# The Relation of Biology to Physics

*Biology—Physics*

THOMAS H. MORGAN, in *Bulletin of the California Institute of Technology*:

I should like to illustrate the need of physical knowledge in biological work by a few very simple examples which, in a general way, are familiar to you, yet will serve, I hope, to bring home the need for the cooperation for which I am pleading.

The egg is a cell, and the first step in development is taken when the egg divides into two parts. Cell-division is one of the most general phenomena of living things. The first indication of division in a living egg is a constriction that appears on the surface, which gradually spreads and encircles the egg. It cuts into the interior until two hemispheres result that flatten against each other. After a pause of less than an hour, a new division appears at right angles to the first, dividing the material into quadrants.

This process continues until a thousand or more cells may be produced before any of the embryonic organs are laid down. Our microscopes reveal, even in a transparent egg, only a small part of what is happening inside the egg. By means of an elaborate technique the interior changes have been made out. This technique consists in staining the substances of the egg in various stages of division. The exploration of the interior is further carried out by cutting the egg into hundreds of thin slices—as many as five thousand to an inch. Such sections show in the middle of the egg an inner sphere, or nucleus. The walls of the nucleus dissolve just before division is to take place, and a number of tiny rods or chromosomes reveal themselves. There is a characteristic number of these for each species of animal or plant. Moreover, they often differ in shape and size. Whenever differences are present we find that there are two chromosomes of each size or shape.

The next step is the appearance of a spindle-shaped figure near the chromosomes. Into the middle of the spindle the chromosomes move, or are carried, and there they arrange themselves in an equatorial plate.

Even before this time we discover a clear line running through the length of each chromosome. Each has split throughout its length and two daughter halves are present.

Each half of each chromosome then moves to one pole and its sister half to the opposite pole.

It is about this time that the constriction appears on the surface of the egg. As it deepens it cuts through the middle of the spindle separating the daughter chromosome groups from each other.

Around each group of chromosomes a fluid accumulates, and the chromosomes begin to lose their staining property. Suitable stains reveal that each chromosome becomes branched and the branches have the appearance of forming a network in the new nucleus that is now formed.

A resting stage of about half an hour follows, and then the same process repeats itself—the nucleus wall in each cell disappears, the chromosomes reappear, a spindle develops, the chromosomes again split lengthwise into daughter halves.

I have given the briefest outline of the process of cell-division that is described in every textbook of biology. What does it all mean? What, to begin with, causes the constriction to appear on the egg at the moment when the chromosomes have alredy divided and separated? The division of the cell impresses us as a simple physical phenomenon. Many attempts have been made to account for it, but none are satisfactory, because, I think, we do not know as yet enough of the physical constitution of the materials of the egg to permit more than provisional guesses.

This, however, is only the first problem that presents itself! What makes each chromosome split lengthwise? The chromosomes are too deeply imbedded in the egg for us to invoke external agents. It must seem that some sort of a molecular event is taking place, whose nature is entirely unknown to us, and yet, who will doubt that it, too, may be a very simple physical process?

How do the chromosomes reach the equator of the spindle? What moves the daughter halves to opposite poles? When they reach the poles, why do they undergo a reverse series of changes and pass once more into a resting stage? What are they doing while resting? Probably each is growing to its original size, but what is the nature of this growth? Here we meet with a dozen questions, all calling aloud for answers. It seems that no one but a physicist can hope to solve them.

There is another important question connected with the chromosomes for which we have no answer: I refer to the union of conjugation of the chromosomes that takes place once, and once only, in the cycle of the life of each individual organism.

When the germ-cells, that is, the egg-cells and the sperm cells, after having passed through many ordinary divisions (such as I have just described), reach their final stage of maturity a strange thing happens. Although the chromosomes have remained apart through a long series of cell-divisions, now they come together in pairs.

The two members of each pair approach each other and come to lie side by side. It looks as though they had fused and reduced the visible number of chromosomes to half the original number. But we have many reasons for thinking that they do not fuse but only lie closely apposed.

There is another fact connected with this union of like-chromosomes that was at first wrongly interpreted: One member of each pair has come from the father of the individual, the other from the mother. It was supposed, wrongly as I have said, that the conjugation of the chromosomes had something to do with their origin—in a word, that they mated because one had come from a male, the other a female.

Now we know that this is not the cause of their union, but that they mate because they are like each other—in fact, they may be identical. Here is a fine opportunity for metaphysical discussion, but I like to think rather that the event is purely physical, even although I must confess that we do not know what kind of an attraction draws like-chromosomes together, and not even if it is an attraction.

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A European invention is an alarm clock which wakens a deaf sleeper by bouncing a rubber ball on him.

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Pecos, one of the largest pueblos in the southwest, was founded about 800 A. D. and was occupied for about 1,000 years.