tions of genetic variability for humankind. He attempted to minimize these negative implications by emphasizing developmental plasticity and the genetic uniqueness of individuals.

Dobzhansky thought of himself as a moderate with respect to the nature-nurture issue. Neither genes nor environments determine the fate of organisms. Instead there is a very complex interaction between the two. At the height of the IQ controversy, as Diane Paul shows, Dobzhansky was distressed by certain geneticists who seemed to be claiming that genes have nothing to do with individual differences in human cognitive abilities and aptitudes. Politically palatable as this position might be, Dobzhansky found it crudely mistaken. For those authors who see eugenics as being inherently evil, the fact that Dobzhansky joined the Board of Directors of the American Eugenics Society in 1964 is likely to come as a shock. Either Dobzhansky was not as saintly as he has been portrayed or possibly eugenics is not quite as evil as it has been portrayed. Dobzhansky for one thought that those people who carry "serious diseases should be convinced—and failing that compelled—not to reproduce" (p. 225).

That Dobzhansky was on the board of a eugenics society is disconcerting enough to a contemporary reader without discovering that he was also the president of the American branch of the Teilhard Society. Ruse concludes the collection by explaining how Dobzhansky could embrace the theological musings of Teilhard de Chardin when other scientists either pointedly ignored them or denounced them outright. Part of the answer is that Dobzhansky came from a long line of priests—Eastern Orthodox priests, I hasten to add—and remained deeply religious all his life. For this reason and others, he believed in progress with respect to both biological evolution and human affairs of the sort proposed by Teilhard. In short, Dobzhansky's own evolution was as complex and multifaceted as the biological process he strove to understand.

David L. Hull
Department of Philosophy, Northwestern University, Evanston, IL 60208, USA

The Golden Bough

Phyllotaxis. A Systemic Study in Plant Morphogenesis. ROGER V. JEAN. Cambridge University Press, New York, 1994. xiv, 386 pp., illus. $74.95 or £45.

Phyllotaxis—the elegant geometrical pattern of leaves along a twig, of florets on the face of a sunflower, of scales on the surface of a pineapple—has long been a source of wonder and inspiration and has drawn the attention of such great minds as Leonardo da Vinci, Kepler, and Goethe. In most plants, such leaves, florets, or scales appear to be arranged in two families of regular spirals, or parastichies, that intersect at roughly right angles. Remarkably, in almost every case the numbers of spirals in these families are adjacent numbers in the Fibonacci sequence {1, 1, 2, 3, 5, 8, 13, . . .}, in which each number is the sum of the preceding two. The divergence angle between successive leaves is the golden angle, an irrational number roughly 137.5°, deeply linked to the Fibonacci sequence and to the golden rectangle of Greek antiquity.

Roger Jean presents an overview of these fascinating phenomena and their roots in a new book that should interest biologists, mathematicians, and historians of science. Over the last 18 years, he has presented several models that shed light on the labyrinthine interconnections among parastichies, Fibonacci numbers, the golden angle, divergence angle, branching processes, growth, allometry, self-similarity, spatial packing, and fractal geometry. Taking these as his base, Jean reviews various aspects of the history of research on phyllotaxis, focusing first on the mathematical relationships seen in phyllotactic patterns and then on how and why such patterns arise.

After important early contributions by da Vinci and others, the modern study of phyllotaxis began in 1837 with a paper by the brothers Bravais (one a botanist, the other a crystallographer), in which they coined the term and summarized some of the precise relationships shown by leaves packed in spirals along stems. Over the next century this paper helped inspire an extensive literature, which became a tangled and confusing web when it was realized that many different sets of spirals could be drawn through any given leaf arrangement. By 1917, D'Arcy Thompson concluded that an irreducible subjectivity had transformed the entire subject into mysticism and fantastic speculation. Jean untangles this confused web and provides an integrated approach to the description and mathematical study of phyllotactic spirals. He outlines the key results of the last 150 years and tabulates the expected relationships among parastichy numbers, divergence angle, primordia size, and size of the shoot apex. The results are quite general: a survey of nearly 13,000 observations on 650 species indicate that 96.5% conform to classic, Fibonacci-type phyllotaxes.

How do plants achieve such a regular leaf arrangement? Jean addresses this question at length, though with mixed success. The main constraint creating Fibonacci spirals appears to be the efficient packing of leaves or other organs on a cylindrical or disk-like lattice. Divergence by the golden angle distributes successive leaves or florets more evenly around a plant's stem or inflorescence than any other angle; deviations of as little as 0.1° from the golden angle decrease the tightness and evenness of packing dramatically, increasing self-shading (as proposed by da Vinci) or decreasing the efficiency of floral packing (see illustration). Hypotheses to account for spiral morphogenesis have centered on diffusion of chemical inhibitors or promoters from leaf primordia; on competition among competing leaves or procambial strands for nutrients; on filling of

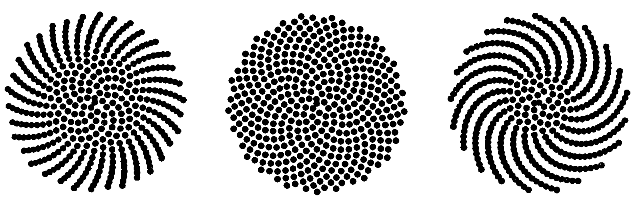
Vignettes: Committee Work

Individual scientists have no doubts about Nature's indifference to popular opinion, no matter how well informed. But the scientific enterprise today is controlled not by individuals but by committees, these relatively modern institutions which, in the words of Sir Barnett Cocks, a former Clerk of the British House of Commons, are cul-de-sacs down which ideas are lured and then quietly strangled.

—*Donald Braben, in To Be a Scientist: The Spirit of Adventure in Science and Technology* (Oxford University Press)

It is an old joke that a camel is a horse designed by a committee, a joke which does grave injustice to a splendid creature and altogether too much honour to the creative power of committees.

—*Michael French, in Invention and Evolution: Design in Nature and Engineering* (second edition; Cambridge University Press)



"Depiction of the critical role of the divergence angle in packing efficiency; the three patterns differ only by a slight value of the divergence angle d. In (**1**) it is equal to 137.3°, in (**2**) to 137.507764 . . . ° (the Fibonacci angle corresponding to the noble number τ^{-2}), and in (**3**) to 137.6°. Notice that in the case of the Fibonacci angle a parastichy pair is visible (not just one family of spirals), and the points are evenly distributed in the disk. In the other two cases, η . . . falls to zero while moving outward, although the area per point is still the same." [Reproduced in *Phyllotaxis* from P. Prusinkiewicz and A. Lindenmayer, *The Algorithmic Beauty of Plants* (Springer-Verlag, 1990)]

the first adequate space on the shoot apex by a new primordium; on contact pressures developed by adjacent primordia; and on mechanical stresses in the developing shoot apex that lead to the formation of new primordia. Jean notes that similar kinds of packing constraints arise in a wide range of contexts outside the purely botanical (for example, snake skins, pangolin scales, jellyfish tentacles, virus coats, α-polypeptide chains), including some that are non-biological (for example, flux lines in superconductors, cloud fields in hurricanes). Presumably, the geometry that arises in each of these cases results from maximizing the efficiency of packing of "soft" objects on a spiral lattice, and not from some infinitely precise internal protractor; that is, the golden angle is generated by efficient packing, not vice versa. While Jean recognizes this underlying isomorphism in a few instances, in others he ignores it and incorrectly criticizes various chemical or physical morphogenetic hypotheses; more careful and critical analyses of these ideas are given by Schwabe in *Positional Control in Plant Development* (P. W. Barlow and D. J. Carr, Eds.; Cambridge University Press, 1984) and Steeves and Sussex in *Patterns in Plant Development* (Cambridge University Press, 1989).

Jean's concluding discussion of why plants display geometrically regular patterns of phyllotaxis is, unfortunately, not very compelling. He raises no adaptive explanation for phyllotactic patterns other than the minimization of self-shading, ignores potential relationships of the latter to primordial packing, and fails to cite relevant papers on the adaptive value of specific leaf arrangements, such as orthotropy versus plagiotropy, distichy versus polystichy, and isophylly versus anisophylly. Worse, the author espouses Lima-de-Faria's bizarre concept of autoevolution, arguing that phyllotaxis is nonadaptive and reflects a pattern of self-assembly based on prebiotic evolution of chemical and physical matter, "the tip of an iceberg resulting from the Big Bang" (!). In seeking explanations for phyllotaxis based solely on patterns of growth while denigrating the role of Darwinian fitness, Jean comes nearly full circle, recapitulating the natural philosophy of D'Arcy Thompson that led many biologists to abandon phyllotaxis as a subject of study. The golden phyllotactic spiral remains one of the most striking phenomena in biology but, as Dobzhansky noted, nothing in biology makes sense except in the light of evolution.

Thomas J. Givnish
Department of Botany,
University of Wisconsin,
Madison, WI 53706, USA

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Metal Ions at Work

Principles of Bioinorganic Chemistry. STEPHEN J. LIPPARD and JEREMY M. BERG. University Science Books, Sausalito, CA, 1994. xx, 411 pp., illus. $40; paper, $30.

Although most of the molecules in living things contain only a few common elements (C, H, N, O, P, S, Cl, Br), a wide range of "inorganic" elements are also required in small amounts for normal growth in one or more species (among them Na, K, Mg, Ca, V, Mn, Cr, Fe, Co, Ni, Cu, Zn, Mo, W, and Se). Many of these elements are found in the active sites of metalloproteins, where they take part in processes that are difficult to achieve with the common elements, such as, electron transfer, O_2 binding and utilization, N_2 reduction, water oxidation, and H_2 binding and oxidation. Another interesting issue is the uptake and storage of essential metal ions, which is best understood in the case of iron, where the proteins involved in its transport and storage have been studied in detail, including the way their expression is regulated.

In addition, a number of nonessential elements are also important in biology. Some bacteria have developed an interesting detoxification mechanism to protect themselves against organomercury compounds. Mercury binding to a protein-DNA complex initiates transcription, which in turn leads to the production of proteins that hydrolyze the mercury-carbon bond and reduce the resulting Hg^{2+} ion to metallic mercury, which evaporates from the cell. Among drug applications, platinum is the key element in a widely used antitumor drug, which can bind irreversibly to DNA and so interfere with replication and tumor cell division. In medical diagnostics, gadolinium reagents can improve contrast in magnetic resonance images and the technetium-99*m* isotope is used in trace quantities for imaging body organs via its gamma-ray emission. The chemical form in which the isotope is supplied determines where it goes and therefore what is imaged (blood, bone, or brain).

Bioinorganic chemistry is therefore a very broad field because it involves the study of the role of all these and other inorganic elements in biology. It includes both the biochemistry of these elements and the study of synthetic model compounds designed to answer structural or mechanistic questions about the natural system. Although biochemists had for decades been studying systems we would now call bioinorganic, bioinorganic chemistry first emerged as a recognized discipline in the late 1960s and early '70s, when a number of inorganic chemists and biochemists became interested in such problems as oxygen uptake, CO_2 hydration, electron-transfer, nitrogen fixation, and coenzyme–B-12–dependent reactions, all of which are carried out by metalloproteins. Today a typical meeting on bioinorganic chemistry is likely to have as many biochemists and biophysical chemist participants as inorganic chemists, and the presentations usually cover a breathtaking array of problems.

A bioinorganic chemistry course, often part of the senior undergraduate and graduate student curriculum, poses difficult problems for the college teacher because basic ideas from coordination chemistry, biophysical chemistry, and biochemistry are all needed to understand most topics, and there are a very large number of topics from which to choose. This means that the instructor must be very selective. A severe problem has been the lack of suitable textbooks, and only in the last few years have the first useful ones been published. Lippard and Berg, well-known figures in the field, have now written what is probably the best textbook to date. In it, they present the field in a way that emphasizes important organizing principles. The first four chapters serve to introduce the essence of coordination chemistry, biochemistry, and biophysical chemistry. This is followed by a discussion of uptake of metal ions by cells, the typical cofactor structures in which metals are found, and the effect on proteins and nucleic acids of metal binding. Electron transfer is given close attention, together with mechanistic