

Lecture 29

Rise of Science in the 17th and 18th Century

New Systems of Philosophy and Experimental Sciences

The scientific revolution in this period was responsible for advances from supernaturalism to secularism, from theology to science, from hope of heaven and fears of hell to plans for the enlargement of knowledge and the improvement of human life (Will and Ariel Durant).

Francis Bacon 1561–1626 (English)

Rene Descartes 1596–1650 (French)

William Hobbes 1588–1679 (English)

Baruch Spinoza 1632–1677 (Dutch)

Gottfried Leibnitz 1647–1716 (German)

Isaac Newton 1642–1727 (English)

New concepts by the above philosophers and scientists brought about a fusion of theoretical and applied sciences and development was accelerated by the invention of new scientific instruments such as the barometer, air pump, and sextant. For the first time, technology allowed mankind to move outside of the visual world: astronomy via the telescope by Galilei Galileo (1564–1642) [Jannssen, a Dutch spectacle maker, invented the telescope in 1590]; biology via the microscope (an “inverted” telescope). Science was to become an important force in Western culture. The **Royal Society of London** was founded in 1662. Scientific Societies soon followed by agricultural and horticultural societies.

Microscopy

Robert Hooke (1634–1703)

Hooke, an English experimental physicist, had wide interests in science. He was the first to state clearly that the motion of heavenly bodies must be regarded as a mathematical problem and he approached, in a remarkable manner, the discovery of universal gravitation. Hooke had a strong personality and temper and made virulent attacks on Newton and other scientists claiming that their published work was due to him.

Hooke is remembered in biology for the discovery and naming of “cells” as the units of plant structure. With the aid of a microscope he examined a wide range of materials and substances including feathers, lice, fleas, and cork. His observations were published in *Micrographia* (1665), a famous work on the wonders of microscopy. He first recognized that charcoal, cork, and plant tissues were “all perforated and porous, much like a honeycomb.” To these pores he gave the name cells although the cell walls (*interstitia*) were not considered a constituent part. He stated “*for in several of these vegetables whilst green, I have with my microscope plainly enough discovered these cells filled with juices, and by degrees sweating them out.*”

Anton Van Leeuwenhoek (1632–1723)

This Dutch microscopist, called “Father of Scientific Microscopy,” was a cloth merchant and wine taster by trade. His works were published under title *Secrets of Nature* (1668). He refers to *animacules* or “little animals.” Van Leeuwenhoek extended Malpighi’s demonstration of blood capillaries and six years later gave the first accurate description of red blood corpuscles, completing Harveys’ (1578–1657) discovery of the circulation of the blood in 1628. He discovered the effect of aphids on plant life and showed that they reproduced parthenogenetically. He described different stem structures in monocots and dicots. He understood the nature of red blood corpuscles and studied human male spermatozoa. He observed polyembryony in citrus seed. He was respon-



A.V. Leeuwenhoek

sible for the first representation of bacteria by a drawing in 1683. He constructed over 400 microscopes and bequeathed 26 to the Royal Society of London.

Plant Anatomy

Marcello Malpighi (1628–1694)

Malpighi was an Italian physician, anatomist, physiologist, and a pioneer microscopist. He graduated in medicine in 1653, became lecturer in 1656, and was appointed to the chair of Theoretical Medicine at the University of Pisa, Italy. He was Professor at Messina, but eventually returned to Bologna, his birthplace, where he spent the next 25 years. He became the personal physician to Pope Innocent XII. His major contribution was *Anatome Plantarum* (1675).

Malpighi was one of the first to utilize the microscope in the study of animal and vegetable structure and is considered the founder of microscopic anatomy. He applied himself to vegetable histology and became acquainted with spiral vessels of plants in 1662. He made the important discovery that the layers of tissues in leaves and young shoots are continuous with those of the main stem. He distinguished fibers, tubes, and other constituents of wood and was the first to understand the food functions of leaves. He observed stomata in leaves and nodules on legume roots. He realized that the ovule developed into a seed and the carpel into a fruit or a portion thereof. He arrived at the curious conclusion that the flower leaves were organs for the excretion of ignoble saps in preparation for fruit formation. He first observed the circulation of the blood.



Marcello Malpighi

Nehemiah Grew (1641–1712)

Grew, co-founder of plant anatomy with Malpighi, was born in Coventry, England. He was a practicing physician first in Coventry and then in London and became secretary of the Royal Society. His work in plant anatomy began in 1664 with the object of comparing plant and animal tissues and his essay, read before the Royal Society of London in 1670, was published one year later. (Malpighi, working independently on the same subject in Italy, also sent his work to the Royal Society and an abstract was read at the December, 1671 meeting where Grew's manuscript, now in print, was "laid on the table." Both works then bear the same date although Grew is entitled to priority.)

The second part of Grew's treatise appeared in May, 1672 and a third in the spring of 1674. The object of the work is indicated by Grew's preface, "by thus comparing of them (*i.e.*, the several plants or parts of plants) we shall be able more exactly to state the orders and virtues." He approached botany from the medical standpoint (as in herbals) but his knowledge of animal and human anatomy opened his mind to the possibilities of similar work with plants.

Grew's fundamental thesis was that every plant organ consists of two "organical parts essentially distinct," that is, a "pithy part" and the ligneous part. In the seed, "the pithy part" is composed of "parenchyma," a term first used by Grew. He described stages of seed germination although the underlying physiology was hopelessly confused. He used the term "radicle" for embryonic root and "plume" for "plumule." He called cotyledons "leaves" and recognized that they could appear above ground and turn green. He observed monocot stems with scattered (vascular) bundles and a lack of distinct bark and pith; resin ducts in cortex pine stem; wings and "feathers" on seeds and fruit; protection and economy of space gained by overlapping of bud scales; folding rolling of leaves in buds; buds formed months before they expand; "a



Nehemiah Grew

bulb is, as it were, a great bud under ground"; described tulip flower in bulb in September; noted that pollen grains were "bee-bread"; believed the micropyle allowed water to enter seed and cause germination.

Grew initiated the study of tissues (histology); his major contribution was to relate anatomy and physiology. He made the first successful attempt to extract chlorophyll from leaves using oil as a solvent. His important work was *Anatomy of Plants* (1682). No important advances were made on the ideas of Grew and Malpighi for more than a century.

Plant Classification

Jos. P. de Tourneford

(1656–1708) suggested flower and fruit as basis of classification.

Rudolph Camerarius (1665–1721)

Explained the function of pollen and egg; first modern understanding of plant sexuality. (Note: the Babylonians hand pollinated dates.)

Carolus Linnaeus (Carl Von Linne) 1707–1778

Linnaeus was a Swedish botanist and physician. He began his education as a theology student but at the age of 23 became Curator of the gardens of the University of Lund. From 1732 to 1738 he traveled in Lapland, Holland, England and France, returning to Stockholm where he practiced medicine. In 1741 he became Head of Botany at the University of Upsala where he remained until his death. His labors have earned him the title of "Father of Taxonomy." Linnaeus established groups of organisms, large and small, that depended upon structural or morphological similarities and differences. The basic taxonomic criteria for grouping plants was based on the morphology of their reproductive parts—the plant organs least likely to be influenced by environmental conditions. His "sexual system" of classification used the number of stamens and carpels (styles) as a method of grouping plants (an artificial system that is no longer used). Linnaeus singlehandedly described and assigned names to more than 1300 different plants (and as many or more animals) around the earth. He is credited with the establishment of the binomial nomenclature and with having replaced the long-winded and confused descriptions of the herbalist by clean and succinct description. He did not invent the binomial nomenclature, as the beginning of the idea is found in Theophrastus. His works include *Systema Naturae* (1735), *Fundamenta Botanica* (1736), *Genera Plantarum* (1737), *Classes Plantarum* (1738), and *Philosophia Botanica* (1751).

Hybridization

Joseph Gottlieb Koelreuter (1733–1806)

Between 1760 and 1766, Koelreuter carried out the first series of systematic experiments in plant hybridization using tobacco (*Nicotiana paniculata* × *N. rustica*). He demonstrated that the hybrid offspring generally resembled the pollen parent as closely as the seed parent. Thus, for the first time it was found that the pollen grain has an important part in determining the characters of the offspring. This was a novel idea and disbelieved by his contemporaries. He also observed accurately the different ways in which the pollen can be naturally conveyed to the stigma of the flower. He discovered the function of nectar and the role played by insects and wind in



J.P. de Tourneford



Rudolph Camerarius



Carolus Linnaeus

flower pollination. He also observed that hybrid plants often exceed their parents in vigor of growth (hybrid vigor, now called heterosis).

Plant Physiology

Early physiologists were concerned with absorption and translocation of sap stimulated by the sensation caused by Harvey's discovery of blood circulation.

Joachim Jung (1587–1657)

Philosopher who argued that plants have no soul; studied the absorption by roots.

M. Malpighi and N. Grew (see above)

Established leaves as producers of food.

J.B. van Helmont (1527–1644)

Known today for an infamous study in plant nutrition. In his famous experiment he planted a 5 lb. willow in 300 lb. of dry soil. In 5 years the willow grew to 164 pounds but the soil lost only 2 oz. The increased mass was assumed not to be from soil but from water. (Most of the weight increase, in fact, comes from carbon fixation from air, and oxygen and hydrogen from water.)

Stephen Hales (1671–1761)

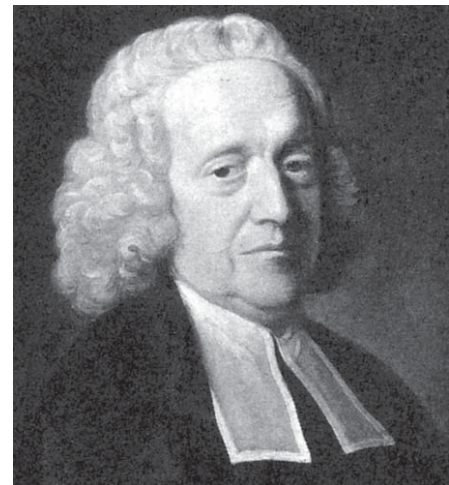
The Reverend Stephen Hales was an English physiologist, chemist, inventor, and country vicar. In 1709 he resigned a fellowship at Corpus Christi College, Cambridge University, to become a perpetual curate at Teddington, now part of London. He studied physiology based on the foundation of Grew's work on plant anatomy.

For 40 years he devoted his leisure time to research in botany and zoology. His memoirs were published in a collected form as the *Statical Essays*, the first dealing with problems in plant physiology and the second with corresponding problems in animal physiology. *Vegetable Staticks* (1727) is the classic work in plant physiology and Hales is considered the founder of experimental plant physiology.

Hales did little vague theorizing and the greater part of his work is a record of successive experiments. An attempt to stop "bleeding" in a badly pruned grape vine by means of a piece of bladder tied over the wound gave him the idea of manometer. He found that root pressure showed a daily periodicity and was affected by changes in temperature. He noticed that leaves gave off water ("perspired") and proceeded to measure the amount of transpiration and to compare it with the amount absorbed by the root. He studied variations in the quantity of water transpired over a 24-hour period and demonstrated reduction in transpiration at night.

Sachs, the great German physiologist in his *History of Botany* stated, "*Hales made his plants themselves speak.*" Hales also had definite notions of the part that the leaves played in plant nutrition and studied leaf structure. He contended that "plants very probably draw through their leaves some part of their nourishment from the air" and that leaves also absorbed light.

Hales had a scientific mind of the highest order and is ranked along with Grew and Malpighi as outstanding leaders in botany and physiology up to the end of the 18th Century. He was the first to use quantitative results in botanical experiments such as movement of sap, transpiration, and flow of nutrients by girdling.



Stephen Hales

Joseph Priestley (1733–1804)

proved that oxygen (dephlogistinated air) is produced by plants; discovered photosynthesis and respiration.

Botanical Exploration

Hans Sloan (1660–1750) introduced 800 species from West Indies.

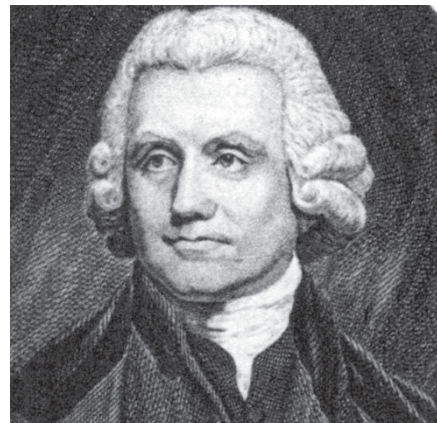
J. Cunningham was sent to China in 1698.

Rumphius (1628–1702)

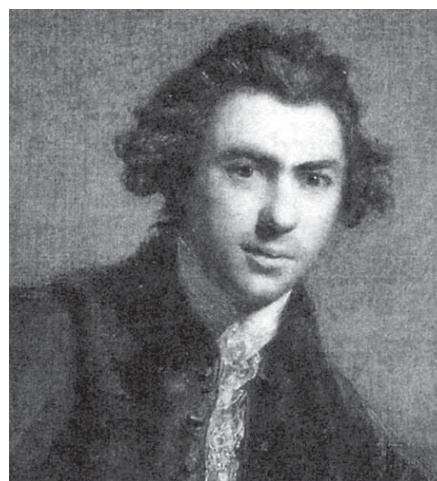
Known as “Pliny of the Indies” explored the Moluccas, described 1700 species.

Sir Joseph Banks (1743–1820)

Banks was a wealthy landowner who for 42 years was President of the Royal Society of London where he was known as the “Dictator of British Botany.” He explored Newfoundland and collected in Brazil, New Zealand, and Australia. His fame rests on his discoveries as a plant explorer, sailing with Captain Cook on the Endeavour at the age of 25. He returned after three years with a vast collection of plant specimens. Banks was named the unpaid Director of Kew Gardens in 1772 by George III and continued in this position until his death in 1820. As an aristocrat, he travelled in great style and panache and turned down one trip with Cook because the accommodations were unsuitable. As Director of Kew he sent out many collectors to bring back new plants for the gardens and the herbarium. Fuchsia and hydrangea were introduced during this period. He was considered as the greatest Englishman of his time by many foreign scientists.



Joseph Priestley



Sir Joseph Banks

Reference

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