

magnetic fields are also discussed. Chapter 11 concludes with various aspects of pre-processing the acquired data.

Three main groups of EM methods used in geophysical exploration: DC and IP methods, natural-field EM methods, and CSEM methods, are discussed in detail in chapters 12–14 respectively. In chapter 12, the new edition has introduced a generalized effective medium theory of the IP effect (GEMTIP), which includes elliptical inclusions in a model of the multiphase medium. A new section in this edition discusses 3D inversion of the magnetotelluric (MT) phase tensor, as the phase relationship between electric and horizontal magnetic field vectors is not significantly affected by near-surface heterogeneity, unlike the observed electric field amplitude. The only flaw that I found in this otherwise comprehensive book is in the description of the natural EM field of external origin provided by currents flowing in the Earth's magnetosphere and ionosphere, which the author may have included for the sake of completeness. For currents flowing in the ionosphere at an altitude of about 100 km above the surface of the Earth, effects of non-uniformity of the source field are not discussed in the book. In MT and magnetovariational methods, currents flowing in the magnetosphere are often considered as the external sources of plane EM waves incident normally on Earth's surface. Frequency bands used in these methods are such that the displacement current may be neglected. These frequency bands are considered to arise from complex interactions between Earth's magnetic field and flow of plasma from the sun. However, the statement (p. 503) that magnetic storms are associated with solar flares, and the suggested mechanism of a storm, are incorrect. Earth-directed coronal mass ejections (CMEs) from the sun generally cause major magnetic storms, when the interplanetary magnetic field accompanying the CMEs has a southward component allowing reconnection with the Earth's magnetic field. This finds no mention in the book. High-speed solar streams from coronal holes, which give rise to co-rotating interaction regions are generally associated with weaker magnetic storms. This lacuna may be skipped by readers as in natural-field EM methods, unlike the CSEM methods, parameters of the source of the external field are not specified.

Scientists and technologists involved in two important areas of geophysical exploration: offshore hydrocarbon exploration using EM methods and exploration of mineral deposits using airborne electromagnetic (AEM) methods should find the inclusion of recent developments in these two areas to be useful. The new approach to 3D inversion of AEM data may lead to improved reliability of the results of such exploration. Finally, a separate chapter devoted to specific case studies involving the use of different EM methods in tectonic and crustal studies, mineral and hydrocarbon exploration should be highly instructive.

This book is a complete treatise on the subject by an authority in this field, which should be included in the library of a university, institute, or organization involved in teaching or using EM methods of geophysical exploration. In the exposition of the theoretical foundation of these methods, the level of complexity of subsurface geological structures has been increased in steps. The first few chapters provide excellent material for an introductory course on EM methods for postgraduate geophysics students. For those engaged in research in this area, the book offers deep insights into many aspects of EM methods. It would enable researchers to explore how they can develop their own tools to extract reliable and useful information from EM data obtained in different settings.

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Annual Review of Phytopathology, 2017. Jan E. Leach and Steven E. Lindow (eds). Annual Reviews, 4139 El Camino Way, P.O. Box 10139, Palo Alto, California 94303-0139, USA. Vol. 55. x + 610 pages. ISBN: 978-0-8243-1355-5. Price: US\$ 107.

This volume includes 25 authoritative reviews. The main subjects dealt with are emerging themes, plant immunity, ecological and epidemiological issues, pathophysiology, pathogen biology and disease management. The opening chapter is an

autobiographical sketch of a molecular plant pathologist, Nickolas J. Panopoulos. His research career bloomed in USA during the period when the era of molecular plant pathology sprouted from developments in recombinant DNA. The personal reflection of his accomplishments along with the growth of molecular phytopathology have been admirably described. Youngsters can derive inspiration from this presentation.

Toxin–antitoxin (TA) systems widely present in the prokaryotic kingdom are ancient sets of closely linked self-killing or suicide genes consisting of a toxin gene and its cognate antitoxin gene. The bacterial genomes harbour several of them with diverse structure, and these move between genomes through horizontal gene transfer. They encode a proteinaceous toxin capable of killing the host and a labile antitoxin which are either small proteins or small RNAs (sRNAs) directly inhibiting the toxin or controlling toxin production. It is now clear that these gene modules are present in plasmids as well as in chromosomes. The past 34 years, since the discovery of a TA system involved in plasmid stability in host bacterium¹, have widened our knowledge, more particularly with bacterial pathosystems in animals revealing their multiple cellular functions, including persistence or bacterial stress tolerance, pathogenicity and virulence, phage defence and biofilm formation. However, the functions of chromosomally encoded systems still remain an enigma. TA systems are prevalent in plant-associated pathogenic and symbiotic bacteria. Shidore and Triplett mine the TA systems in host–microbe interactions and examine their role in bacterial lifestyles with the plant which would trigger a new theme for expanding our understanding of plant–microbe interactions. This review attempts to project TA systems offering opportunities for development of novel strategies to manage plant diseases, similar to the approaches in biomedical field towards applications for clinical infections.

The host microbiota presents opportunities for pathogens interacting with other microorganisms of varied ecological lifestyles of commensalism, symbiotic and pathogenic forms in their biotic environment resulting in the cause of disease or altering the disease manifestations either directly or indirectly. Knowledge gained on this in recent years has led to the evolution of a new concept of

'pathobiome' from pathogenesis². Brader *et al.* examine the complexity of these multitrophic interactions in the context of plant-pathogenic and nonpathogenic endophytic interactions along with the abiotic environmental effects presenting a network of factors influencing the disease occurrence. In parallel, Shikano *et al.* present a case for the importance of three-pronged mixtures or tritrophic interactions involving plants, insects (herbivore and parasitoids) and, beneficial and pathogenic microbes in influencing the insect behaviour and fitness. Despite limited indications, microbial communities of insects and their environment, including their host plants, might offer opportunities for manipulating their relationships to our advantage in insect pest management.

Disease resistance or plant immunity in crop varieties is necessary for obtaining high yields in an environmentally sustainable manner. Plant immunity is a function of recognition and specificity at molecular level between host and pathogen in the cellular environment. Plants launch the pattern-triggered immunity (PTI) as the first line of defence response (basal immunity). This response is elicited by the recognition of the conserved molecular signatures consisting of structural components, or molecular patterns or epitopes (elicitors) of pathogen origin (PAMPs/MAMPs), or those released by injured or pathogen-damaged host cells (DAMPs) by the cognate plant cell surface-localized (plasma membrane resident) pattern recognition receptors (PRRs). Successful pathogens defeat this primary defence layer by delivering effector proteins to inactivate the defence responses by altering host metabolism. To counteract this defence suppression, plants have evolved a second line of defence for monitoring host-delivered virulence factors/effectors (avirulence proteins) mediated by intracellular nucleotide-binding and oligomerization domain (NOD)-like receptors (NLRs). This layer of defence is known as effector-triggered immunity (ETI). PTI and ETI refer to what has been classically known as basal or horizontal disease resistance and gene-for-gene resistance or vertical resistance respectively^{3,4}. This modern outlook has helped dissect the molecular interplay and associated gene functions underpinning the cause and effect relationships in plant-pathogen interactions more precisely. Boutrot and Zipfel doc-

ument basal immunity comprising the molecular patterns and plant receptors that perceive them. The strategies for their identification by functional characterization and by genetic and biochemical approaches used for this purpose are presented. This opens up options of modifying the specificity involved in pathogen recognition through either interspecies transfer of PRRs or through *in situ* molecular engineering for evolving novel plant genotypes that can ward-off the devastating pathogens in a durable manner. PTI, offering nonspecific broad-spectrum resistance against pathogens, results in a series of cellular and physiological responses, and transcriptional reprogramming. Yu *et al.* consolidate, re-examine and update information on this. Zhang *et al.* present recent advances on the functioning of plant NLRs in comparison with some of the animal NLRs and the molecular events during post-receptor activation through defence expression. The authors note that the plant and animal systems may complement each other for wider understanding and open up possibilities of novel disease management strategies.

Our understanding of plant immunity is based on the interactions between specific pathogen species at strain level and its host plant. Keeping pathogens at bay and accommodating beneficial microbes of the plant microbiota while balancing their contrasting outcomes is essential for plant health. Hacquard *et al.* conceptually link plant immunity with the milieu of microbiome in an ecological context, to stress the need for obtaining deeper insights toward plant fitness in nature. Iron homeostasis is important in tritrophic interactions among plants, pathogens and beneficial microbes, and its role in plant immunity is molecularly complicated. However, for lack of information on the recognition and specificity-driven plant immunity with reference to the role of iron, the review by Verbon *et al.* examines the available downstream molecular responses of plants close to the phenotypic expressions of resistance and susceptibility coupled with the ecological function of this nutrient rather than immunity per se, true to its title. Circadian rhythm is the process by which living organisms adapt their physiology to the daily environmental fluctuations. Plants encounter microbes of different lifestyles with their own biological rhythm in their biotic envi-

ronment and respond molecularly for maintaining their fitness through immunity functions. Lu *et al.* view the genetic basis and molecular crosstalk between these two physiological expressions to point out the possibility of a regulatory role for the circadian clock in the multi-layered innate immunity of plants.

Adapted pathogenic strains succeeding in neutralizing the plant immunity layers harmonize themselves to the host cellular environment for their growth and development. This adaption is facilitated by a shift in the fungal gene expression upon invasion as revealed by transcriptomic studies. van der Does and Rep examine the changes in gene expression of the non-obligate fungal pathogens from the point of view of sensing the host cues and explore the whole gamut of cellular events of biochemical, molecular and genetic factors, including transcription factors involved in gene expression influencing the pathogen adaptation. Wildermuth *et al.* present the case with the both beneficial and harmful biotroph-induced genome replication without mitosis of the host cells leading to increased nuclear DNA ploidy, a process known as endoreduplication which is common to evolutionarily distant viral, bacterial and fungal biotrophs. This is facilitated by changes in the cell-cycle transcriptional machinery together with cell-wall modifications revealed by a small set of parasitic biotroph-plant interactions that aid biotroph colonization of the host cells. The review points out that with the availability of genomes of these biotrophic fungi, it is possible to track the effectors and their cellular targets and functions paving the way to widen our understanding of endoreduplication in host-biotroph relationships.

The present understanding of *Fusarium* wilt is examined in depth revealing the importance of ecological barriers in the form of soil microbiota and obstacles posed by the host, like nature of root exudates, anatomy and responsiveness of the outer layer of root tissue, to invasive growth of the pathogen prior to the R gene activity expressed in the xylem arena (Gordon). These impediments offer opportunities for halting the wilt pathogen during the pre-immunity phase and complement the effectiveness of major gene resistance during invasive phase of the successful strains. The molecular insights gained with the model plant *Arabidopsis*-pathogen relationships underpin

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a pivotal role for the phytohormones in plant defence. Considering this along with the available genome information of other plant species, Berens *et al.* examine the phytohormones signalling networks mediating plant immunity and stress tolerance. This review opens a new window onto the possibilities of engineering hormone crosstalk to improve plant fitness and crop production. Being the third important class of plant constituents, lipids participate in signalling events in growth and development besides serving as stored energy source and as structural components of cell membranes. Lim *et al.* deal with the biosynthetic aspects of fatty acids and lipids in plants, and their role in downstream responses of plant defence. Despite the recent demonstration of the possibility for the formation of organosilicon biological compounds in microbial systems using directed evolution technique⁵, their absence in plant biochemistry has been evoking interest to understand the role of silicon in the ability of plants to protect themselves against biological and non-biological stresses. Debona *et al.* collate information on silicon-induced physiological responses of plants in their defence against stresses, besides presenting a physical barrier against microbes and environmental cues by silicon polymerization and deposits in plant cells.

Molecular epidemiology of diseases dealing with risk factors identified at the molecular and biochemical level to the etiology, transmission, spread within and between populations and in landscapes, including disease management has gained momentum in recent years. Picard *et al.* provide a critical assessment of molecular epidemiology approaches for plant viral diseases. Chromosome biology of pathogenic fungi by Mehrabi *et al.*

sheds light on the behaviour of fungal pathogens. The discussion reveals newer areas of research to expand our understanding of pathogen adaptation, speciation, shifts in host range and emergence of novel virulence strategies in fungal pathogens.

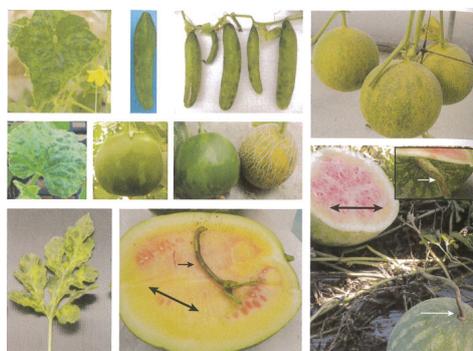
While examining the genome evolution of plant parasitic nematodes, Kikuchi *et al.* reveal the significance of genome adaptations for parasitic existence with plants. These include horizontal gene transfer from bacteria and fungi, emergence of effector gene families and adaptations of existing housekeeping proteins for functions in host–nematode interactions. The parasitic nematodes uniquely possess lesser immune response genes as they exploit the host responses against other pathogens for their protection.

The vulnerability of agricultural commodities to diseases remains a constant threat to food security and can jeopardise agro-based industries. Three of the reviews deal with diseases that have threatened the (i) cucurbit (Dombrovsky *et al.*), (ii) kiwifruit (Vanneste), and (iii) citrus (Wang *et al.*) industries. These project: (i) the seed transmissibility of cucumber green mottle mosaic virus and disease spread through international seed trade as the cause for accelerated spread of the disease worldwide; (ii) the ability to recover from bacterial bleeding canker of kiwifruit trees in a short span of six years period was through development and deployment of less susceptible cultivars by timely government investments in scientific programmes, and (iii) updated presentation of pathogen biology, disease syndromes (including molecular aspects) of yet unculturable and insect-vectored group of bacterial pathogens placed under *Candidatus* Lebribacter

(syn. Lebrobacter) species affecting citrus, potato and many other important crops, stressing the need for finding long-term solutions for disease management through genetic manoeuvring.

New threats posed by emerging diseases and appearance of pathogens with novel virulence traits emphasize the need to strengthen the surveillance strategies for effectively managing crop diseases. Parnell *et al.* emphasize the use of epidemiological factors, especially of disease spread for use with spatially explicit stochastic models to refine surveillance and control resources. Execution of disease control action at an appropriate time that would result in an expected beneficial outcome is vital in disease management. Hughes presents a model using disease risk curve based on two-parameter binary regression, considering the situations before the onset of disease and at a subsequent disease assessment. Use of lower or higher doses of fungicides than the prescribed levels for managing diseases is common with the growers, although the basis of their decisions is not free from ambiguities. Jorgensen *et al.* analysing the case studies with reference to foliage-applied fungicides in relation to farming practices, expose the existing gaps that need attention for strengthening the decision processes with the purpose of maximizing the benefits of fungicidal use through integrated management practices.

These reviews are highly stimulating, appropriately referenced and suitably illustrated. Students and researchers in the field of plant pathology, crop science and plant breeding and related fields will benefit from this comprehensive volume.



Disease symptoms caused by *Cucumber green mottle mosaic virus* in foliage and fruit of different cucurbit species.

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