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Introduction

In a previous article, science and how science operates was discussed from a philosophical point of view. In this article, the history of the Germ Theory of Disease (and hence a large part of the history of microbiology) is discussed from the philosophical perspective presented in the first article. The history presented in this article is not intended to be definitive but rather to view the history of the Germ Theory of Disease from a different perspective.

The Humoral Theory

Prior to 500 B.C. there was no single view (paradigm) to explain disease. Most of the explanations of how diseases were caused involved demons and other supernatural powers. The demonic explanations for the origin of disease, however, failed to satisfy the enlightened Greeks of 500 B.C. It became clear to them that disease processes were governed by natural laws. A leading Greek physician at this time was Hippocrates (460-377 B.C.). Hippocrates developed the humoral theory of disease.

According to this theory, a proper balance of our humors--blood, phlegm, yellow bile, and black bile--was characteristic of good health. If this balance was disturbed in any way, disease appeared. Treatment required restoration of the proper balance of the humors. Hippocrates believed that nature would restore this balance if the patient were given rest, food, and care. Some practitioners of the humoral theory thought that nature could be helped to restore the balance of the humors by blood letting. This practice persisted for centuries; in fact, George Washington was bled with leeches during his terminal illness. Many deaths may have been hastened by this procedure, the opposite of today's practice of giving blood transfusions to strengthen the patient!

The humoral theory of disease guided the practice of medicine for nearly two thousand year. As a theory, it was vulnerable to change. Before its overthrow, two related events took place. The first was the emergence of the cell theory and the second was the overthrow of the theory of spontaneous generation by the biogenesis theory.

The Cell Theory

The cell theory (*i.e.*, that cells are the basic unit of all life) was put forth by Theodor Schwann (1810-1882) in 1839. Up to this point, most of the microscopic work had been done with plant tissue so to "prove" his theory, Schwann made three hypotheses: (i) animal tissue was composed of cells (like plant tissue); (ii) animal cells were composed of a cell wall and nucleus (like plant tissue); and (iii) animal cells grow by a process similar to crystal formation of minerals (as previously observed by Schleiden in plant tissue). Schwann "proved" to himself that hypothesis (i) was correct by examining a variety of animal tissue, all of which he found were composed of cells. To test hypothesis (ii) he chose to examine cartilage tissue of tadpoles. This particular animal tissue is one of the few exceptions where animal cells have cell walls! One might say it was a lucky choice but it does not explain why in his survey of other animal tissues he did not note the presence or absence of a cell wall. To test hypothesis (iii) he again examined a variety of animal tissue and found cell growth to be similar to that in plant tissue, *i.e.*, by crystallization. The result of his work was that the Cell Theory became the accepted paradigm. Man's perception of an object or event is often influenced by what he expects or wants to see. Even today scientists do the same as will future scientists.

The Cell Theory has persisted with modifications. But one must remember that it is a theory, an invention of man and, therefore, may be replaced by another theory.

The Germ Theory

The second significant event that led to the formulation of the germ theory of disease was the overthrow of the theory of spontaneous generation. Spontaneous generation means that life can originate from non-living things. This theory had its beginnings with an observation of Aristotle (384-322 B.C.).

BSCS translation of *Historia Animalium* (1):

> The great majority of fish develop from eggs. There are some fish, however, that develop from mud and sand. A pond near Cnidos dried up –– even the mud at the bottom. Later the pond was filled by rain. It was then observed that the pond contained many tiny fishes. From this fact it is clear that certain fishes come spontaneously into existence, not being derived from egg or from copulation.

A revolutionary period ensued for almost 300 years (from the early 1600's to the late 1800's). The spontaneous generation theory was finally overthrown by Louis Pasteur (1823-1895) who performed a series of experiments before the French Academy of Science in 1864. Pasteur believed in biogenesis, that is, that life can only come from existing life. The dispute between the two factions centered around experiments involving hay infusion broth. After hay infusion broth was boiled, microorganisms were seen to reappear in the broth in a few days. The experiment was based on the assumption (which Tyndal later disproved) that all organisms, eggs and spores are destroyed (an assumption believed by biogenesists, too) by boiling for a short period.

The conclusion reached by spontaneous generationists was that new life arose from the dead infusion. The biogenesists believed that organisms were reintroduced from the air. When Pasteur conducted his experiments, he did not use hay infusion broth but rather infusions of yeast and sugar. After boiling his infusion and then sealing the flasks with cotton plugs, no organisms appeared in the broth. The Commission of the French Academy ruled in favor of Pasteur and biogenesis.

There is one small bit of irony to this major event in science. The assumption that all organisms are killed by a short period of boiling is incorrect. The spores of some bacteria (Genus – *Clostridium*) can survive boiling several hours. Furthermore, these spores are widely distributed in nature. Had Pasteur performed his experiments using hay infusions, he very likely would have obtained results to support spontaneous generation.

New Theory of Disease

With the cell theory and biogenesis firmly established, the stage was set for the emergence of a new theory of disease. The humoral theory of disease was simply not capable of explaining the new phenomena that were being discovered. The humoral theory was abandoned and a "revolutionary" period ensued. Several new theories had been proposed (characteristic of a revolution). One such theory was put forth by Rudolf Virchow (1821-1902). Virchow believed that a person's health depended upon the health or sickness of a person's individual cells. Another theory emerged with the work of Robert Koch (1843-1910). Koch discovered minute organisms in the blood of cattle that had died of anthrax. He grew these bacteria in cultures in his laboratory, examined them microscopically to be sure he had but one kind present, and then injected them into other animals to see if they became infected and developed clinical symptoms of anthrax. From these experimental animals he isolated germs like those he had originally found in cattle that died of anthrax. The germ theory of disease (*i.e.*, that disease is caused by microorganisms) finally became the accepted theory in the early 1900's. The textbooks imply that the germ theory of disease was the "victor" because it was a true explanation of how disease is caused in humans. A more accurate reason would be that it was better suited to guide future research. In any event, the germ theory of disease (subsequently abbreviated as "germ" paradigm) has continued to be paradigm for bacteriology. It has the total commitment of the scientific community. It has provided the "overall" answers to the problems of bacteriology and has continued to guide the research of bacteriology.

Conclusion

Research under a paradigm consists of increasing the "fit" between observation (sense data) and the paradigm's predictions. This type of research is what is reported in scientific journals. An example of increasing the "fit" between observation and paradigm's predictions was the discovery that fungi, rickettsia, and viruses also "cause" disease (originally bacteria were thought to be the only infectious agents.)

Many advances for civilization have come about from the paradigm's guidance. For example, methods of sanitation, sterilization, immunization and chemotherapy (antibiotics) have made the world a healthier place in which to live. Progress in normal science, then, results in the intensive investigation in a limited area and the invention of machines assist the investigation. This could not happen without a specific paradigm to show the way because nature is too complex to be explored at random.

A paradigm change is both constructive and destructive. It is constructive because it accounts for a wider range of natural phenomena or greater precision of something previously known. It is destructive because some beliefs and procedures are discharged.

The "germ" paradigm still persists. However, bacteriology could be at the initial stages of a revolution, for a revolution begins with the awareness of anomalies. The "germ" paradigm within the last decade has developed some serious anomalies, especially in the area of cancer research. The "germ" paradigm has told the cancer researchers what to look for and where to look for it. But in many cases infectious agents (viruses) cannot be found in cancerous tissue. In addition, in those cancerous tissues in which viruses have been found, the isolated viruses have proved to be non-infectious. The resolution of the problems facing cancer research may come about by articulating the "germ" paradigm or it may require that a new paradigm overthrow the "germ" paradigm.

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A Chemistry Tip

In the CHEMS laboratory reaction of hydrochloric acid with Mg ribbon, addition of some food coloring to the acid solution makes gas volume easier to read. This increases student interest as the dynamics of the reaction are easier to observe. *The Oregon Science Teacher*