nature. It is what determines whether he shall be a beast or a man. Consequently in the diagram (Fig. 1), the triangle of life is represented as resting solidly upon the side marked "heritage" for its foundation.

Environment and training, although indispensable, are both factors which are subsequent and secondary. Environment is what the individual *has*, for example, housing, food, friends and enemies, surrounding aids which may help him and obstacles which he must overcome. It is the particular world into which he comes, the measure of opportunity given to his particular heritage.

Training, or education, on the other hand, represents what the individual *does* with his heritage and environment. Lacking a suitable environment a good heritage may come to naught like good seed sown upon stony ground, but it is nevertheless true that the best environment cannot make up for defective heritage or develop wheat from tares.

The absence of sufficient training or exercise even when the environment is suitable and the endowment of inheritance is ample will result in an individual who falls short of his possibilities, while no amount of education can develop a man out of the heritage of a beast. Consequently the biologist holds that, although what an individual *has* and *does* is unquestionably of great importance, particularly to the individual himself, what he *is*, is far more important

in the long run. Improved environment and education may better the generation already born. Improved blood will better every generation to come.

What, then, is this "blood" or heritage? Exactly what is meant by heredity?

2. A Definition of Heredity

Professor Castle, in his recent book on "Heredity in Relation to Evolution and Animal Breeding," has defined heredity as "organic resemblance based on descent." The son resembles his father because he is a "chip off the old block." It would be still nearer the truth to say that the son resembles his father because they are *both chips from the same block*, since the actual characters of parents are never transmitted to their offspring in the same way that real estate or personal property is passed on from one generation to another. When the son is said to have his father's hair and his mother's complexion it does not mean that paternal baldness and a vanishing maternal complexion are the inevitable consequences.

Biological inheritance is more comparable to the handing down from father to son of some valuable patent right or manufacturing plant by means of which the son, in due course of time, may develop an independent fortune of his own, resembling in character and extent the parental fortune similarly derived although not identical with it.

So it comes about that "organic resemblance"

between father and son, as well as that which often appears between nephew and uncle or even more remote relatives, is due not to a direct entail of the characteristics in question, but to the fact that the characteristics are "based on descent" from a common source. In other words, an "hereditary character" of any kind is not an entity or unit which is handed down from generation to generation, but is rather a *method of reaction* of the organism to the constellation of external environmental factors under which the organism lives.

To unravel the golden threads of inheritance which have bound us all together in the past, as well as to learn how to weave upon the loom of the future, not only those old patterns in plants and animals and men which have already proven worth while, but also to create new organic designs of an excellence hitherto impossible or undreamed of, is the inspiring task before the geneticist to-day.

3. The Maintenance of Life

So far as we know, every living thing on the earth to-day has arisen from some preceding form of life.

How the first spark of life began will probably always be a matter of pure speculation. Whether the beginnings of what is called life came through space from other worlds on meteoric wings, as Lord Kelvin has suggested; whether it was spontaneously generated on the spot out of lifeless components; or whether life itself was the original condition of

matter, and the one thing that must be explained is not the origin of life, but of the non-living, no one can say. Leaving aside the first speculation as untenable and the third as irrational, since it jars so sadly with what astronomers tell us of the probable evolution of worlds, the theory of spontaneous generation seems to be the last resort to which to turn.

In prescientific days this idea of spontaneous generation presented no great difficulties to our imaginative and credulous ancestors. John Milton, with the assurance of an eye-witness, thus described the inorganic origin of a lion: —

> "The grassy clods now calved; now half appears
> The tawny lion, pawing to get free
> His hinder parts — then springs as broke from bonds,
> And rampant shakes his brindled mane."
>
> ("Paradise Lost," Book VII, line 543.)

Ovid also in his "Metamorphoses," not to mention a more familiar instance, easily succeeded in creating mankind from the humble stones tossed by the juggling hands of Deucalion and Pyrrha.

Although under former conditions on the earth it might have been possible for life to have originated spontaneously, and although it may yet be possible to produce life from inorganic materials in the laboratory or elsewhere, the exhaustive work of Pasteur, Tyndall and others effectually demonstrated a generation ago that to-day living matter always arises from preceding living matter and this conclusion is generally accepted as an axiom in genetics.