Annual Review of Neuroscience, 2016. Steven E. Hyman, Carla J. Shatz and Huda Y. Zoghbi (eds). Annual Reviews, 4139 El Camino Way, P.O. Box 10139, Palo Alto, California 94303-0139, USA. Vol. 39. x + 440 pages. Price: US$ 102.

The field of neuroscience is burgeoning with every passing year and is becoming increasingly interdisciplinary. Neuroscience research spans scales in space and time: from molecular levels to cellular, systems and behavioural levels and from the embryo to adult to senescence. The current volume of the *Annual Review of Neuroscience* quite suitably reflects this broad range of topics in its collection of articles. I will discuss a few of these reviews and present key advances.

Your smart phone has a global positioning system (GPS) in it to help you navigate but, believe it or not, our brain has its own positioning system! In recognition of the significance of their discovery of this positioning system, John O'Keefe, Edvard Moser and May-Britt Moser were awarded the Nobel Prize in Physiology or Medicine in 2014. Components of the positioning system are found in the hippocampus and in the medial entorhinal cortex (MEC). MEC cells turn on ('fire') as a function of the speed, heading or location of the animal. One of these cell types is the grid cell. The Mosers' group discovered grid cells in 2005 and in the present volume they provide a comprehensive overview of what is known about these cells after ten years of work. Grid cells encode hexagonal regions within a 2D space. The size and spacing of these hexagonal grids vary from cell to cell, with just a few cells being sufficient to cover the entire environment. Interestingly, grid cells maintain their location specificity irrespective of the speed and heading of the animal. What generates the hexagonal grid firing pattern? Several computational models have been proposed based primarily on Turing's reaction–diffusion model, and incorporating centre-surround inhibition or spike frequency adaptation to get spatially selective firing patterns. Grid cells are thought to provide inputs to the relatively well-studied hippocampal place cells although how grids get transformed to place fields is not yet understood.

To determine how one group of neurons affects the activity of another group of neurons, the wiring diagram or connectivity between these two groups must be known. There is great enthusiasm for defining connectomes or the wiring diagram of nervous systems, as advanced methods are now available for mapping synaptic connections. Swanson and Lichtman present a review of approaches to deciphering connectomes, their implications and the potential pitfalls to be wary of in utilizing these massive data sets. Connectomes can be defined at multiple spatial scales – for example, a wiring diagram describing connections between two different regions of the brain would constitute a macroconnectome. Mesoconnectome refers to connectivity maps between different cell types within a brain region. Microconnectome defines the wiring diagram between particular cells with complete reconstruction of their projection patterns and synaptic connections. At the most detailed level, nanoconnectomes can be built which will define the number of synaptic contacts using ultrastructure data from electron microscopy. While generating connectomes at all of these scales is possible, one must also remember the lessons learnt from the assembly of genomes. Just like sequence alone does not provide an understanding of gene regulation, the connectome alone will not yield an understanding of nervous system function. But just like the sequence is necessary for further analysis of gene regulation, the wiring diagram is a necessary map onto which functional studies can be overlaid. To extract meaningful knowledge from vast amounts of connectomics data at every scale, neuroscientists need to build collaborations with mathematicians and computer scientists for automation and visualization. Such efforts will pave the way for understanding how structure leads to function – i.e. how the wiring of the nervous system constrains its output.

The final output from the nervous system is in the form of movement and movement is critical for survival. Spinal circuits that generate rhythmic locomotion such as walking have been studied in a number of animals ranging from jawless fish like lamprey to primates. Humans, because of their upright stance and bipedal locomotion, could have spinal control mechanisms that are distinct from other primates. In his review, Jens Bo Nielsen describes the descending control pathways that have been demonstrated in humans. One of these is a direct synaptic connection from the motor cortex to spinal motor neurons and is called the cortico-motor (CM) neuronal projection. What is the purpose of such a direct projection to motor neurons in addition to the indirect control exerted by the cortex via spinal interneurons? Several possibilities are proposed. One is that such a direct projection enables deliberate, conscious and willful control of muscle activation. It may also be particularly useful when we are doing difficult or unfamiliar movements, requiring a lot of attention to be paid. In addition, CM projections may control movements that require coordination of muscles throughout the body such as during upright standing.

The motivation to move is typically driven by either a desire to seek pleasure or an urgency to avoid pain. An ability to predict reward and punishment is a beneficial trait such that suitable behavioural action can be initiated to seek the former and avoid the latter. Hailan Hu provides a detailed review of the current knowledge on neural circuits that mediate processing of reward and aversion. Dopaminergic neurons in the midbrain show phasic activation when an unpredicted reward is given and suppress firing when reward is expected but is not given. This led to the proposal of reward prediction error (RPE) hypothesis, according to which, the magnitude of firing in dopaminergic neurons is directly proportional to the difference between the likelihood of occurrence versus expectation of reward (error). Thus, these neurons are active when the reward prediction is poor and the error is high but become silent when the animal has learnt to predict reward accurately. Recent optogenetics experiments have provided further support to this hypothesis. The predominantly serotonergic raphe system also plays critical roles in the processing of reward and punishment. Serotonergic neurons in the dorsal and median raphe nuclei (DRN and MRN) project to forebrain regions and have been shown to be activated by rewarding stimuli such as food, sex or social interactions but not by aversive stimuli such as foot shock or bitter-tasting quinine. Conversely, GABAergic neurons in the same nucleus are activated by aversive stimuli but not by hedonic stimuli. Thus serotonergic and GABAergic neurons in DRN and MRN seem to process complementary signals.

Are there genetic differences that predispose individuals to certain kinds of behaviours? This explosive question can be studied well in eusocial insects such as honey bees and ants. Friedman and Gordon present a review on the genetics and behaviours of ants. An ant colony is a super organism. The colony consists of workers, which are sterile females, reproductive queens and males that are short-lived. By looking at genome sequences of each of these 'castes', one can determine genetic bases for certain kinds of behaviours such as nursing or foraging or for longevity and reproductive success. Whole genome sequences are available for seven ant species, in addition to transcriptomics data from different castes and developmental stages. Interestingly, the most interspecies differences in expression levels occurred for genes associated with chemosensation. Genes associated with the synthesis of cuticular hydrocarbons (CHCs) show an expansion in ant genomes. Within species, whole-body transcriptome comparisons revealed differences in genes associated with longevity between queens and the comparatively short-lived workers.

To study behaviour quantitatively, such as in the studies described above, advanced computational methods are required. To analyse behaviours, scientists most often rely on video recordings at suitable frame rates. Once videos are made, how does one extract the most useful features for an understanding of the behaviour? The review by Roian Egnor and Branson describes the latest tools and techniques available to researchers for automated and semi-automated behavioural analysis. The first task is to segment the animal from the background such that in every frame, each pixel is either labelled as being part of the animal or the background. This is readily achieved in high quality videos with proper lighting and when the camera is stable. A frame is captured prior to introduction of animals, which is then subtracted from every frame of the video to detect the animals. When multiple animals are present, it is also necessary to identify each animal such that they can be individually tracked. This can be done using the position and pose of each animal in one frame to estimate the direction of its motion in the next. After this is achieved, specific behaviours can be detected and quantified using rule-based approaches, supervised machine learning or unsupervised machine learning. While these approaches work well with behaviour recorded in the lab under controlled conditions, automated analysis of behaviour recorded in the wild still presents huge challenges because of variations in lighting, background texture and number of individuals. Increasing collaborations between biologists and computer scientists will pave the way for working out appropriate solutions to these problems.

VATSALA THIRUMALAI

National Centre for Biological Sciences,
NCBS–TIFR, Bellary Road,
Bengaluru 560 065, India
e-mail: vatsala@ncbs.res.in

Chemistry: The Impure Science, 2nd Edition. Bernadette Bensaude-Vincent and Jonathan Simon. Imperial College Press, 57 Shelton Street, Covent Garden, London WC2H 9HE. 2012. 296 pages. Price: £79. ISBN 9781848168114.

Picture this: A far-off, bucolic land that you have heard of, but never stepped into. A land that on the one hand draws you to it because of its ideologies, and on the other, is overshadowed by the eminence of bigger, easily-accessible countries nearby. An almost Shangri-la in the sense that not everyone knows this country exists, and you have never heard of a Frommer's travel guide to reach and explore this place.

If academic disciplines were countries, Philosophy of Chemistry would be this remote, idyllic land.

Modern chemistry labs are not really the breeding grounds for philosophy of chemistry talk, but on the rare occasion when a philosophical or historical reference is made regarding an experiment, it is but natural that it should evoke a sense of wonder in the lab coat-latex gloves-safety goggles attired chemist who can tell barium from strontium, but in all probability would be hard-pressed to tell, say, how Kant's enlightenment philosophy helped shape the concept of element as it emerged.

The book under review shows by way of several examples that philosophy and chemistry have much to say to each other. The book is a delightful synthesis of thought beginning with chemistry as we know it – the good and the not-so-good, and traces a path back to the alchemical period. The second section of the book puts chemical philosophy on its forward journey with significant milestones along the path like atomism, elemental theory, the periodic table, chemical positivism, etc. In the last section, the reader finds looking at the path's map with a *You Are Here*, placed at 'nanosciences,' with pointers heralding the terrain's final destination – Chemistry for Future.

The authors begin by emphasizing the importance of chemistry in modern life and add that despite chemistry's ubiquity in our lives, it gets a bad press at times due to its deleterious effect on the environment. It is this downside of pollution that half persuades the authors to term chemistry an impure science. Conviction emerges from the secondary status of chemistry held to the helm of physics and mathematics, and by the rather hybrid nature of chemistry today, in being a mix of science and technology.

The negative image of chemistry, it turns out, the authors indicate is not something new, but has been around right from the days of alchemists toiling over their pots. The discipline's image was not helped either by early chemists who were intent on playing God. Literature too contributed to these Faustian ambitions of chemists. A case in point being the rather infamous Frankenstein's monster. Chemistry emerges from its shroud of negativity as the authors take us along on a philosophical journey of chemistry's history.

Chemistry, the authors point out, has been a cognitive toolkit of synthesis in that it has always created its object unlike other sciences. Citing Berthelot, it is pointed out that he thought of synthesis as a means to know the world and to delve deeper into nature.

The concept of matter is handled in much detail in the book, spanning the imaginary phlogiston, Kant's noumenal world, the concepts of element and atom, and finally leading to a discussion on whether chemistry is the heir to Aristotle's philosophy. This could well be one of the highlights of the book for those who have questioned 'How did Chemistry come to be?'

The dialogue on the elemental theory is moved forward with the introduction