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Introduction

“Science is not a collection of facts or of unquestionable generalizations, but a logically connected network of hypotheses that represent our current opinion about what the real world is like.”

— P. B. Medawar

In other words, Medawar is saying that our understanding of science should be driven by provisional theory and core ideas. Details either support or refute those ideas, showing us how reliable our ideas are. Core ideas drive new research and discovery. Therefore, I think it is the first duty of teachers and learners alike to make certain they identify and understand the core ideas of their discipline. This book is dedicated to that end.

Rationale for a Core Ideas Book

What the brain produces is a kind of mental model of the world, a system for handling the information that flows from sense organs to the generation of appropriate responses. The integration of the sensory data is central to monitoring the world “out there” and to creating a model of it “in here.” The “in here” becomes the real world as far as animals and people experience it. To explain what we know about how all this occurs in the brain is no trivial task.

Too many books, in my opinion, fall short of providing the “big picture” of how nervous systems work, because the books are so heavily laden with factual, often highly technical, detail that the essence of understanding can be obscured. Students are easily confused over what they must know as opposed to what is nice to know. Even when

“nice to know” is deemed “must know,” there are over-arching ideas that ought to be mastered first. What a student-oriented text should be is one that focuses on principles and concepts — the BIG ideas! If you get the big picture first, then it is easier to integrate the details into that conceptual framework. Learning the other way around is harder to do.

Many of the textbooks that claim to be about “principles” are really about principles only in the sense that a forest is about ecology or equations are about mathematics. The standard science textbooks have gotten progressively larger, serving better a role as reference books than as textbooks. This trend is especially pervasive in such active research areas as neuroscience, where students and teachers alike are swamped with new information.

How bad have things gotten? We can best illustrate the problem by the annual meeting for the Society of Neuroscience. For years now, the attendance has been running about 25,000-28,000 scientists and the number of papers presented hovers between 14,000 to 16,000, with each paper presented in excruciating detail. Who can digest all that? No professor can keep up. How can students do so? Probably no other field of science is in such dire need for condensation and integration into core ideas.

This learning problem is especially acute for professionals who are not neuroscientists, but whose work must be informed by neuroscience. These professionals include physicians, osteopaths, veterinarians, dentists, clinical and experimental psychologists, computer scientists, bioengineers, animal behaviorists, biologists, nurses, and allied health workers. For them, a book like this one may serve as their primary source of neuroscience understanding.

Certainly, the typical neuroscience textbook does a poor job of condensing the oceans of neuroscience information into drinkable amounts. Even one of the early, well-known neuroscience principles book, *Elements of Neurophysiology* (by Ochs, 1965, Wiley & Sons), took 621 pages to specify the “Elements” (principles). At the time of the writing of this *Core Ideas* book, the most popular book, *Principles of Neural Science* (4rd Ed.), is that by Kandel et al., 2000, Elsevier. This

book is 1,414 pages long and has 44 authors. A competing book, *Fundamental Neuroscience*, by Zigmond et al. 1999, is 1600 pages long, has 15 editors and 150 authors. Clearly, such books tell most readers more than they want or need to know.

The practical value of texts should lie in their pedagogical approach, which is the opposite from the tack taken in many textbooks on biological and medical subjects. Students don't need encyclopedic texts to learn, though they can certainly find them useful as references. Students and professors alike are tired of an educational process devoted to pouring information into one ear while it spills out the other. The exponential expansion of new knowledge is causing cognitive overload in both students and professors, short-circuiting their ability to sustain perspective about the whole of biomedical science and to think coherently about the details of how the body works in both health and disease. We are learning more and more about less and less, and that causes a progressive loss of capacity for synthesis and ability to think about the larger meanings of biomedical science.

In recognition of the cognitive overload problem, several medical schools (McMasters, Harvard, Southern Illinois, Bowman Gray, U. New Mexico) pioneered in the now popular teaching approach of converting the traditional lecture-based curriculum to a tutorial, group-based learning format where critical thinking and information management skills are emphasized rather than rote memory. Some veterinary colleges are also making similar curricular changes. This trend will surely grow, because it is aimed at teaching students to manage and integrate an ever-expanding biomedical data base.

The situation argues for a new kind of textbook, one that is focused on the first-principles of the discipline. In addition to encyclopedic tomes for each discipline, we need small supplementary texts that give the big picture and explicitly describe the basic foundational ideas of the discipline — and no more! The time it takes to learn is important for students (if they work part time, for example, time is money). An inexpensive e-book like this will speed the time it takes to grasp instruction from a traditional, detail-oriented textbook.

Defining a Core Idea

We must have some kind of working definition of core idea or “principle.” While many ways can express the idea, this text uses the following working definition:

A principle must go beyond a collection of observations. Principles integrate multiple observations and help to explain these observations, providing understanding and insight. A principle embodies the underlying rules or mechanisms of structure, organization, or operation that give rise to the observations. We distinguish principles from concepts only in the sense that concepts often embody more than one principle.

In identifying these core ideas, we must recognize that they are commonly held beliefs about what is true and fundamental. Not everyone will agree that each of the approximately 75 “core ideas” in this book deserves such lofty status. Never mind. We should not quibble over what ideas deserve to be included and what ought to be thrown out or merged. This can only lead to endless debate and interfere with what is a practical way to teach and learn.

Many of the statements of principle are incomplete. They may also lack sufficient qualification. Statements of principles often serve to inspire debate and more complete or precise exposition. The effort to identify principles comes at a cost: arbitrariness, uncertainty, and controversy — but the value is worth the price.

Rationale for An E-book

This book should be considered as a complement to a traditional text in neuroscience. When students have to pay hundreds of dollars for traditional textbooks, it is unrealistic to expect them to buy a supplementary text. Several leading neuroscience books cost on the order of \$150 each. E-books are inexpensive and at a price low enough that most students should be willing to pay. The e-book also has the advan-

tage of hyperlinking, making it easy for students to find quickly what they are looking for. If the student uses Adobe Professional, the Adobe pdf file format of this e-book makes it possible for students to annotate the e-book with in-context commentary or memory tips. The pdf format can also make this book very portable for use in PDAs that have the Adobe Reader version for PDAs. While many people prefer reading hard copy rather than a computer screen, it needs to be remembered that this book has a modular design and it only takes a few minutes to read a given module.

Organization of the Book

Most of what everybody needs to know about the nervous system can be summarized in a list of 75 principles or core ideas. Each core idea is treated as a distinct module, although there are links indicating other closely related ideas. Most of the ideas in the book are presented in the form of the reductionistic research tradition in which the nervous system is understood in terms of molecules, single-cell physiology, anatomical pathways, and input-output relationships. Despite all the powerful insights that have accumulated, mostly in the last 5 years or so, we know that reductionistic research has its limits and cannot answer the most important questions about how the brain assigns meaning to life experience, generates intentionality, and makes choices and decisions. It is now increasingly clear that the more profound thinking actions, such as memory, emotions, and consciousness, derive from interactions of huge populations of neurons. Dynamic interactions of large neuronal ensembles are best revealed by monitoring concurrent activity in multiple neuronal populations, using such tools as functional MRI for metabolic indicators and quantitative electroencephalography for indications of extracellular voltage fluctuations at various frequencies and degrees of coherence.

The modular construction of topics allows the reader to pick and choose to read a minimal amount of material to get prepared for understanding the more comprehensive and detailed traditional textbooks and research papers. Maybe even highly specialized expert neuroscien-

tists may find some useful perspectives from this approach to explaining the subject of neuroscience from a holistic perspective.

Core ideas are grouped into categories to make it easier to organize and remember them. The categories are:

Overview

Cell Biology

Senses

Information Processing

States of Consciousness

Emotions

Learning and Memory

Motor Output and Control

Development/Trophism

The “Overview” section contains certain ideas that transcend more than one of the other categories. Each section begins with a short introduction that presents an overview of the “big ideas” in that category. There is a “concept map” that helps to display graphically the relationships among the various ideas. Then there follows a succession of modules, each of which explains one of the ideas in that category. Each module has a name, reflective of the idea. Each core idea is first stated succinctly in a few sentences, followed by a short section of key terms. Then the core idea is explained, followed by some examples to illustrate how the idea is typically used in neuroscience. The next section lists other principles that are most directly related. Finally, there is a reference section that may include lists a list of “Citation Classics.” The Classic papers are highly cited publications that scientists generally agree have helped to define the field. A “Classic” is a highly cited publication, that was identified by the *Science Citation Index*, published by ISI Press, in Philadelphia. For some of the classics, there is an associated publication that appeared in the ISI publication, *Current Contents*, that contains a history of the research that enabled the publication to have such a major impact. In some cases, I have taken the liberty of includ-

ing some references in the Classic section that have not been officially “annointed” by ISI’s data. Sometimes, it is because these were landmark papers that were published before ISI began keeping citation records. In a few other cases, the choice is strictly my opinion.

Unfortunately, even these classics seem to have a short life span. One of the things I have noticed over the years as neuroscience information has accumulated is that there is much need for a sense of history of the discipline. Young scientists, who tend to be the most active in research, tend to work in the currently “hot” areas. Ideas and data over a few years old are often ignored. As a result, I see more and more research reports that have either “reinvented the wheel,” or that would have been greatly enriched had the authors been aware of older literature.

Suggested Uses By Teachers

This book is not meant to be read front to back like a textbook. Its modular construction allows the teacher to pick and choose what topics need to be covered at any particular time. This design makes the e-book useful for traditional neuroscience courses or for other kinds of courses where only a portion of the neuroscience discipline needs to be taught to students. The idea is to use these core ideas as an introduction that should precede what is planned for a given day’s class. Teachers know that students typically won’t study ahead of time, but there are ways to make that happen. The first approach should be to convince students that it is in their interest to read about the relevant core ideas before coming to a class where those ideas are explored. If gentle persuasion does not work, there are always the options of pop quizzes or advance assignments, where, for example, the student writes a summary of the relevant core idea or submits written questions or insights about the core idea before class.

If students will come to class thus prepared, the students and teachers alike will find this book very liberating from the stifling tedium of traditional lectures. Now class time can be spent in more sophisticated and interesting ways. Thus primed before class with appropriate information and understanding, students can engage in such enrichment class-time

activities as:

- Discussion of questions at the back of each chapter.
- Discussion of other questions that emerge from the text (instructor can project the text on a screen and highlight statements in Adobe that trigger other ideas or questions.
- Critique of related research papers, presented either by the teacher or the students.
- Participation in assignments, problems, projects, or case studies.
- Socratic dialog to explore the implications of the core ideas as they relate to neuroscience theory or to medical or psychiatric situations.
- Presentation and discuss information of related neurological disorders.
- Presentation and discuss related news items from television, newspapers, magazines or the Internet.

Less can be more. By condensing information that students must have a working understanding of, we increase the odds that students will remember what they really need to remember in order to think creatively and critically about subsequently presented information.

There is also the issue that professors increasingly are becoming disenchanted with traditional textbooks. There are not only the problems of cost and built-in obsolescence, but also the advent of the Internet is changing the way information is communicated and used. Students are going to use the Internet anyway to get neuroscience information. This book on core ideas is a quick way to prepare them to use the Internet in an informed and discriminating way.

Suggested Uses By Students

For the newcomer to a given area in neuroscience, the learning tactic should be to study this book first. Then the student is better prepared to understand traditional lectures or what is read in other textbooks, reviews, and primary literature. A basic learning strategy should always be to get the big picture first and then fill in the details. Students have great difficulty in approaching neuroscience in the other direction of learning

details first and then trying to infer by inductive logic the core ideas. It is all too easy to get so bogged down in the massive detailed knowledge of neuroscience that the basic core ideas go undetected. Even professional neuroscientists may need the opportunity to step back from their myopic sub-specialty perspective and view the nervous system less reductionistically and more comprehensively — at least that is what I discovered as I developed this book.

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