causal link between seemingly disparate parameters like population density, aggression, reproductive strategies, lipid metabolism, insulin signalling and longevity. The suggestion that the phenomena of stress may be revaluated on Darwinian principles is worth pursuing. In the chapter on 'Time to give up stress', the author classifies different forms of stress and points towards an interesting observation that low incidences of diabetes were recorded during the war time. The prescription that one may resort to additional soldier-style stress, in our otherwise diplomat way of life, seems quite relevant.

On occasions, the narrative strays from the main course and gets mired in the web of preparative arguments. The chapter 'Hawks and doves' ponders on an interesting evolutionary question as to why they may resort to differing energy budgeting strategies. However, the transition of the argument as to how these may influence metabolism is rather tenuous. Similarly, in chapter 12, the reader finds himself in a maze of arguments justifying the needs to have glucose-sensing systems, in the brain as well as the periphery, and the relative speed with which each might swing following glucose dysregulation. Why can we not resort to simpler logic? Since glucose is an extremely important source of energy, the regulatory systems have evolved glucose-sensing mechanisms in a number of places in the brain as well as the periphery. And these systems, redundant as they seem, may interact at several levels and manage glucose homeostasis. This should be straightforward and convincing enough. A lot of conclusions are based on presumptions, not adequately validated in the literature. Similarly, in the chapter on 'Why blood sugar goes up', the author argues that the mechanisms must have evolved not to protect the brain from a drop in plasma glucose, but to ensure adequate glucose supply under conditions of increased brain demand. The frame of this logic is rather unsettling.

This book is a great source of information. Particularly to those interested in the literature on diet and insulin resistance. The information collated in Appendix I through IV will be much useful in deciphering diabetes-related jargon. Watve has shed a part of his responsibility by admitting 'ignorance' of the subject. This gives him the rare freedom of uninhibited imagination. But this strategy has a negative side, it reduces the impact of the message, and how far the author has achieved his goal depends much on the reader. In spite of these limitations, Watve has been greatly successful in his mission – pursuit of truth in unchartered waters.

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**Annual Review of Plant Biology, 2012.** Sabeeha S. Merchant, Winslow R. Briggs and Donald Ort (eds). Annual Reviews, 4139 El Camino Way, P.O. Box 10139, Palo Alto, California 94303-0139, USA. Vol. 63, x + 726 pp. Price: US$ 89.

There is a significant change in the character of plant science from observational science of morphology, anatomy, cell biology (light microscopic cellular structure), classical physiology and Mendelian genetics to presently molecular genetics, proteomics, genomics, gene analysis and gene engineering. In addition, new emerging techniques have revolutionized plant science research with unprecedented expansion of knowledge with the development of incredible conceptual framework and excellent models that have improved our understanding of complex plant systems. The reviews in the current volume of the *Annual Review of Plant Biology* distinctly reflect the significant changes and advances made in plant science in recent years. Not surprisingly, most of the articles in this volume focus on the recent works with *Arabidopsis thaliana* as a model plant system, of course, with citation of the literature relating to other plant systems to understand the basics of plant structure, function and behaviour in general. In addition, most of the articles provide coloured illustrations, tables and concluding remarks that make the reviews impressive and more informative.

This volume contains 27 articles, which could be grouped under the following themes: plant evolution, transport mechanisms, regulation, signalling systems, plant development, metabolism, techniques and environmental biology. The titles of most of the articles are catchy and fascinating that immediately draw attention of researchers and students of plant biology. The reviews not only provide current updates in different areas, but also provide critical discussion in the areas of controversies and future challenges in plant science.

The first article by Joseph A. Berry (Carnegie Institution for Science, Stanford, California) is an excellent review on the use of equations and models that can lead to the development of our understanding of science on a global scale. Berry, an outstanding plant biologist, provides a critical analysis of historical development of knowledge in the area of $C_4$ photosynthesis and suggests how equations and models can provide means to organize principles to link the basic plant physiology to atmospheric science, hydrology, ocean sciences and climate change on Earth. It is a wonderful review that covers the journey of his scientific career from chemistry to photosynthesis (plant biochemistry) and finally to science of Earth system. The author has beautifully narrated his experience and interaction with top plant biologists working in the area of $C_4$ photosynthesis and photorespiration. He opines how sharing of information and input of ideas and their analysis help in the performance of experiments to develop models in interdisciplinary research.

Currently, evolutionary biology is emerging as a major discipline of plant science with new ideas and concepts.

The origin and evolution of $C_4$ pathway through several characteristic transients is the focus of the review by Sage and colleagues. The article critically describes the initiation and evolutionary modifications that finally have resulted in the establishment of $C_4$ metabolic cycle. The authors have proposed conceptual models of major phases of $C_4$ evolution, which provide a base to explain phylogenetic relationships. The next article by Losi and Gartner tells the story of photoreceptor flavoproteins, specifically their structure, functional significance and evolution. It briefly describes new ideas that are emerging on evolution of flavoproteins with genomics, metagenomics and phylogenetic relationship.

On the other hand, Young and Bharti provide a beautiful comparison of known legume genomes, their analysis and implication in shaping the development of legume-specific characteristics during evolution. The article concludes with a critical discussion on the impact of genome

duplication on legume biology and specific contribution of the duplication on evolution of nodulation. Another article of interest by Köbler and co-authors describes how the imprinted genes either from male or female gametes function primarily to either repress or activate expression of genes without change in DNA sequence. In the background of epigenetic mechanism, imprinted expression is regulated by DNA methylation. The review critically discusses evolution of genomic imprinting mechanisms and evolutionary conservation of imprinting for some genes in plants.

There are several articles in the volume that describe the molecular mechanisms of acquisition of ions, transport pathways, transport-induced metabolic modulation, molecular mechanism of association of transport systems with basic plant development and physiological processes.

The story of transport of iron, one of the most essential micronutrients in plants is old. The article by Kobayashi and Nishizawa, although a small one, provides a beautiful analysis of recent data on reduction and chelation processes for iron uptake, intracellular trafficking and their genetic regulation. Most of the materials on central genes and enzymes responsible for iron homeostasis in plants are precisely summarized in a table, thus reducing the size of the text. It describes molecular mechanisms of gene regulation and possibility of production of transgenic crop plants with enhanced tolerance to excess or limited iron. Continuing the theme, the review by Xu and associates describes the current literature on acquisition of nitrogen, its transportation, assimilation and remobilization in plants. The review updates literature on the genetic control of variations in nitrogen use efficiency in different environmental settings. The possibility of genetic manipulation of nitrogen transporters and nitrogen use efficiency is discussed.

**Figure 1.** Larva of the generalist lepidopteran herbivore *Spodoptera littoralis* feeding on a lima bean (*Phaseolus lunatus*) leaf.

This volume also includes two interesting articles on integration of modes of action of vacuolar transporter systems and their interconnectivity with regulatory network of plant metabolism, plant development and in stress responses. The review by Martinoia and associates emphasizes on the specific role of vacuoles in cellular surface expansion and volume changes through transport-mediated accumulation of osmolytes. The authors highlight recent findings on several vacuolar transporters with excellent illustrations and models. On the other hand, Liu and Bassham in another article have critically reviewed recent work on vacuolar participation in autophagy, a physiological process required for cellular macromolecular degradations and recycling during plant development, including senescence and in stress response.

The basics, structure, origin, type of transporter system and primary role of plasmodesmata that interconnect individual plant cells for sharing of resources and information consequently maintain cytoplasmic integrity are long known and are available in many reviews and textbooks of plant biology. But the article by Burch-Smith and Zambryski in this volume summarizes plasmodesmata biology with a different approach. The review emphasizes on the recent literature in the area of plasmodesmata-mediated transport, signalling systems and regulation associated with its function.

In recent years, several plant-specific signals (both environmental and cellular), receptors and signal transduction pathways down to gene expression regulating developmental and physiological responses are being extensively studied.

The review by Nelson and colleagues describes regeneration of plant ecosystem by several chemical signals after fire, and from char and smoke of the fires that regulate and stimulate the regeneration. Discovery of chemical signals, including karrikins and cyanohydrins, molecular mode of their action, physiological response and their possible interactions with light and hormone responses are critically discussed. The authors have summarized several signal transduction pathways associated with karrikins and their mode of action using genetic tools in *A. thaliana*.

There are two important articles on plant hormone signalling operating in plants. Hwang and co-authors, renowned experts in cytokinin biology, have provided an up-to-date sketch of complex physiological function of cytokinins, their signalling network and crosstalk with auxins and other signalling systems in plants. The article summarizes historical development of cytokinin discovery, its diversified responses and integration of signalling systems associated with the hormone into genetic regulation of plant development. The beauty of the article is that it could be used as text material for undergraduate/graduate students and high-level research material for those who are working specifically in the area of cytokinin signalling. The next article, however, focuses on phytohormone-mediated signalling associated with cell wall biology. Wolf and colleagues review the recent advances made in cell wall synthesis and assembly, regulation of the wall properties and cell wall modulation of cell expansion and plant growth. The citations in the review provide a clear picture of downstream signalling associated with the cell wall involving reactive oxygen species, phytohormones, including ethylene, jasmonate and salicylic acids. The other article on plant signalling by Boss and Im provides an analysis of the current literature on phospholipids signalling and their association with several metabolic fluxes with a focus on signalling function of inositol family of negatively charged phospholipids.

This volume comprises of articles in areas like embryo development, germination, leaf ontogeny, stomatal development and finally development of root, covering the major part of whole plant development.

A small but highly informative article with several coloured illustrations and tables by Lau and colleagues describes the basics of early embryogenesis, essential patterning processes, including polarity of apical–basal axis, different types of tissues and both root and shoot poles in a molecular framework. The expression patterns of genes, transacting factors and signal transduction pathways responsible for early development of the embryo that finally determine shape of the whole plant body with different structures are summarized in the review. Embryo development and seed germination are two close events of plant development. It may be a coincidence that this issue contains two separate articles on both the

events. The potential of the embryo primarily determines germination vigour of seeds. The article by Rajjou and colleagues critically reviews recent literature on the major contributors of successful germination, including DNA integrity, stability and quality of stored m-RNA, sulphur amino acid pathways and finally hormone signalling system associated with several critical metabolic pathways linked to germination. The next article in the sequence of plant development surveys the literature on advances made on the concepts of leaf ontogeny, primarily through elucidation of gene regulatory network associated with the organ development. New ideas are emerging on the concepts of leaf development and morphogenesis by integrated approach that involves evolution, development and genomics. The review by Townsley and Sinha concludes with a critical discussion, how the modular nature of gene regulatory network is involved during development that has been used by nature as an evolutionary force to optimize leaf structure and shape. On the other hand, the article by Pillitteri and Torii focuses on molecular background of stomatal development, which is less known and less refined by developmental biologists. Regulation of stomatal cell-state transition and specification by transacting factors through positional signalling, and possible modulation of stomatal development by integration of intrinsic signalling network and environmental stimuli are nicely presented with citation of the appropriate current literature.

Another article under the theme of plant development by Petricka and associates deals with the development of roots. Recent progress made on the molecular biology of root development has significantly contributed to our understanding of initiation and development of different cell types, cell patterning, root architecture and stress responses. The authors have reviewed the reconstruction of gene regulatory network associated with root development in *Arabidopsis* and have proposed models and transcriptional modules for experimental verification. From the recent data on root development of *Arabidopsis*, they propose that modelling gene regulatory network has potential to address the complexity of root development.

The last article, one of current interest, under the theme analyses the progress made so far in stem cell research and applications which have taken centre stage in biological research in recent years. Although there is significant advance made in the area of animal stem cell research and its applications in medicine, plant stem cell research with potential in the field of agriculture and breeding programme is rather new. In addition, stem cell research in plant science is likely to contribute to our understanding of the fundamentals of plant development. Aichinger and co-authors have cited literature generated primarily with *Arabidopsis* and provide a sketch of different models in plant stem cell research. The authors summarize the basic principle of the regulatory system that coordinates the pluripotent stem cells and differentiating decendents and maintains a balance between them. A critical analysis of the regulatory role of the mobile signals on several transcriptional modules that balances cell fates makes the article impressive.

The article by Maeda and Dudareva provides a distinct metabolic and molecular framework of Shikimate pathway and biosynthesis of aromatic amino acids in plants. Although historically a traditional subject, its importance in human diet and in plant biotechnology is well recognized. The review covers a small textual introduction on this important pathway and the metabolic significance of aromatic amino acids derived from the pathway. The authors, however, highlight the current literature on enzymes involved in the pathway, molecular organization and subcellular compartmentalization of the pathway and finally transcriptional/post-transcriptional controls of biosynthesis of aromatic amino acids. The article briefly provides a note on the possibility of metabolic engineering for better production of aromatic amino acids.

Mithöfer and Boland focus on plant defence chemicals, including the defensive functions of secondary metabolites, explaining the chemistry of several plant defence components and their modes of action. The other article on plant defence, reviewed by Schwessinger and Ronald, however, describes how the conserved microbial signatures localized in the plasma membrane and cytoplasm are sensed by plants for development of appropriate defence response through complex signalling network system. In addition to a brief historical note on discovery of plant receptors that perceive conserved microbial signature, the authors have focused on identities of receptors, their functions and characteristics, signal perception and finally the signal transduction systems associated with development of defence response and resistance.

Tropospheric ozone, an anthropogenic greenhouse gas is now considered as one of the major air pollutants that greatly contributes to global climatic change. Ainsworth and co-authors provide an excellent review on the chemistry of tropospheric ozone, regulation of its concentration in the atmosphere and its impact on the ecosystem with special reference to plant and grassland productivity. The article, however, focuses on its impact on basic plant physiology – like its harmful effects on stomatal conductance, carbon uptake, its assimilation and utilization in metabolic pathways. The literature on signalling systems, ozone-induced damage and adaptive mechanisms by plants is cited. The authors conclude with a short note on the complex interactive effects of ozone and increased level of $CO_2$, their impact on global climatic change and finally plant productivity.

The volume includes three reviews on innovative methods and technology. Hicks and Raikhel outline chemical biology, specifically chemical genomics as tools for basic and applied research in plant sciences. The authors rightly point out the limitation of the routine approach of plant biologists to probe protein function by perturbing its structure directly or indirectly through gene mutation. Currently, however, successful attempts are made to use bioactive small molecules as reversible protein target perturbing agents to produce phenotypes. The review highlights the spectacular successes achieved with chemical genomics that have facilitated identification of receptors and other cellular proteins.

The questions of changing the whole biochemical pathways or their suitable modifications in order to alter the properties of the pathways for relevant biotechnological applications in agriculture and industry through chromosome engineering are addressed in the article by Gaeta and associates, who have written a beautiful review on synthetic chromosomes and their application in biotechnology. The synthetic chromosomes, as suggested by the authors supported by the current literature, are likely to contribute to the protection of transgenic crops with

new and superior traits and in other areas of plant biotechnology.

The last article of this volume describes fluorescence imaging technique, extensively used by plant biologists in recent years. Fluorescent proteins are well known as reporters of gene expression and protein localization. Okumoto and associates, however, have analysed the limitation of the previously used probes and have cited the literature on the technique of quantitative imaging with fluorescent biosensors to study protein and membrane dynamics, enzyme activity and other molecular dynamics directly. They have summarized the design principles of several types of fluorescent biosensors emphasizing genetically encoded fluorescent sensors and their use to study complex plant cell dynamics.

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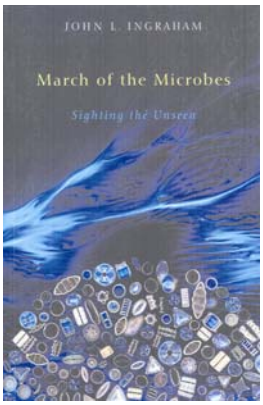


**March of the Microbes: Sighting the Unseen.** John L. Ingraham. The Belknap Press of Harvard University Press, Cambridge, Massachusetts, USA. 2012. x + 326 pp. Price: US$ 16.95.

Theodosius Dobzhansky's (1900–1975) essay 'Nothing in biology makes sense except in the light of evolution' (*Am. Biol. Teach.*, 1973, **35**, 125–129) presents one of the best arguments I have read in support of evolution. But its celebrated title seemed a bit discomfiting when I learned that the bacterium *Deinococcus radiodurans* can withstand radiation intensities (5 million rads) that possibly were never before experienced by life on earth. I am relieved to read that my discomfiture is shared by no less distinguished a microbiologist than John L. Ingraham, former President of the American Society of Microbiology, Professor Emeritus of Microbiology at the University of California, Davis, and in whose honour *Psychromonas ingrahamii* is named, a bacterium that can grow even at –12°C. The last page (p. 306) of the book under review notes that the extraordinary radiation resistance of *D. radiodurans* presents an evolutionary conundrum. Shared discomfiture is only one of many reasons why I like the book, and unreservedly recommend it to all curious minds – expert, student and layperson.

The 14 chapters present a broad palette of ways in which microbes make their effects felt by us, thus enabling us to 'sight' them without microscopes. The sightings provide answers to a vast range of questions. Here is a sampling – Why are fungal diseases so difficult to treat? Why do fish from the sea begin to smell 'fishy' sooner than fish from freshwater? Why is the Black Sea black? Why do boiled eggs spoil faster than raw eggs? How do cows thrive on a diet of merely grass or hay? What is their major source of protein? How do our intestinal microbes contribute to obesity? What role do microbes play in helping an angler fish attract its prey? What triggers aphids to switch between parthenogenesis and the sexual cycle? What is the historical link between manure piles and gunpowder? What is the half-life of atmospheric nitrogen? How does one distinguish elemental sulphur of microbial provenance from that spewed by volcanoes? How do fairy rings form? Why are salt ponds so vividly coloured? Why does photosynthesis by chloroflexi not produce oxygen? How do yeast cells survive as dry yeast powder? What is the longest duration for which a bacterium is known to have withstood freezing? Why is rabies called hydrophobia (fear of water)? How was the anthrax bacillus attenuated to produce the anthrax vaccine? Why do pediatricians recommend against feeding honey to infants? Why are radiation-killed cells of *Pseudomonas syringae* added to the water and compressed air in snowmaking machines? How do dinoflagellates regulate the sunlight that reaches the oceans? How might phytoplankton be employed to transfer atmospheric carbon dioxide to the ocean floor? What role did microbes play in carving out the Carlsbad Caverns? Why do coral reefs bleach? Why were people in the Northern Hemisphere advised never to eat seafood in months lacking an 'r' in their name? How does diatomaceous earth control cockroach infestation (Lakshman rekha)? Why are more remains of carnivores than herbivores found in the Rancho La Brea Tar Pits near Los Angeles? What motivated Frederick Griffiths to do the experiment that led to his discovering DNA as the genetic material? Why do rats and rabbits eat their own faeces? Which element is found in RNA but not DNA? How does photosynthesis contribute to the hydrothermal vent ecosystem? How do *Caulobacter* thrive in tap water? Why is the unnecessary use of antibiotics for any purpose a threat to the utility of the antibiotic for all purposes?

We enologists naturally stand up for each other. Ingraham was at the Department of Viticulture and Enology before moving to the Department of Microbiology in 1964. And I had served as a Teaching Assistant for several semesters in the 'Introduction to Enology' course offered at Stony Brook University in the early 1980s (it helped that the course was taught by Eugene R. Katz, my Ph D advisor). So it was heartening to read all the standard 'chestnuts' of introductory enology courses – Why are European wine grapes grafted onto the stock of American grape vines? Why are champagne bottles heavy and closed with wired corks? Why is champagne sparkling, but vinho verde only semi-sparkling? Why do sommeliers offer you the cork pulled from a wine bottle for examination? What 'rot' do the world's most admired dessert wines, namely, French Sauternes, Hungarian Tokaj and German Trokenbeerenauslese, share? Knowing the answers to these questions is thought by some to lubricate the passage into 'society'.

For many questions we do not currently have any good answer, and Ingraham does not shirk from asking them and provoking thought. No archaea are known to cause diseases of humans, animals, and plants. Why? Viruses have DNA or RNA, but not both. Why? And, of course, *Deinococcus* is damned radiation-resistant. Why?

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