

Science Reunified

Todd H. Rider thor@riderinstitute.org 13 November 2019

Any suggestions for improvements would be greatly appreciated.

“The end of our foundation is the knowledge of causes, and secret motions of things; and the enlarging of the bounds of human empire, to the effecting of all things possible.”

—senior scientist of Salomon’s House,
in Sir Francis Bacon’s *New Atlantis* (1627)

Overview

This work is a collection of surveys or summaries of major science-related subjects in undergraduate and graduate education, covering the fields of applied mathematics, physics, nuclear engineering, mechanical and aerospace engineering, electrical engineering, earth science, chemistry, biology, and medicine. Each summary is intended to rapidly and easily introduce readers to the main points of a given subject, with emphasis on very short, physically intuitive derivations and explanations. All are subject to continual expansion and revision, so comments and suggestions are welcome.

I devoted myself to studying the texts—the original and commentaries—in the natural sciences and metaphysics, and the gates of knowledge began opening for me. Next I sought to know medicine, and so I read the books written on it... I cared for the sick and there opened to me some of the doors of medical treatment that are indescribable and can be learned only from practice... I returned to reading logic and all the parts of philosophy... I compiled a set of files for myself, and for each proof... I pondered over the conditions of its premises, until this problem was verified for me... So when I had reached the age of eighteen I was finished with all of these sciences; at that time I had a better memory for learning, but today my knowledge is more mature...

–Ibn Sīnā (Avicenna), *Autobiography* (ca. 1037 AD)

Here is a catalogue of all his books: ...*The Shifā* [summary of sciences], eighteen volumes; *The Canon [of Medicine]*, fourteen volumes... He began with the Physics of a work which he called the *Shifā*. He had already written the first book of the *Canon*, and every night pupils would gather at his house, while by turns I would read from the *Shifā* and someone else would read from the *Canon*...

I asked him to finish the *Shifā*; he sent for Abū Ghālib and asked him for paper and an inkstand, which he brought. The Master wrote down the main topics in approximately twenty quires of one-eighth size, continuing on it for two days, until he had written down the main topics without the presence of a book or source to consult, but entirely from his memory and by heart. Then he placed these quires before him, took a sheet of paper, examined each problem and wrote a commentary on it. He would write fifty pages every day, until he had finished all of the Physics and Metaphysics with the exception of the book on Animals. He then began on the Logic and wrote one section of it...

He occupied himself in Iṣfahān with finishing the *Shifā*, completing the Logic and the Almagest [astronomy], since he had already summarized Euclid [geometry], the Arithmetic, and the Music. In every book of the Mathematics he presented additional materials, the need for which he thought to be compelling... And elsewhere in the Almagest on the science of astronomy, he presented materials which were unprecedented. In Euclid he presented some geometrical figures, in the Arithmetic some excellent numerical properties, and in the Music some problems which the ancients had neglected. Thus he finished the *Shifā*, except for the two books on the Plants and the Animals, which he wrote on the way in the year that Alā al-Dawla attacked Sābūr Khwāst... The *Canon of Medicine*, part of which he wrote in Jurjān and in al-Rayy... was finished in Hamadhān.

–al-Jūzjānī, *Biography of Ibn Sīnā* (ca. 1037 AD)

Science Reunited is intended to be a collection of concise, clear presentations of major university-level subjects in physics, engineering, chemistry, biomedicine, and earth science:

1. **Applied Mathematics**

Physics:

2. Classical Mechanics
3. Electromagnetism & Acoustics
4. Nonrelativistic Quantum Physics
5. Statistical Physics
6. Special & General Relativity
7. Relativistic Quantum Physics

Mechanical/Aerospace Engineering:

8. Mechanics of Materials
9. Fluid Mechanics & Aerodynamics
10. Thermodynamics & Propulsion
11. Heat Transfer

Nuclear Engineering:

12. Nuclear Physics
13. Fission Power
14. Plasma Physics & Fusion

Electrical Engineering:

15. Analog & Digital Circuits
16. Semiconductor Devices
17. Solid State Physics
18. Optics & Quantum Electronics

Chemistry:

19. Inorganic Chemistry
20. Organic Chemistry
21. Materials Science

Earth Science:

22. Geology
23. Oceanography
24. Meteorology

Biology:

25. Cell Biology
26. Biochemistry
27. Molecular Biology & Genetics
28. Microbiology
29. Zoology
30. Botany

Medicine:

31. Cardiopulmonary & Renal Physiology
32. Gastrointestinal Physiology
33. Neuroscience & Sensory-Motor Systems
34. Immunology
35. Reproductive & Developmental Physiology
36. Miscellaneous Tissues

Subjects have been listed by fields merely for convenience; note that some subjects are essential for fields other than just the one under which they are listed. For example, nuclear engineering requires not only the topics listed under that heading but also the topics listed under mechanical and aerospace engineering. Likewise, the field of chemistry covers the topics listed under that heading, yet also includes biochemistry, nonrelativistic quantum physics and statistical physics (dubbed physical chemistry by chemists), and other topics.

Hopefully this work will:

- Allow students to learn subjects more easily, thus permitting them to more rapidly reach the frontiers of those subjects and make original contributions.
- Allow students to learn more subjects than they otherwise could, thereby slowing the drive toward microspecialization and encouraging cross-fertilization of ideas among different scientific areas.
- Permit experienced scientists to quickly and easily brush up on an old subject or learn a new one.

The philosophy guiding the presentations of these subjects may be summarized as follows:

- The major topics of each subject are included. Topics within a subject are chosen because they have modern relevance, regardless of whether or not they are included in the traditional “canon” of that subject’s classical topics. Therefore some traditional but less relevant topics have been ignored to make room for more important things that are often neglected.
- The topics are described with as much physical insight as possible, instead of merely bombarding them (and the reader) with mathematical analysis. This seemingly obvious principle is often overlooked in other books.
- The choice of subjects and the depth to which each is explored are determined by the author’s personal prejudices about what the well-rounded general scientist should know, as opposed to what specialists in various fields should know. In that sense, this work bears some similarity to L.D. Landau’s “theoretical minimum,” the material which he felt every good physicist should know. However, the present work clearly covers much more than just physics.
- As a mercy to the reader, the presentation of each subject is kept as brief as is consistent with the requirements of including and clearly explaining all of the major topics. Typically the completed and polished expositions are less than 100 pages per subject.
- While some of the subject presentations are prerequisites for fully understanding some of the other presentations, the only prerequisites for the entire collection are a good knowledge of high school advanced placement level calculus, physics, chemistry, and biology.
- This work is not intended to be a replacement for textbooks. The aim of these subject expositions is to provide a gentle first look at the main points of a subject, not an exhaustive, textbook-length treatment of all aspects of the subject. Numerous textbooks are recommended for each subject, and the reader is often referred to particular books for information about certain specialized topics beyond the scope of this work.
- This book is not intended to be merely a formulary. Every effort has been made to avoid stating important results without proof. Generally a rigorous derivation of each major result is given, except in cases where the rigorous derivation would be extremely long and relatively opaque to physical insight. In those cases, the result is justified by a “hogwash” derivation which uses physical insight and brevity to compensate for what it lacks in rigor.
- This work is not a handbook in the sense of including endless tables and graphs describing the properties of various things. There are already several good books of this type, and the reader is referred to them when appropriate. Rather than being an exhaustive handbook in which one may look up any scientific detail imaginable, the present book is intended to be an unimposing guide to *why* the major aspects of each subject are the way they are.