the problems of mechanics, solid-state physics, specific heat, photo-electricity, the production of X-rays, atomic model of gases, and the application of energy quanta.

Even though the Nobel Committee acknowledged Planck's work in 1918, it did not find the quantum theory worthy of a Nobel Prize, due to contradictions within the theory. The Nobel Committee in its report of 15 September 1919, first noted that since 1907 Planck had received the most nominations over the years from the most competent nominees. In 1919, Einstein, Born, von Laue and Wien were among the notable nominees. The report referred to the discussion about Planck's candidacy in 1908 and the unanimous opinion of the Nobel Committee members, and decline of the proposal by the Royal Swedish Academy of Sciences.

The Nobel Committee considered Planck's discoveries on par with the classical theories. It even implicitly described him as a pioneer of science and discoverer of the elementary quanta and subsequently proposed his name for the 1918 Nobel Prize. The recommendation of the Nobel Committee was accepted by the Royal Swedish Academy of Sciences and Max Planck was awarded the Nobel Prize in 2019.

Chapter 5 gives the country-wise classification of nominees of Planck in a tabulated form from 1907 to 1919. Subject-wise classification of nominations is given by the authors as follows: (i) his work on thermodynamics and his radiation law are mentioned 44 times, (ii) the discovery of the Planck constant and/or energy quantum 13 times, and (iii) for his quantum hypothesis theory 28 times. These three categories are given as the main reasons in the 74 nominations. Planck was one of the highly nominated scientists in the history of the Nobel Prize. For the entire period of 1907–19, there was an average of ~5.6 nominations per year. Planck received nominations from nine different countries during 1907–19, of which Germany accounted for about 61.2% of the nominations.

Chapter 6 gives an account of the nominations made by Planck. Even before he won the Nobel Prize, his nominees won it. This list includes W. C. Roentgen, the first Nobel laureate in history, H. A. Lorentz, J. Stark, Einstein, Neils Bohr, A. H. Compton, Werner Heisenberg and Erwin Schrödinger. Planck's last nomination went to Enrico Fermi in 1937, who was nominated for his investigations on artificial radioactivity. It proves that Planck's reputation as a scientist was established beyond any doubt for his fundamental contributions to science.

Chapter 7 gives conclusions of the authors based on data of nominations received by Planck: 'In the first decade of the 20th century, Planck's energy quantum did not play any role. Its application to explain the specific heat by others, such as A. Einstein, Peter Debye, and Walther Nernst attracted the attention of scientific community. In the second decade of the 20th century, on the one hand Planck's energy-quantum won popularity; and at the same time its drawbacks became clear.' The authors are of the opinion that the Nobel Committee was not to be blamed for the delay in awarding the Nobel Prize to Planck. It was due to lackadaisical attitude of his nominators, who expressed reservations about the veracity of his quantum ideas. After much wrangling for 11 years (1908–19), Planck was awarded the Nobel Prize for his 'speculative' idea of energy quanta proposed to explain the black body radiation spectrum over all wavelengths, now known as the Planck's law.

In 1924, S. N. Bose derived Planck's law of black-body radiation using Einstein's light quantum. This derivation is the most popular in the literature. It is unfortunate that Bose missed the Nobel Prize in physics despite his fundamental contributions to science. Planck's legacy is so strong that more than hundred institutions are named after him in Germany and elsewhere. The authors of this book deserve praise for telling the reader the interesting story of Max Planck winning the Nobel Prize in physics.

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This volume contains 131 well-compiled reviews contributed by experts mainly from USA, Europe, Canada and a few from Japan, Vietnam, etc. The prefatory chapter is by Maarten Koornneef (Max Planck Institute (MPI), Germany and Wageningen University (WU), The Netherlands).

Broadly, the volume has two chapters on light perception – one on phytochrome and the other on UV receptors. Following different environmental clues, plants produce various signals. There is a chapter on histidine kinases and two-component signalling. The role of ions as regulated by ion channels and salicylic acid as a signal in defence and other responses is covered in two elaborate reviews. A major portion of the book is devoted to new work that has been reported to explain various developmental responses. Accordingly, there is a chapter each on cell cycle, tuberous and tuber root development, regulation of leaf shape and epidermis, and development of male gametophyte. In addition, there is a review on pollen–pistil interactions and embryogenesis.

Under metabolism, there is a chapter on evolutionary history of plant metabolism and others specifically dealing with the role of trehalose. There is a review on next-generation mass spectrometry for a detailed analysis of the metabolome. Interestingly, some detailed reviews on recent work regarding genomics and transcriptomics are on single-cell transcriptomics, shuttle RNA, long non-coding RNAs and on systems biology approach to search for gene regulatory networks. There is chapter on pan-genome technology and another on the utilization of natural variation in crop plants towards their applications in agriculture and crop improvement. Three plant-specific reviews deal with cotton, *Marchantia* and carnivorous plants. The importance of diploidization in land plants is also reviewed separately. A novel and interesting study on biological phase separation and its functions is discussed. New findings on plant foliar and microbiome interactions, and on biological phase separation are mentioned. Molecular mechanism of energy dissipation and engineering crassulacean acid metabolism have also been elaborated in two separate reviews. With respect to biotic stress, the function of NLRs (nucleotide-binding domain leucine rice repeat receptors) in innate immunity as defence components is covered in detail.

The chapter on phytochrome signalling networks by Cheng *et al.* has brought in focus the role of both positive and negative components under dark and light conditions in downstream signalling, following photo-perception, in controlling various developmental and biological functions.

Most of the work that is summarized has been done on *Arabidopsis*. The work has been well-illustrated as current models in five figures. The involvement of PIFs and other transcription factors in light and temperature is brought out clearly, as also an interesting aspect of phyB-mediated, light-regulated alternate splicing of pre-mRNAs. Podolec *et al*. describe the properties of UV-B receptor and how its monomeric form competes with COP1 to check its ubiquitin ligase activity. The UVR8-mediated signalling also influences gene expression. Figure 1 provides molecular details regarding the functions and actions of UVR8 concisely. A brief description of UVR8 in antagonizing shade avoidance, thermo-morphogenesis and its role in circadian clock entrainment is also given. They have also shown how UVR8 signalling can be integrated with other photoreceptor pathways.

An update on structural diversity, localization, interactions and various functions of the signal receptor histidine kinase, which forms part of a two-component system, is given by Hoang *et al*. This includes cytokinin receptor, ethylene receptors and phyB signalling pathways of different HK receptors, which have all been illustrated in figure 1 that is self-explanatory. Functions of these HK receptors under different stresses, as also in different plants, have been covered. Peng *et al.* have covered the recent developments in salicylic acid biosynthesis and signalling. This review focuses on the role of SA receptors in plant immunity. It also briefly mentions about its role in flowering and senescence, and crosstalk with other hormones like ethylene and jasmonic acid. In fact, there is a separate chapter by Duxbury *et al*. which deals with the role of NLRs in plant immunity, wherein they have also compared the functions with animal systems. Like animal inflammasomes, plants also show NLR resistosomes. Plant NLRs also have different functions like in hybrid necrosis and surveillance, and in some fungi, cell death during heterokaryon incompatibility. A detailed review on the structure and function of plant ion channels present in different organs like roots, leaf, stem, guard cells and pollen tube, and within these on different organelles has been well illustrated and described in terms of structure of the proteins, maintaining ion homeostasis and also function as signals under certain conditions.

A few of the reviews focus on plants other than *Arabidopsis* and some known model systems. One that interested me is on the origin of carnivory by Rainer Hedrich and Kenji Fukushima. Darwin wrote a treatise on insectivorous plants in 1875. This chapter highlights the molecular work that has been done in the recent past to understand the hunting trap cycle which, for example, has been well illustrated in figure 2 for Venus flytrap. Details of capture organs, the channels involved and the biochemistry of ‘green stomach’ are provided. The well-written chapter regarding perspectives on cotton research by Hunag *et al.* describes the evolution of allopolyploidization with A and D genome using an assembly of five different cotton genomes. Details regarding the role of hormones like ethylene in cotton fibre elongation following regulation of fibre development through involvement of transcription factors and epigenetic modifications and the role of small RNAs. All these processes are well presented in figure 4. The gossypol biosynthesis pathway is described as also the genetic improvement of cotton plants for biotic and abiotic tolerance. Among lower plants, development and molecular genetics of model bryophyte *Marchantia polymorpha* are described by Kohchi *et al*. This organism has become a model plant to study eco–evo–devo biology. With all the information and mutants available and also amenable to genome editing, regulation of its development by light, etc. it can provide important clues for the development of land plants during early evolution.

On the genomics front, there are three reviews at different scales of investigation. Sefferth *et al*., describe how investigations on transcriptomics at the single cell level can broaden our understanding of plant development by developing a cell atlas, as has been done now in many plants. Emerging techniques in this area have been described. Alvarez *et al*. have reviewed the work that describes dynamic changes in gene regulatory networks which constantly modulate in response to environmental signals. More specifically, they deal with transcription factors and also present various methods to employ machine learning tools to forecast gene expression events at the single-cell level. Lei *et al*. cover the area of pan-genomics, wherein one should be able to catch all the variations, as a single reference genome may not give full representation. Currently, this work has been done on many species, as described in table 1. The challenges are in terms of analysis before this vast information can be used for practical applications.

An interesting review by Emenecker *et al*. is on biological phase separation and biomolecular condensates, which are now being reported in plants. Being introduced for the first time to plant biologists, the basic principles and concepts have been covered on liquid–liquid and protein phase separation. A few examples of condensates or phase separation systems are described and illustrated in figure 4.2, which includes phyB, ARF19/ARF7, FCA, etc. This topic needs more research and the authors have brought out clearly the future directions in the area.

In recent years, there have been major technological developments in mass spectrophotometry and computational metabolomics to assist in identifying the diversity of specialized metabolites produced in different plants, and relate them with some ecological studies, especially with respect to their role in plant defence. Work in this direction has been well reviewed by Li and Gaquerel. In a somewhat related review, Maeda and Fernie describe the evolution of plant metabolite networks. They include processes like photosynthesis, TCA, amino acid pathways, carotenoids. They also dwell upon the diversification of C3, C4 and crassulacean acid metabolism (CAM). Schiller and Brautigam describe how the CAM pathway can be engineered. More specifically, Fichtner and Lunn have reviewed the role of trehalose-6-phosphate in regulating plant metabolism and development by affecting sucrose balance and thereby acting as a signal controlling flowering, embryogenesis and shoot branching. They refer to it as sucrose – trehalose-6-phosphate nexus.

A few interesting and updated reviews on cell-cycle regulators, and how the hormones and other environmental cues influence the cycle both positively and negatively are presented by Shimotohno *et al*. The conditions leading to endo-reduplication, as also the role of epigenetic regulation have been covered. Michael *et al*. present the process and significance of diplodization, leading to polyploidization in land plants. A few other chapters deal with the development of leaf shape diversity (e.g. by Bhatia *et al.*), viz. components and regulation in simple and complex leaves, as also how carnivorous plants form three-dimensional insect traps. Shape regulation in plant epidermal cells which perform many different functions is reviewed by Liu *et al*. The role of auxin, signalling pathways like ROP dependence, etc. and importance of microtubules is well discussed. There is an in-depth review on comparative embryogenesis by Dresselhaus and Jurgens. This also includes current information on parthenogenesis, and the role of small RNAs and chromatin. They describe how different embyro shapes and patterning may be initiated in a time-dependent manner. Evolutionary origin of male gametophyte in angiosperms, and the complex mechanisms which involve post-transcriptional regulation and signalling, including cell-to-cell communication within the reproductive tissues are discussed by Hafidh and Hony. Similarly, detailed molecular mechanisms of pollen–pistil factors associated with reproductive barriers are described by Broz and Bedlinger. The role of mobile signals (mobile RNAs) and other factors in the development of tuberous roots, using potato and cassava is described by Zierer *et al.* Cai *et al.* deal with how small RNAs shuttle, as also proteins, between cells and also with interacting microorganisms using extracellular vesicles. How these can be used as carriers of RNA interference for crop protection is also discussed.

There is an interesting review by Hawkes *et al.* on the recent emerging area of plant microbes. They describe how foliar microbiome can influence plant phenotype, thereby highlighting the importance of studying functional relationships between plant growth and ecology.

Overall ARPB 2021 has wealth of information presented in a readable and understandable manner with good illustrations, tables and models. A must read for every plant biologist engaged in teaching and research.

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