Gerald Bergtrom

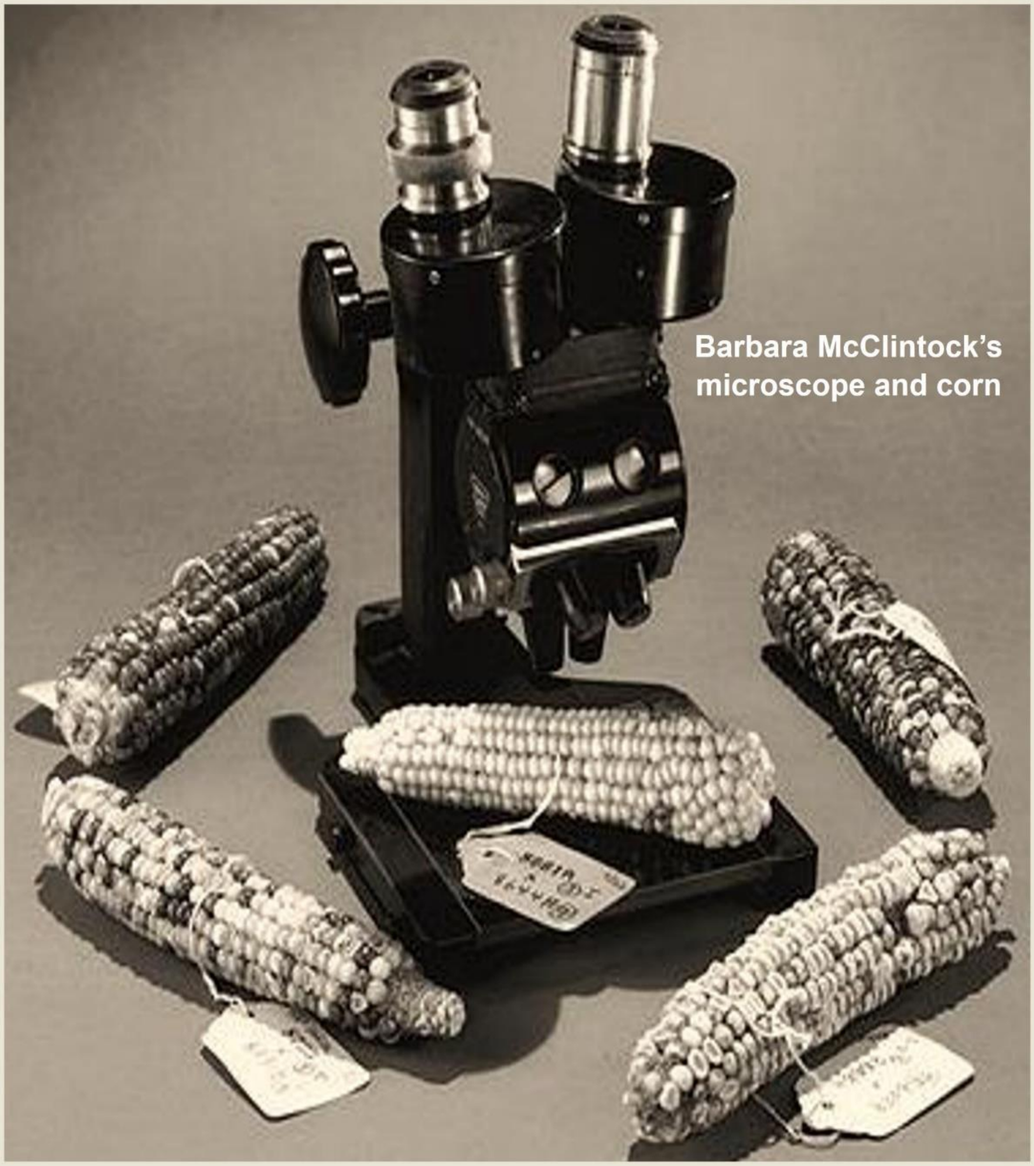
Cell and Molecular Biology
What We Know & How We Found Out (5th edition)
Annotated CMB5e iText (Digital Edition)

NOTE: In the following excerpts from the text, some hyperlinks do not work.

Cell and Molecular Biology

What We Know & How We Found Out

Annotated CMB5e iText (Digital Edition)



by

Gerald Bergtrom

Cell and Molecular Biology

What We Know & How We Found Out

Annotated CMB5e iText (Digital Edition)

An interactive textbook published under a Creative Commons (CC-BY) license

By

Gerald Bergtrom

Revised October, 2022

ISBN# 978-0-9961502-7-9

New in CMB5:

- ✓ *Reformatted to include*
  - ➢ *New typeface*
  - ➢ *QR codes to enable access to external websites from printed pages*
  - ➢ *A comprehensive index*
  - ➢ *Larger figures, now accompanied by Alternative Text to increase accessibility*
- ✓ *Many content updates*
- ✓ *New Challenge boxes*

Cover: Public Domain image from Microscope and Corn- Barbara McClintock

Published by UWM Digital Commons at ***https://dc.uwm.edu/***

From the Preface to CMB5…

Details, goals, and hopes for teaching and learning

A grasp of the logic and practice of science is essential to understanding the world around us. So, all editions/versions of **CMB** focus on experimental support for what we know about cell and molecular biology, and on showing students the relationship of cell structure and function. Rather than trying to be comprehensive reference, the book selectively details investigative questions, methods and experiments that lead to our understanding of cell biology. This focus is nowhere more obvious than in the chapter ***learning objectives*** and in links to the author's short YouTube voice-over PowerPoint (VOP) videos. Numbered links to each of these VOPs are embedded near relevant text and includes edited, optional closed captions. These are easily launched by clicking a *play-video* symbol or descriptive title on a computer or tablet app or by using *QR codes*, as in the example below:

102 Golgi Vesicles & the Endomembrane System

▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪

All digital (the *Basic, Annotated,* and *Instructors* ***CMB5e***) as well as the hard-copy version (the *Annotated* ***CMB5p***) include these interactive features. In addition, the ***Annotated CMB5e*** and ***CMB5p*** have ***Challenge boxes*** that typically include questions about significant new science that is not necessarily definitive and still subject to confirmation. Finally, the **Instructors' CMB5e** adds interactive short ***25 Words or Less*** short writing assignments. The ***Instructors'*** CMB5e is available on request. All interactive elements are intended to expand on concepts discussed in the text. My hope is that that you will engage and experience some of them. In writing and updating ***CMB***, I tried to make it *user-friendly*, current, and accurate. I invite you to use the interactive features of the iText to think about:

- how good and great experiments were inspired and designed.
- how alternative experimental results were predicted.
- how data was interpreted.
- how investigators (and we!) arrive at the most interesting "next questions".

This book is available in several digital OER versions (*Basic*, *Annotated* and *Instructors*) at *https://dc.uwm.edu/biosci_facbooks_bergtrom/*

Table of Chapters

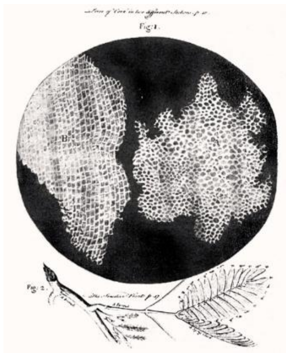
Use these links to navigate CMB5e (an online version of CMB5p)

Excerpts from Chapter 1…

Cell Tour, Life’s Properties and Evolution, Studying Cells

Life’s domains, scientific method, cell structures, Study methods (microscopy, cell fractionation, functional analyses); Common ancestry, Genetic variation, Evolution, Species diversity

Reminder: For inactive *links,* google key words/terms for alternative resources.




CELLS: *Left*, Robert Hooke’s drawing of cork slices seen through a microscope from his 1665 *Micrographia;* Right, a monk’s cell.

1.1 Introduction

You will read in this book about experiments that revealed secrets of cell and molecular biology, many of which earned their researchers Nobel and other prizes. But let’s begin here with a *Tale of Roberts*, two among many giants of science in the renaissance and age of enlightenment whose seminal studies came too early to win such coveted prizes.

One of these, **Robert Boyle**, was born in 1627 to wealthy, aristocrat parents. In his teens, after the customary *Grand Tour* of renaissance Europe (France, Greece, Italy…) and the death of his father, he returned to England in 1644, heir to great wealth. In the mid 1650s he moved from his estates where he had already set about studying physics and chemistry, to Oxford. There he built a laboratory with his own money to do experiments on the behavior of gasses under pressure. With some help, he discovered *Boyle’s Law*, confirming that the gasses obey mathematical rules. He is also credited with showing that light could travel through a vacuum, that something in air enables combustion, that sound travels through air in waves, that heat and particulate motion were related, and that the practice of alchemy was bogus! In fact, Boyle pretty much converted alchemy to chemistry by performing *chemical analysis*, a term he coined.

As a chemist, he also rejected the old Greek concept of the elements: earth, air, fire, and water. Instead, he defined elements as we still do today: the element is the smallest component of a substance that cannot be further chemically subdivided. He did this a century before Antoine Lavoisier listed and defined the first elements! Based on his physical studies and chemical analyses, Boyle even believed that the indivisible units of elements were atoms, and that the behavior of elements could be explained by the motion of atoms. Finally, Boyle codified in print the scientific method that made him a successful experimental scientist.

The second of our renaissance Roberts was **Robert Hooke**, born in 1635. In contrast to Boyle parents, Hooke's parents were of modest means. They managed nonetheless to nurture their son's interest in things mechanical. While he never took the *Grand Tour*, he learned well and began studies of chemistry and astronomy at Christ Church College, Oxford in 1653. To earn a living, he took a position as Robert Boyle's assistant. It was with Hooke's assistance that Boyle did the experiments leading to the formulation of *Boyle's Law*.

While at Oxford, he made other friends and useful connections. One friend was the architect Christopher Wren. In 1662, Boyle, a founding member of the Royal Society of London, supported Hooke to become the society's *curator of experiments*. However, to support himself, Hooke also hired on as professor of geometry at Gresham College (London). After "the great fire" of London in 1666, Hooke, as city surveyor and builder, participated with Christopher Wren in the design and reconstruction of the city. Ever interested in things mechanical, he also studied the elastic property of springs, leading him to *Hooke's Law*, namely that the force required to compress a spring was proportional to the length that the spring was compressed. Later, these studies led Hooke to imagine how a coil spring might substitute for a pendulum to regulate a clock. While he never invented such a clock, he was appointed to a Royal Commission to find the first reliable method to determine longitude at sea. He must have been gratified to know that the solution to accurate determination of longitude at sea turned out to involve a coil-spring clock! Along the way in his 'practical' studies, he also looked at little things, publishing his observations in *Micrographia* in 1665. Therein he described microscopic structures of animal parts and even snowflakes. He also described fossils as having once been alive and compared microscopic structures he saw in thin slices of cork to monk's cells (rooms, chambers) in a monastery. Hooke is best remembered for his law of elasticity and of course, for coining the word *cell*, which we now know as the smallest unit of living things.

Now fast-forward almost 200 years to observations of plant and animal cells early in the nineteenth century. These observations revealed structural features common to all cells including a nucleus and a boundary (membrane or wall) and the common organization of cells in groups to form multicellular structures in lower life forms as well as in plants and animals. By the 1830s an enriched understanding of cell structure and the role of cells in the structure of animals and plants led botanist **Matthias Schleiden** and zoologist **Theodor Schwann** to propose the first two precepts of a unified ***Cell Theory***:(1) *Cells are the basic unit of living things*; (2) *Cells can have an independent existence*. Later in the century, when Louis Pasteur finally disproved *spontaneous generation* and German histologists observed *mitosis* and *meiosis* (the underlying events of eukaryotic cell division), **Rudolf Virchow** added a third precept to round out ***Cell Theory***: (3) *Cells come from pre-existing cells*. That is, they reproduce. We begin this chapter with a reminder of the ***scientific method***, that way of thinking about our world that emerged formally in the seventeenth century. Then we'll take a tour of the cell, reminding ourselves of basic structures and organelles. After the 'tour', we consider the ***origin of life*** from a common ancestral cell and the subsequent ***evolution*** of cellular complexity and the incredible diversity of life forms.

Finally, we consider some of the *methods* we use to study cells. Since cells are small, several techniques of microscopy, cell fractionation (in essence a biochemical dissection of the cell) and functional/biochemical analysis are described to illustrate how we come to understand cell function.

Learning Objectives

When you have mastered the information in this chapter, you should be able to do the following:

1. Compare and contrast *hypotheses* and *theories* and place them (and other elements of the scientific enterprise) into their place in the cycle of the *scientific method.*
2. Compare and contrast structures common to, and that distinguish *prokaryotes*, *eukaryotes,* and *archaea*, and groups within these *domains of life.*
3. Articulate the function of different cellular substructures.
4. Explain how *prokaryotes* and *eukaryotes* accomplish the same functions, i.e., have the same *properties of life*, even though prokaryotes lack most structures found in eukaryotes.
5. Outline a procedure to study a specific cell *organelle* or another substructure.
6. Describe or speculate on how the different structures (particularly in eukaryotic cells) relate/interact with each other to accomplish specific functions.
7. Describe some structural and functional features that distinguish prokaryotes (eubacteria), eukaryotes, and archaea.
8. Place cellular organelles and other substructures in their evolutionary context, i.e., describe their origins and the selective pressures that could have led to their *evolution.*
9. Distinguish between the roles of random *mutations* and *natural selection* in evolution.
10. Relate archaea to other life forms and speculate on their origins in evolution.
11. Suggest why evolution leads to more complex ways of sustaining life.
12. Explain how *fungi* are more like animals than plants.

Reviews/Comments for earlier editions/versions of *Cell and Molecular Biology What We Know & How We Found Out*

Reviews (Open Textbook Library, University of Minnesota)

2022: "No other text offers a broader understanding of this exciting science." Zhiming Liu, Professor of Biology, New Mexico University: ★★★★★

2021: "Gerald Bergtrom's Basic Cell and Molecular Biology... textbook is a tour de force showcasing his passion for teaching... Bergtrom's periodic updates makes sure that the text stays accurate and relevant." Adriana LaGier, Assoc.Professor, Grand View University: ★★★★★

2021: "This as comprehensive and up to date as any upper-level Cell Biology text I have used. I think is suitable for both higher-level college and introductory graduate school cell biology classes... It is excellent..." Philip Rock, Professor of Biology, Virginia Wesleyan University: ★★★★★

2020: "The text is easy to read. It almost feels as if the instructor is talking to the reader. Topics are presented in a clear manner with the learning objectives in mind. Meltem Arikan, Adj. Faculty, Massachusetts Maritime Academy: ★★★★★

2017: "...great introductory text that includes the basics of cell and molecular biology. Each chapter includes... video presentations which add to comprehension. There is a theme based on evolution utilized throughout each chapter with appropriate examples. Main points are reinforced with guided exercises for students." Kate Kenyon, Assoc. Professor, Umpqua Community College: ★★★★★

2016: "(The book) is written in a narrative form with a somewhat casual tone which makes it easy to read and easy to follow... Learning objectives are outlined at the beginning of each chapter. Throughout the entire text evolution is a constant theme, providing context, rationale, and examples of its importance in the biological sciences". Brendan Mattingly, Acad. Prog. Associate, University of Kansas: ★★★★★

Comments

2022: "Thank you for providing such a valuable open access text..." (Ali Azghani, Fulbright Scholar & Professor of Biology, Univ. of Texas at Tyler)

2020: "I appreciate the approach your textbook takes..., providing students with a relatable narrative on how things were discovered, rather than simply stating the facts." (Dr. Maria Vassileva, MVSc, PhD; Assoc. Prof. of Biological Science, Nagoya University)

2020: "I have used Campbell and Raven, Hillis, and am now considering the Openstax textbook and find yours so much superior. And then the additional resources like your short, recorded PowerPoints (are) amazing in their conciseness and clarity" (Crima Pogge, Instructor, City College of San Francisco)

2019: "I simply LOVE your book, your historical approach to the study of biology, your challenges for the students that stimulate critical thinking... (Daniela Fadda, Istituto di Istruzione Superiore Desanctis Deledda [Linguistic H. S.], Sardinia Italy)

An OER hardcopy (print) version of this *Annotated CMB5e iText* (CMB5p) is available; search *Bergtrom* at https://www.lulu.com/shop/.