

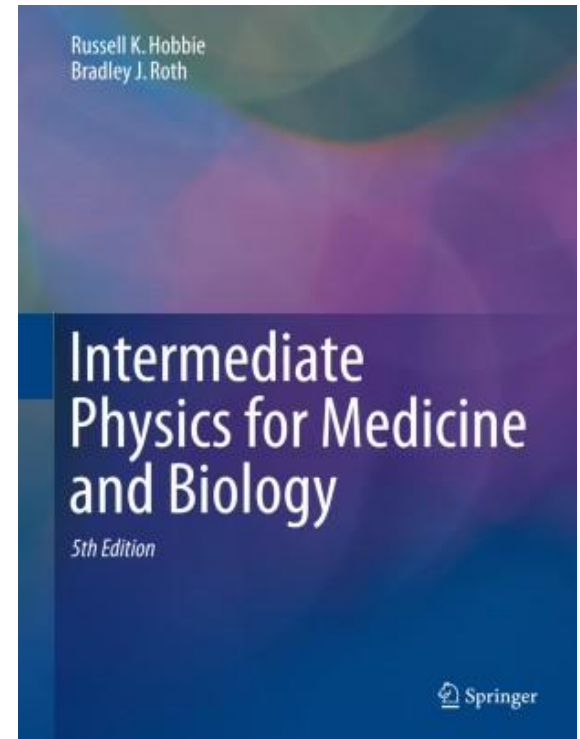
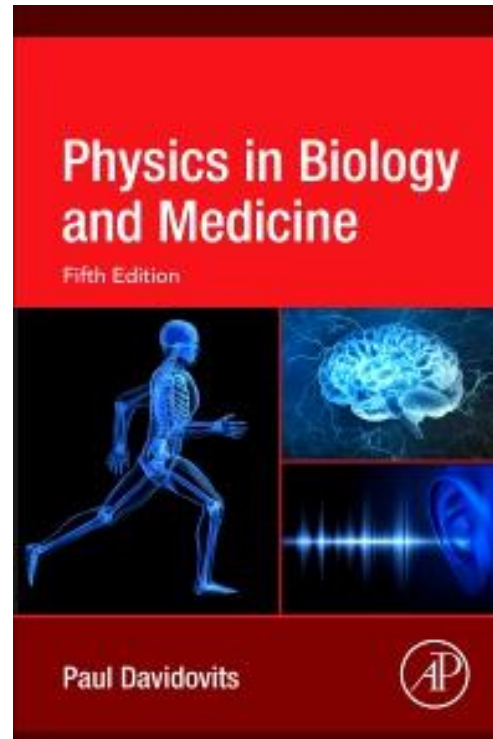
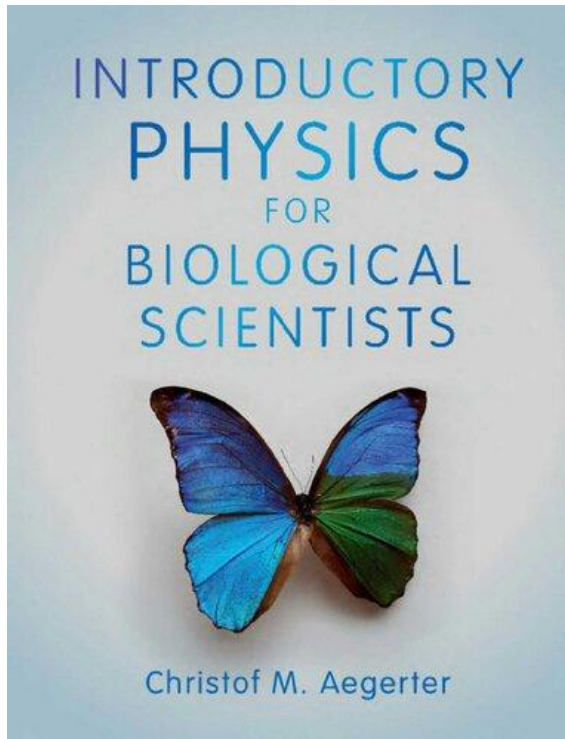
Introductory Physics for the Zhang Lab

Shao-Qing Zhang

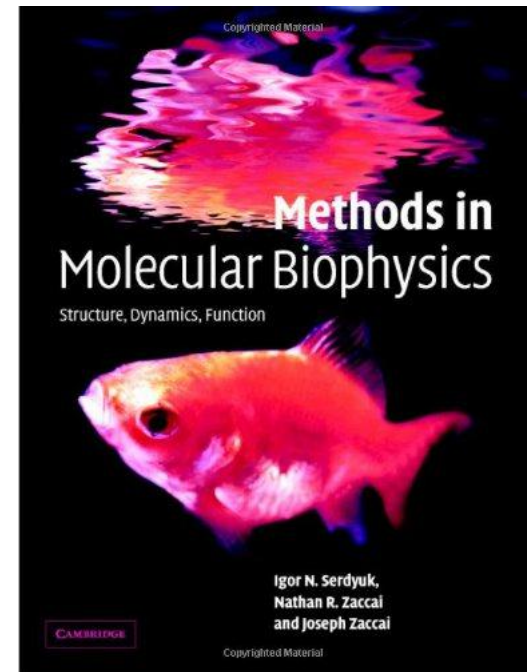
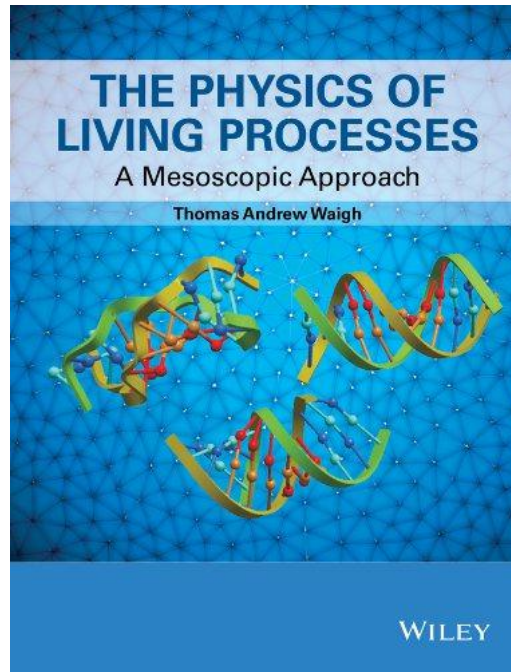
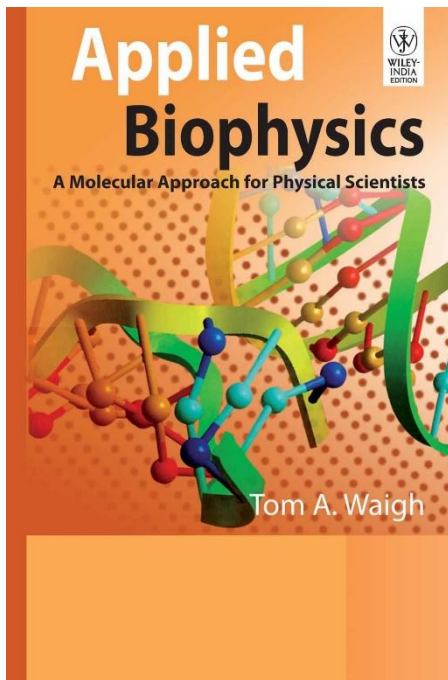
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Online resources are credited.

Physics books for biology and medicine



Molecular Biophysics books



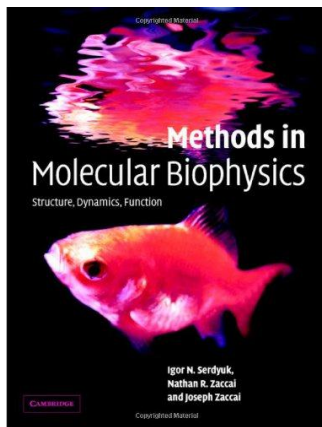
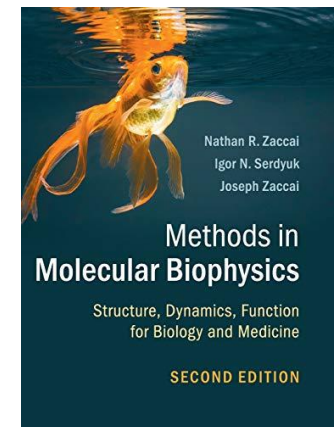
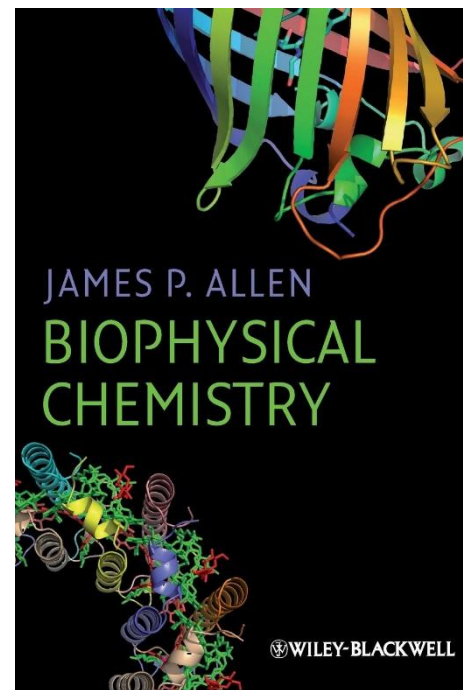
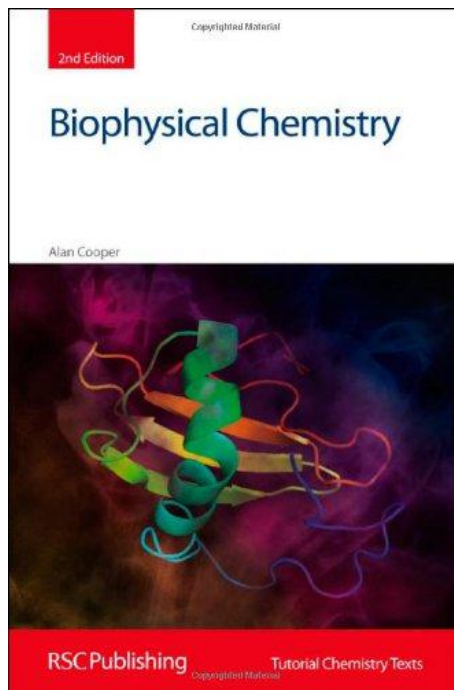
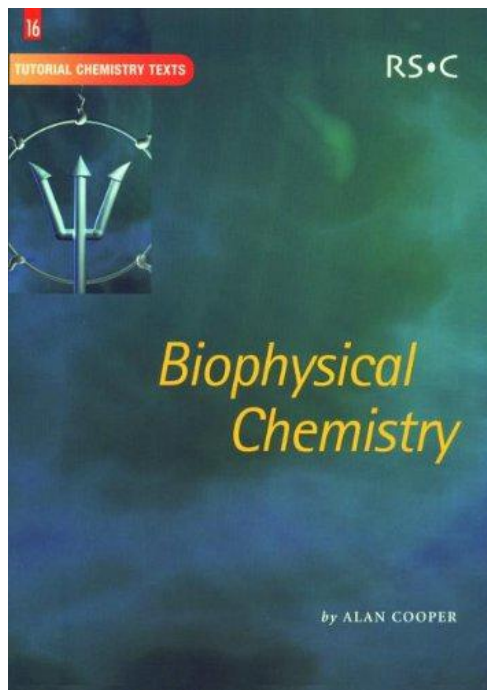


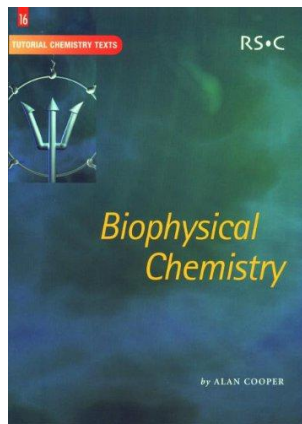
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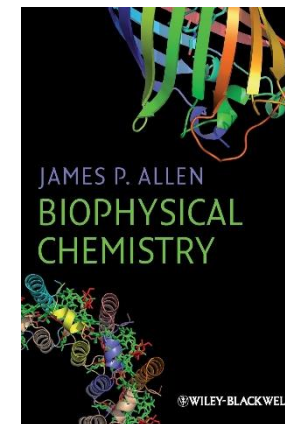
- Part A **Biological macromolecules and physical tools**
- Part B **Mass spectrometry**
- Part C **Thermodynamics**
- Part D **Hydrodynamics**
 - D1 Biological macromolecules as hydrodynamic particles
 - D2 Fundamental theory
 - D3 Macromolecular diffusion
 - D4 **Analytical ultracentrifugation**
 - D5 **Electrophoresis**
 - D6 Electric birefringence
 - D7 Flow birefringence
 - D8 Fluorescence depolarisation
 - D9 Viscosity
 - D10 **Dynamic light scattering**
 - D11 **Fluorescence correlation spectroscopy**
- Part E **Optical spectroscopy**
 - E1 Visible and IR absorption
 - E2 Two-dimensional IR spectroscopy
 - E3 Raman scattering
 - E4 Optical activity
- Part F **Optical microscopy**
 - F1 Light microscopy
 - F2 Atomic force microscopy
 - F3 Fluorescence
 - F4 Single-molecule detection
 - F5 Single-molecule manipulation
- Part G **X-ray and neutron diffraction**
- Part H **Electron diffraction**
- Part I **Molecular dynamics**
- Part J **Nuclear magnetic resonance**
- Part K **Medical Imaging**

Biophysical chemistry books





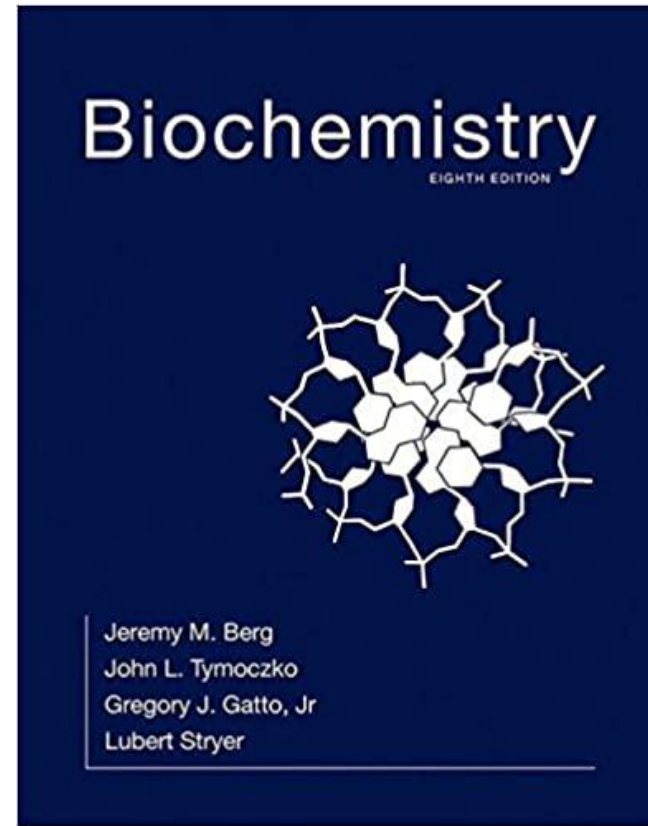
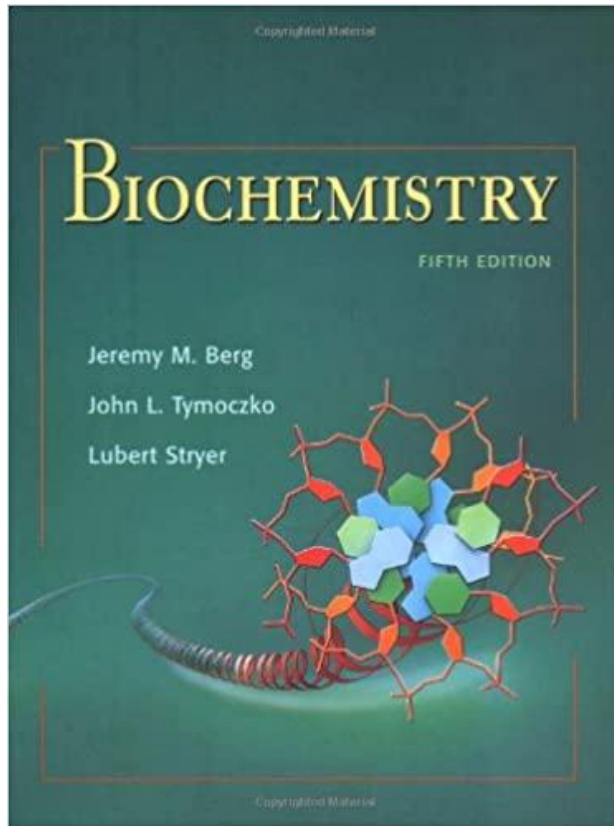
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- 1 **Biological Molecules**
- 2 **Spectroscopy**
 - 2.1 Electromagnetic Waves and their Interactions
 - 2.2 UV/Visible Spectroscopy
 - 2.3 Circular Dichroism
 - 2.4 Fluorescence
 - 2.5 Vibrational Spectroscopy: IR and Raman
 - 2.6 NMR (Brief Overview)
- 3 **Mass Spectrometry**
- 4 **Hydrodynamics**
- 5 **Thermodynamics and Interactions**
- 6 **Kinetics**
- 7 **Chromatography and Electrophoresis**
- 8 **Imaging**
- 9 **Single Molecules**

- Part 1: **Thermodynamics and kinetics**
 - 2 First law of thermodynamics
 - 3 Second law of thermodynamics
 - 4 Phase diagrams, mixtures, and chemical potential
 - 5 Equilibria and reactions involving protons
 - 6 Oxidation/reduction reactions and bioenergetics
 - 7 Kinetics and enzymes
 - 8 The Boltzmann distribution and statistical thermodynamics
- Part 2: **Quantum mechanics and spectroscopy**
 - 9 Quantum theory: introduction and principles
 - 10 Particle in a box and tunneling
 - 11 Vibrational motion and infrared spectroscopy
 - 12 Atomic structure: hydrogen atom and multi-electron atoms
 - 13 Chemical bonds and protein interactions
 - 14 Electronic transitions and optical spectroscopy
 - 15 X-ray diffraction and extended X-ray absorption fine structure
 - 16 Magnetic resonance
- Part 3: **Understanding biological systems using physical chemistry**
 - 17 Signal transduction
 - 18 Membrane potentials, transporters, and channels
 - 19 Molecular imaging
 - 20 Photosynthesis

Biochemistry book



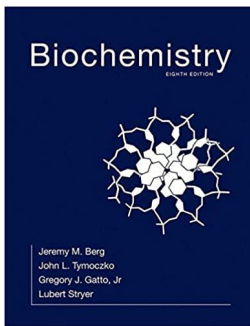
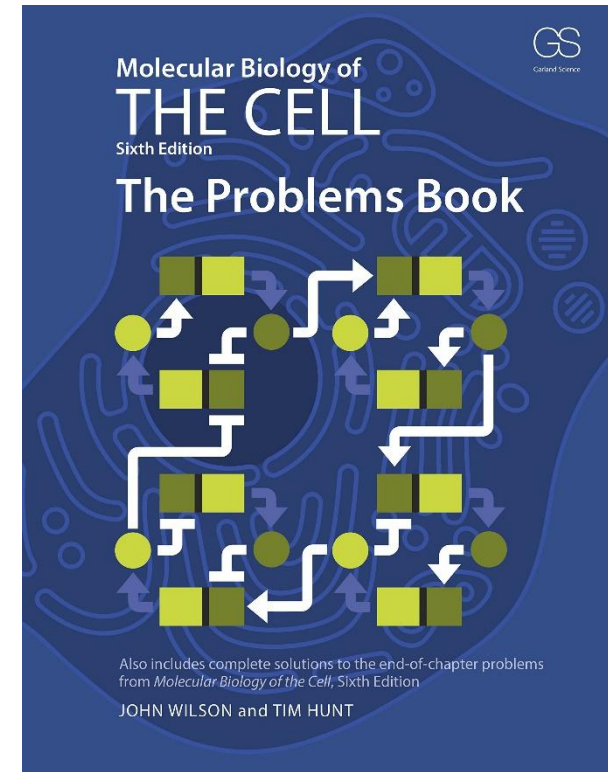
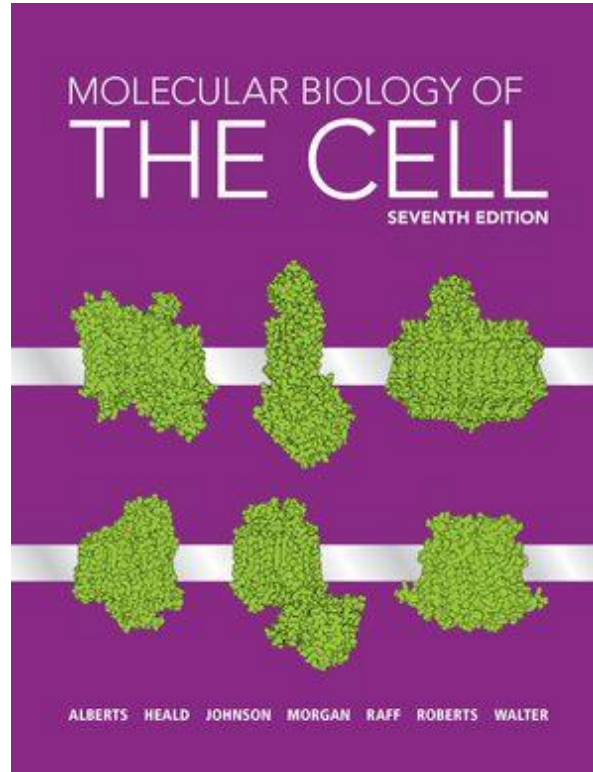
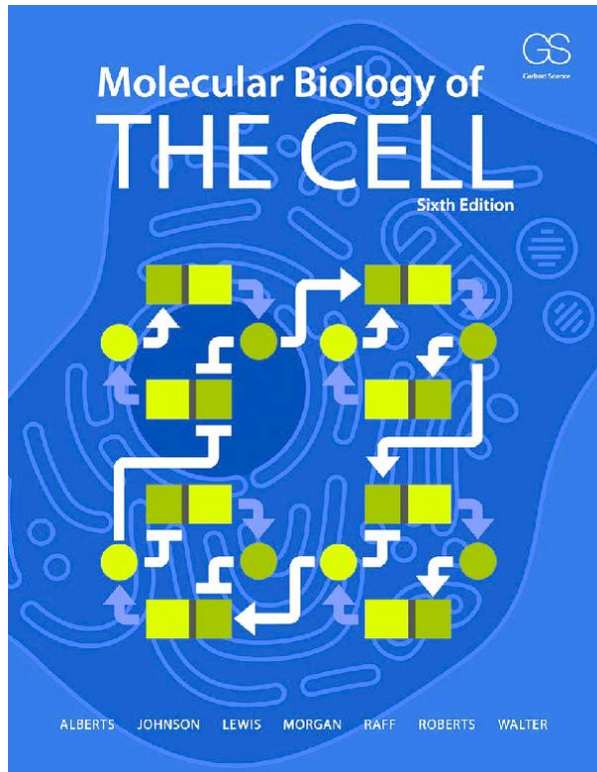


Table of contents (~1300 pages)

- Biochemistry: an evolving science
- Protein composition and structure
- Exploring proteins and proteomes
- DNA, RNA, and the flow of genetic information
- Exploring genes and genomes
- Exploring evolution and bioinformatics
- Hemoglobin: portrait of a protein in action
- Enzymes: basic concepts and kinetics
- Catalytic strategies
- Regulatory strategies
- Carbohydrates
- Lipids and cell membranes
- Membrane channels and pumps
- Signal-transduction pathways
- Metabolism: basic concepts and design
- Glycolysis and gluconeogenesis
- The citric acid cycle
- Oxidative phosphorylation
- The light reactions of photosynthesis
- The calvin cycle and the pentose phosphate pathway
- Glycogen metabolism
- Fatty acid metabolism
- Protein turnover and amino acid catabolism
- The biosynthesis of amino acids
- Nucleotide biosynthesis
- The biosynthesis of membrane lipids and steroids
- The integration of metabolism
- DNA replication, repair, and recombination
- RNA synthesis and processing
- Protein synthesis
- The control of gene expression in prokaryotes
- The control of gene expression in eukaryotes
- Sensory systems
- The immune system
- Molecular motors
- Drug development.

Molecular Biology of the Cell



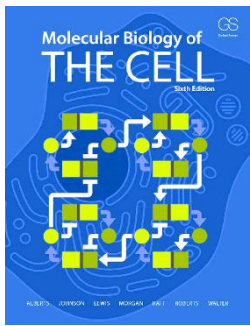


Table of contents (~1500 pages)

Part I INTRODUCTION TO THE CELL

- 1. Cells and Genomes
- 2. Cell Chemistry and Bioenergetics
- 3. Proteins

Part II BASIC GENETIC MECHANISMS

- 4. DNA, Chromosomes, and Genomes
- 5. DNA Replication, Repair, and Recombination
- 6. How Cells Read the Genome: From DNA to Protein
- 7. Control of Gene Expression

Part III WAYS OF WORKING WITH CELLS

- 8. Analyzing Cells, Molecules, and Systems
- 9. Visualizing Cells

Part IV INTERNAL ORGANIZATION OF THE CELL

- 10. Membrane Structure
- 11. Membrane Transport of Small Molecules and the Electrical Properties of Membranes

- 12. Intracellular Compartments and Protein Sorting
- 13. Intracellular Membrane Traffic
- 14. Energy Conversion: Mitochondria and Chloroplasts
- 15. Cell Signaling
- 16. The Cytoskeleton
- 17. The Cell Cycle
- 18. Cell Death
- 19. Cell Junctions and the Extracellular Matrix

Part V CELLS IN THEIR SOCIAL CONTEXT

- 20. Cancer
- 21. Development of Multicellular Organisms
- 22. Stem Cells and Tissue Renewal
- 23. Pathogens and Infection
- 24. The Innate and Adaptive Immune Systems

Differences between biodisciplines

Biochemistry is study of chemical substances and vital processes occurring in living organisms. Biochemists focus heavily on role, function and structure of biomolecules.

Chemical biology involves the application of chemical techniques, analysis, and often small molecules produced through synthetic chemistry, to the study and manipulation of biological systems. In contrast to **biochemistry**, which involves the study of the chemistry of biomolecules and regulation of biochemical pathways within and between cells, **chemical biology** deals with chemistry applied to biology (synthesis of biomolecules, simulation of biological systems etc.).

Systems biology, Synthetic biology

Biophysics employs and develops theories and methods of the physical sciences for the investigation of biological systems. Studies span all levels of biological organization, from the molecular scale to whole organisms and ecosystems.

Biophysical chemistry employ various techniques used in physical chemistry to probe the structure of biological systems.

Physical Biology aims to accurately measure and describe the structure, function and behavior of biological systems by using the newly developed advanced concepts and techniques of physics, while **biophysics** focuses on the study of the basic physical laws of living matter.

Zhang Lab's Research

The **principle behind is** a PHYSICS,

The **reactions undergoing** is a

CHEMISTRY,

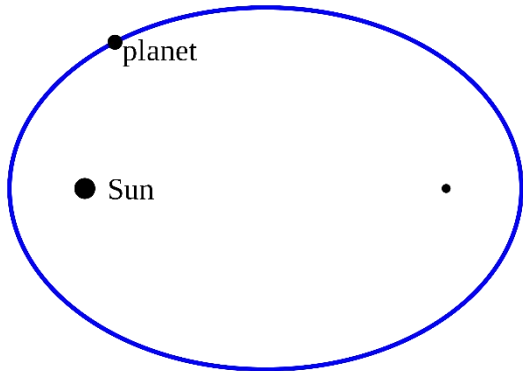
AND

The **resultant obtained** is BIOLOGY

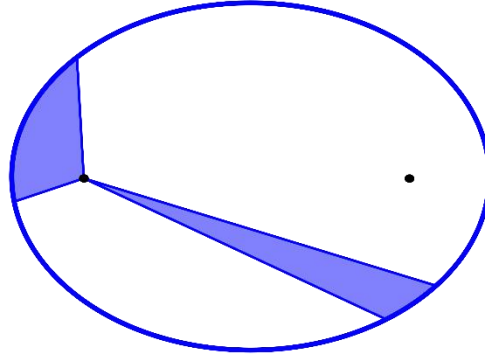
Or for BIOLOGICAL Purposes.

开普勒定律 (1609, 1618)

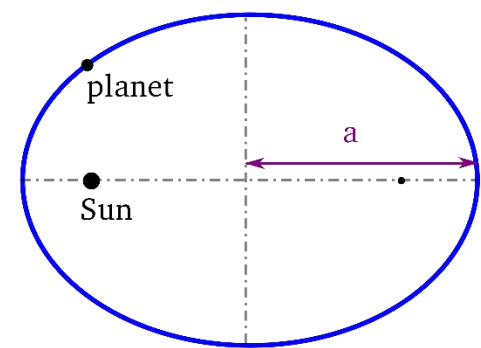
- **开普勒第一定律**，也称为椭圆定律、轨道定律：每一个行星都沿各自的椭圆轨道环绕太阳，而太阳则处在椭圆的一个焦点中。
- **开普勒第二定律**，也称为等面积定律：在相等时间内，太阳和运动着的行星的连线所扫过的面积都是相等的。
- **开普勒第三定律**，也称为周期定律：各个行星绕太阳公转周期的平方及其椭圆轨道的半长轴的立方成正比。
- **牛顿万有引力定律**可推导出三定律。



开普勒第一定律



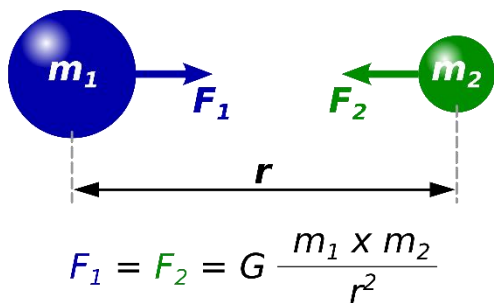
开普勒第二定律



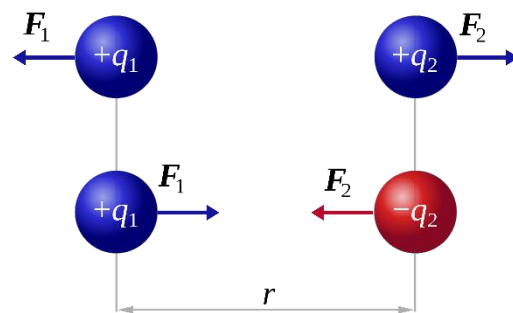
开普勒第三定律

平方反比定律

- **牛顿万有引力定律**（1687）。
- 首次发表《自然哲学的数学原理》。
- 可以推导出开普勒三定律。
- 现代理论已经被爱因斯坦的**广义相对论**所取代。
- **库仑定律**（1785）。
- 电学研究从定性进入定量阶段，是电学史中的一块重要的里程碑。
- 实验给出库仑定律与平方反比关系的偏差小于 2.7×10^{-16} 。



牛顿万有引力定律



$$|F_1| = |F_2| = k_e \frac{|q_1 \times q_2|}{r^2}$$

库仑定律

《自然哲学的数学原理》 (1687)

- 科学史上最重要的论著之一，标志一个物理学革命的新纪元。
- 发明微积分。
- 提出牛顿三定律。
 - **第一定律**：假若施加于某物体的外力为零，则该物体的运动速度不变（惯性定律）。
 - **第二定律**：施加于物体的外力等于此物体的质量与加速度的乘积（加速度定律）。
 - **第三定律**：当两个物体相互作用于对方时，彼此施加于对方的力，其大小相等、方向相反（作用力与反作用力定律）。
- 提出万有引力定律。
- 超高速或非常强烈重力场的状况下，我们需要**相对论**修正和解释一些天体运动和现象，例如黑洞。在原子尺寸，我们需要**量子力学**解释原子的发射光谱等物理现象。
- 现代物理中，动量、角动量、能量的守恒定律比牛顿定律更为基础。

麦克斯韦方程 (1865)

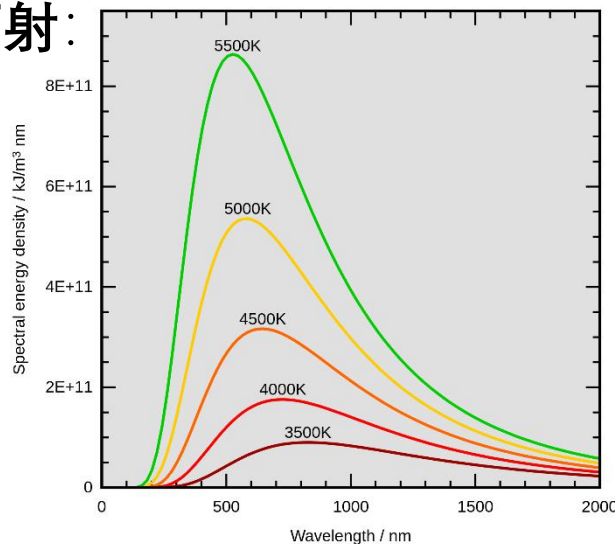
- 发表于《**电磁场的动力学理论**》，为物理学史的一个重大里程碑。
- 将**电学**、**磁学**和**光学**联结成一个统一理论。
- 历史上首先建立了**场论**的基础概念。
- 推导出光波是**电磁波**。
- 由于麦克斯韦方程组完全不能表达**光子**的概念，任何涉及到单独光子的现象，例如光电效应、普朗克定律等等。

名称	微分形式	积分形式
高斯定律	$\nabla \cdot \mathbf{E} = \frac{\rho}{\epsilon_0}$	$\oiint_S \mathbf{E} \cdot d\mathbf{s} = \frac{Q}{\epsilon_0}$
高斯磁定律	$\nabla \cdot \mathbf{B} = 0$	$\oiint_S \mathbf{B} \cdot d\mathbf{s} = 0$
法拉第电磁感应定律	$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$	$\oint_L \mathbf{E} \cdot d\mathbf{l} = -\frac{d\Phi_B}{dt}$
麦克斯韦-安培定律	$\nabla \times \mathbf{B} = \mu_0 \mathbf{J} + \mu_0 \epsilon_0 \frac{\partial \mathbf{E}}{\partial t}$	$\oint_L \mathbf{B} \cdot d\mathbf{l} = \mu_0 I + \mu_0 \epsilon_0 \frac{d\Phi_E}{dt}$

物理理论上的两朵乌云 (1900)

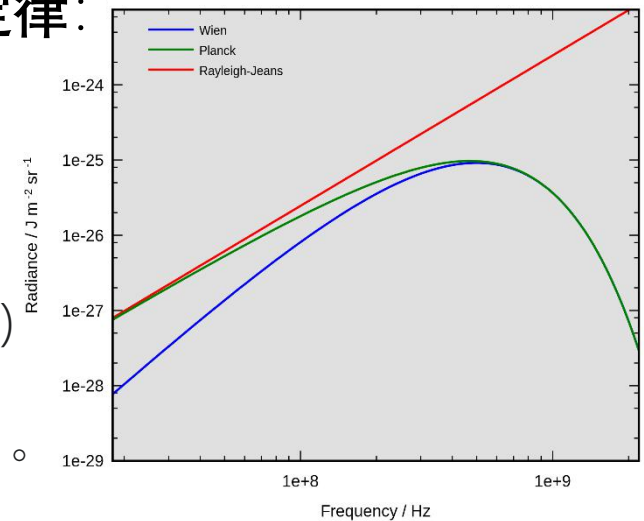
- 迈克耳孙-莫雷实验测量的**零结果**和**黑体辐射**理论出现的问题。
- **迈克耳孙-莫雷实验**：地球以每秒30公里的速度绕太阳运动，就必然迎面受到每秒30公里的“以太风”，从而必然对光的传播产生影响。迈克耳孙干涉仪来测定以太风的速度，发现为零 (1887)。
- 1905年，爱因斯坦在抛弃以太、以**光速不变原理**和**狭义相对性原理**为基本**假设**的基础上建立了**狭义相对论**。

• 黑体辐射：



普朗克定律：

假设能量
只能以不
可分的能
量元素
(即**量子**)
形式辐射
(1900)

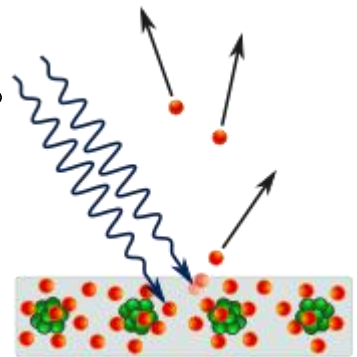


现代量子物理的开端

- 伦琴发现**X射线** (1895)，用于医学成像诊断和X射线晶体学。
 - 冯·劳厄通过晶体衍射方法确定X射线是频率很高**电磁波** (1912)。
- 约瑟夫·汤姆孙发现**电子** (1897)。
- 普朗克使用**能量量子化假设**解释黑体辐射 (1900)。

$$E = h\nu$$

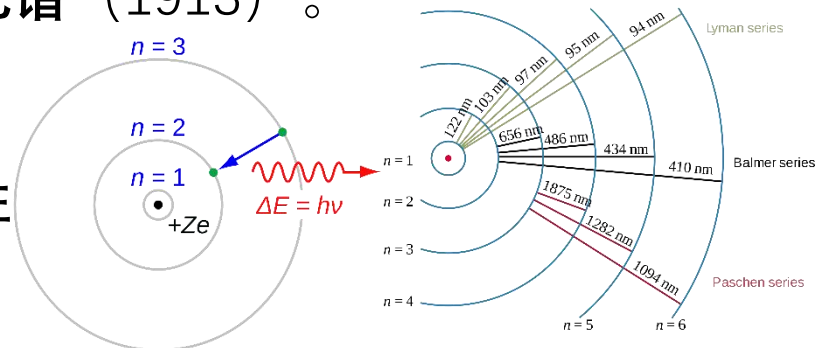
- 爱因斯坦使用光量子论解释**光电效应** (1905)。
- 爱因斯坦提出电磁辐射的**波粒二象性** (1909)。
- 卢瑟福提出**卢瑟福模型** (1911)。



光电效应

- 玻尔提出**玻尔模型**，并解释**氢原子光谱** (1913)。
 - 一个**电子轨道量子化**的氢原子模型。
 - 对其他稍复杂的原子光谱就毫无办法。
- 德布罗意提出**实物粒子的波粒二象性** (1923)。

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

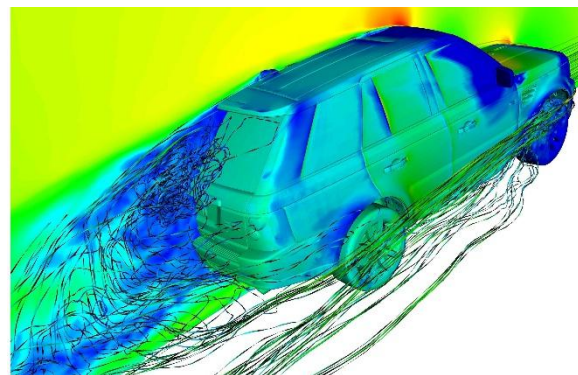


玻尔模型

氢原子光谱

海森堡测不准原理

- 海森堡在索末菲建议下研究湍流问题 (1924)
- 湍流研究依赖于纳维-斯托克斯方程 (1822)
- 和波恩、约当建立量子理论的矩阵力学表示 (1925)。



湍流

$$PQ - QP = \frac{\hbar}{i} I$$

- 矩阵力学和薛定谔的波动力学 (1926) 等价。

$$\left[-\frac{\hbar^2}{2m} \nabla^2 + V(\mathbf{r}) \right] \psi(\mathbf{r}) = E\psi(\mathbf{r})$$

- 波恩提出波函数的概率密度诠释 (1926)。
- 海森堡提出测不准原理 (1927)。

$$\sigma_x \sigma_p \geq \frac{\hbar}{2}$$

- 能量-时间测不准关系被提出 (1945)。

$$\Delta E \Delta t \geq \frac{\hbar}{2}$$

- 超导电子个数和相位测不准关系 (1967)。

$$\Delta N \Delta \varphi \geq 1$$

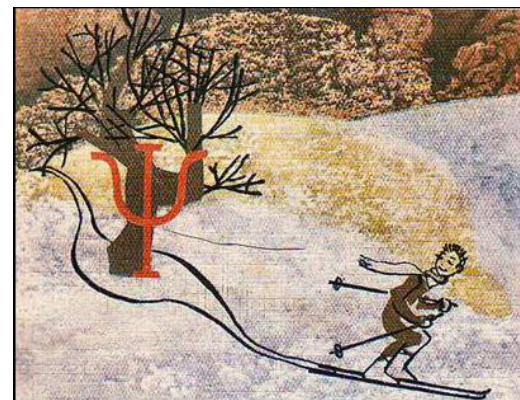
动量守恒公式

$$\underbrace{\rho \left(\underbrace{\frac{\partial \mathbf{v}}{\partial t}}_{\text{非稳态加速}} + \underbrace{(\mathbf{v} \cdot \nabla) \mathbf{v}}_{\text{对流加速}} \right)}_{\text{惯性}} = \underbrace{-\nabla p}_{\text{压强梯度}} + \underbrace{\mu \nabla^2 \mathbf{v}}_{\text{黏滞力}} + \underbrace{\mathbf{f}}_{\text{其他力}}$$

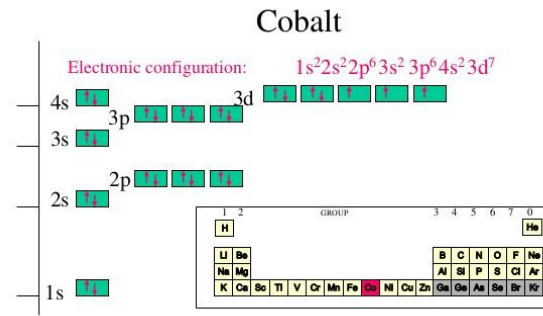
和质量守恒公式

$$\nabla \cdot \mathbf{v} = 0.$$

纳维-斯托克斯方程



泡利不相容原理



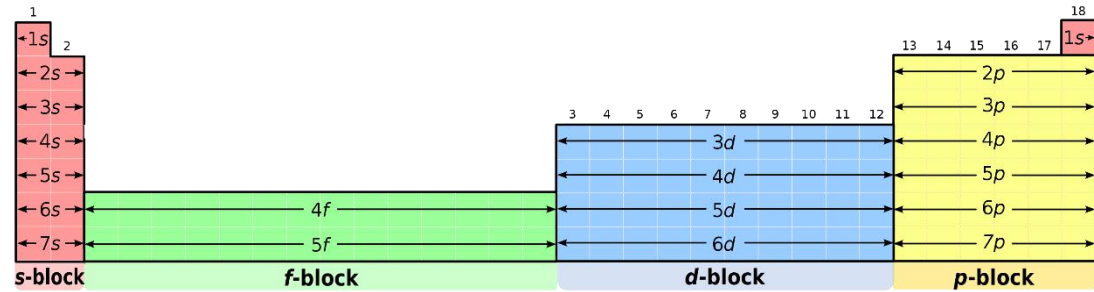
l	Sublevel	Orbital Shape
0	sharp - s	spherical
1	principal - p	dumbbell-shaped
2	diffused - d	cloverleaf
3	fundamental - f	too complex

- **泡利**通过分析实验结果（每个填满的电子亚层都拥有 $2(2l+1)$ 个电子， l 为角量子数）得到（1925）。
- 原理是指处于同一原子轨域的两个**电子**必定拥有相反的**自旋**方向。
- 泡利根据碱金属光谱提出“双值量子自由度”（1924），后乌伦贝克和古德斯米提出电子拥有**自旋量子数**（1925）。
- 泡利提出**泡利矩阵**来用于研究**自旋与磁场的相互作用**（1926）。

$$S_x = \frac{\hbar}{2} \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} \quad S_y = \frac{\hbar}{2} \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix} \quad S_z = \frac{\hbar}{2} \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} \quad \vec{\mu} = \gamma \vec{S}$$

- **狄拉克**推导出**狄拉克方程**，并提出**正电子**的存在（1928）。
- 具有**自旋**的粒子（电子、原子核和其他基本粒子）具有**磁偶极矩**。
- 磁矩与磁场相互作用是**核磁共振技术**和**电子顺磁共振技术**的基础。
- 自旋为半整数的粒子的波函数具有反对称性；当处于相同位置的电子具有相同自旋时，反对称性使波函数为0。
- 泡利不相容原理是原子物理学与分子物理学的基础理论，它促成了化学的变幻多端、奥妙无穷。

泡利不相容原理



- **泡利**通过分析实验结果（每个填满的电子亚层都拥有 $2(2l+1)$ 个电子， l 为角量子数）得到（1925）。
- 原理是指处于同一原子轨域的两个**电子**必定拥有相反的**自旋**方向。
- 泡利根据碱金属光谱提出“双值量子自由度”（1924），后乌伦贝克和古德斯米提出电子拥有**自旋量子数**（1925）。
- 泡利提出**泡利矩阵**来用于研究**自旋与磁场的相互作用**（1926）。

$$S_x = \frac{\hbar}{2} \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} \quad S_y = \frac{\hbar}{2} \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix} \quad S_z = \frac{\hbar}{2} \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} \quad \vec{\mu} = \gamma \vec{S}$$

- **狄拉克**推导出**狄拉克方程**，并提出**正电子**的存在（1928）。
- 具有**自旋**的粒子（电子、原子核和其他基本粒子）具有**磁偶极矩**。
- 磁矩与磁场相互作用是**核磁共振技术**和**电子顺磁共振技术**的基础。
- 自旋为半整数的粒子的波函数具有反对称性；当处于相同位置的电子具有相同自旋时，反对称性使波函数为0。
- 泡利不相容原理是原子物理学与分子物理学的基础理论，它促成了化学的变幻多端、奥妙无穷。

量子力学发展最有影响力十大科学家

普朗克



爱因斯坦



波恩



狄拉克



薛定谔



玻尔



德布罗意



海森堡

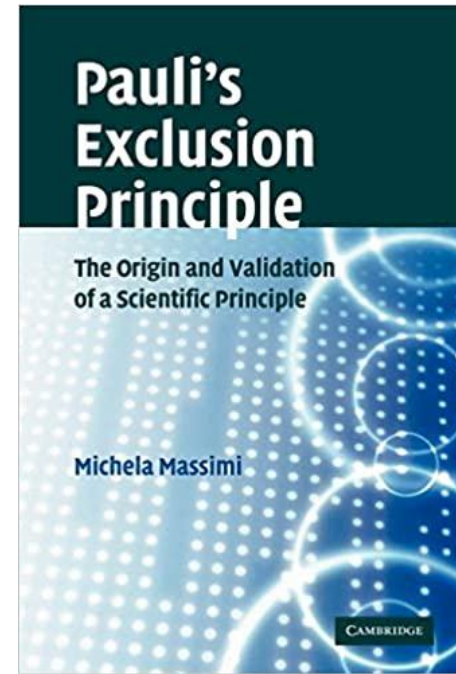
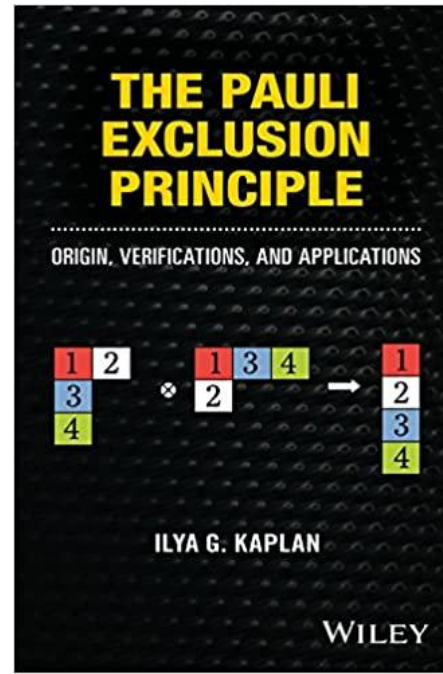
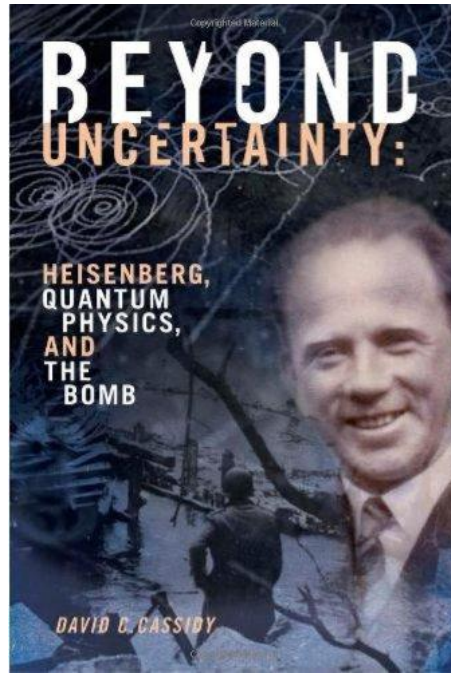
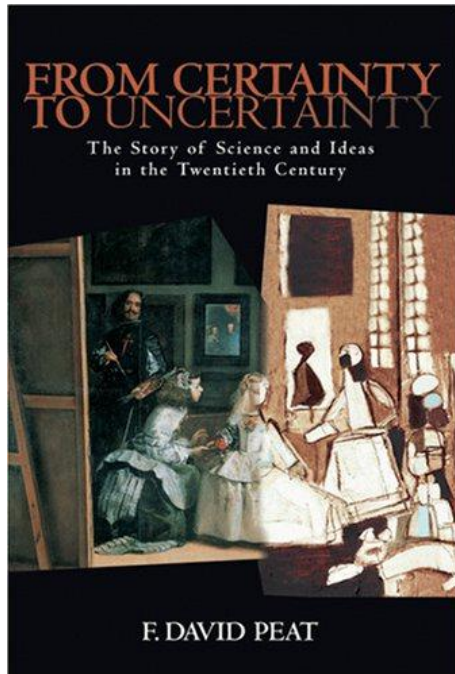


泡利



费曼

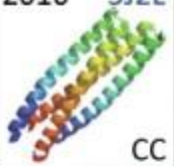

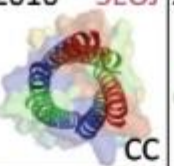


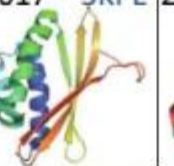
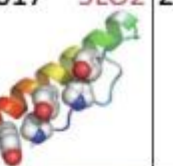
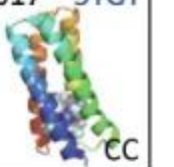


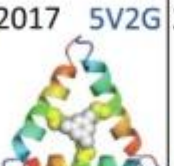
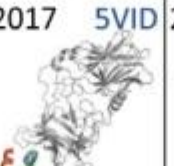
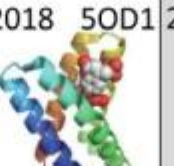
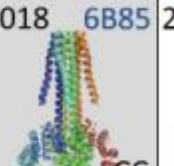





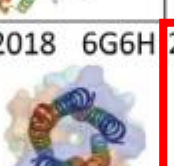





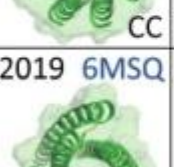
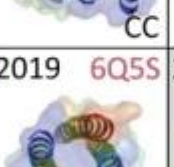
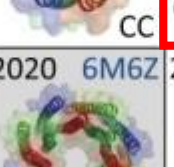

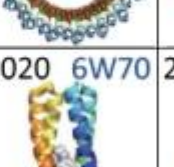

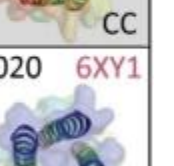
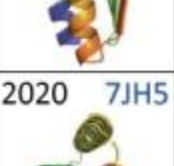
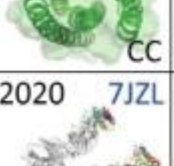
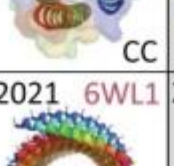
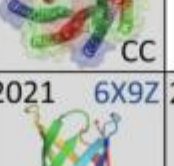
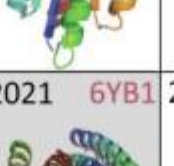
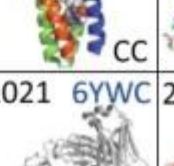

关于不确定性和不相容原理的书



生物技术的时间线

- DNA双螺旋结构 (1953)
- DNA重组 (1973)
- PCR (1983) --- 热循环仪
- 荧光蛋白 (1995) --- 荧光显微镜
- 光遗传学 (2005) --- 激光+光纤
- CRISPR (2013)
- ○ ○ ○

蛋白质设计

2016 5J2L  CC	2016 5EHB  CC	2016 5EOJ  CC	2016 5E2C  CC	2017 4GMR 	2017 5KPE 	2017 5LO2 	2017 5TGY  CC
2017 5UGK 	2017 5UOI 	2017 5V2G 	2017 5VID 	2018 5OD1 	2018 6B85  CC	2018 6CZH 	2018 6EIZ  CC
2018 6FES  CC	2018 6G67  CC	2018 6G6F  CC	2018 6G6H  CC	2018 6O3N  CC	2019 6HQE  CC	2020 6IWB 	2019 6MCT  CC
2019 6MRR 	2019 6MSQ  CC	2019 6Q5S  CC	2020 6M6Z  CC	2020 6VGA  CC	2020 6W70  CC	2020 6XXV 	2020 6XY1  CC
2020 7JH5  CC	2020 7JZL 	2021 6WL1  CC	2021 6X9Z 	2021 6YB1  CC	2021 6YWC 	2021 6ZT1  CC	