

## Synthetic Biology A Primer

“Venter instills awe for biology as it is, and as it might become in our hands.” —Publishers Weekly On May 20, 2010, headlines around the world announced one of the most extraordinary accomplishments in modern science: the creation of the world’s first synthetic lifeform. In *Life at the Speed of Light*, scientist J. Craig Venter, best known for sequencing the human genome, shares the dramatic account of how he led a team of researchers in this pioneering effort in synthetic genomics—and how that work will have a profound impact on our existence in the years to come. This is a fascinating and authoritative study that provides readers an opportunity to ponder afresh the age-old question “What is life?” at the dawn of a new era of biological engineering.

This book provides a comprehensive, up-to-date overview of the opportunities and challenges of the complex field of synthetic biology, which combines various scientific disciplines. The emerging field of synthetic biology employs biotechnological approaches to recreate and enhance basic biological structures, intracellular processes and whole organisms. The book addresses a broad range of topics, including redesigning complex metabolic pathways, DNA/RNA and protein engineering, as well as novel synthetic biomaterials. It discusses both “bottom up” and “top down” approaches and presents the latest genome engineering tools with predictions about how these could change our way of thinking and working. Since the use of synthetic biology raises a number of ethical questions, a chapter is devoted to public awareness and risk management. The book is of interest to scientists from both academia and industry, as well as PhD students and postdocs working in the field.

Cell-free synthetic biology is in the spotlight as a powerful and rapid approach to characterize and engineer natural biological systems. The open nature of cell-free platforms brings an unprecedented level of control and freedom for design compared to in vivo systems. This versatile engineering toolkit is used for debugging biological networks, constructing artificial cells, screening protein library, prototyping genetic circuits, developing new drugs, producing metabolites, and synthesizing complex proteins including therapeutic proteins, toxic proteins, and novel proteins containing non-standard (unnatural) amino acids. The book consists of a series of reviews, protocols, benchmarks, and research articles describing the current development and applications of cell-free synthetic biology in diverse areas.

'Synthetic Biology' provides a broad overview of the emerging field of synthetic biology and the foundational concepts on which it is built. It will be of interest to final year undergraduates, postgraduates and established researchers who are interested in learning about this new field.

Written primarily for mid-to-upper level undergraduates, this primer will introduce students to topics at the forefront of the subject that are being applied to probe biological problems, or to address the most pressing issues facing society. These topics will include those that form the cornerstone of contemporary research, helping students to make the transition to active researcher. Students will acquire a solid understanding of the essentials of microbial biotechnology, its applications in agriculture, diagnostics and urban and artistic conservation, as well as the potential threats genetic modification may pose to public health, the environment and intellectual property.

Now presented in large format, the new Schmid is the ideal primer in biotechnology. The two-page layout with one page being a full color figure and the opposite page being explanatory text is the ideal combination between rapid visual-based learning with in depth information.

Synthetic biology involves the rational design and construction of biological components and systems from genetic elements and metabolic pathways to entirely new organisms. Progress in this field has been rapid, and it promises to significantly expand our capabilities in biotechnology, medicine, and agriculture. Written and edited by experts in the field, this collection from Cold Spring Harbor Perspectives in Biology examines the tools and techniques employed by synthetic biologists, how these may be used to develop new drugs, diagnostic approaches, food sources, and clean energy, and what the field of synthetic biology has taught us about natural living systems. The contributors discuss advances in DNA synthesis and assembly, genome editing (e.g., CRISPR/Cas9), and artificial genetic systems. Progress in designing complex genetic switches and circuits, expanding the genetic code, modifying cellular organization, producing proteins using cell-free systems, and developing biodesign automation tools is also covered. The authors also explore ways to produce new organisms and products that have particular attributes for example, microbial "molecular factories," synthetic organs and tissues, and plants with novel traits. This volume is an essential resource for molecular, cell, and systems biologists who seek to engineer living systems for human benefit.

Synthetic biology gives us a new hope because it combines various disciplines, such as genetics, chemistry, biology, molecular sciences, and other disciplines, and gives rise to a novel interdisciplinary science. We can foresee the creation of the new world of vegetation, animals, and humans with the interdisciplinary system of biological sciences. These articles are contributed by renowned experts in their fields. The field of synthetic biology is growing exponentially and opening up new avenues in multidisciplinary approaches by bringing together theoretical and applied aspects of science.

Microbial Cell Factories Engineering for Production of Biomolecules presents a compilation of chapters written by eminent scientists worldwide. Sections cover major tools and technologies for DNA synthesis, design of biosynthetic pathways, synthetic biology tools, biosensors, cell-free systems, computer-aided design, OMICS tools, CRISPR/Cas systems, and many more. Although it is not easy to find relevant information collated in a single volume, the book covers the production of a wide range of biomolecules from several MCFs, including *Escherichia coli*, *Bacillus subtilis*, *Pseudomonas putida*, *Streptomyces*, *Corynebacterium*, *Cyanobacteria*, *Saccharomyces cerevisiae*, *Pichia pastoris* and *Yarrowia lipolytica*, and algae, among many others. This will be an excellent platform from which scientific knowledge can grow and widen in MCF engineering research for the production of biomolecules. Needless to say, the book is a valuable source of information not only for researchers designing cell factories, but also for students, metabolic engineers, synthetic biologists, genome engineers, industrialists, stakeholders and policymakers interested in harnessing the potential of MCFs in several fields. Offers basic understanding and a clear picture of various MCFs Explains several tools and technologies, including DNA synthesis, synthetic biology tools, genome editing, biosensors, computer-aided design, and OMICS tools, among others Harnesses the potential of engineered MCFs to produce a wide range of biomolecules for industrial, therapeutic, pharmaceutical, nutraceutical and biotechnological applications Highlights the advances, challenges, and future opportunities in designing MCFs Yeast Metabolic Engineering: Methods and Protocols provides the widely established basic tools used in yeast metabolic engineering, while describing in deeper detail novel and innovative methods that have valuable potential to improve metabolic engineering strategies in industrial biotechnology applications. Beginning with an extensive section on molecular tools and technology for yeast engineering, this detailed volume is not limited to methods for *Saccharomyces cerevisiae*, but describes tools and protocols for engineering other yeasts of biotechnological interest, such as *Pichia pastoris*, *Hansenula polymorpha* and *Zygosaccharomyces bailii*. Tools and technologies for the investigation and determination of yeast metabolic features are described in detail as well as metabolic models and their application for yeast metabolic engineering, while a chapter describing patenting and regulations with a special glance at yeast biotechnology closes the volume. Written in the highly successful Methods in Molecular Biology series format, most chapters include an introduction to their respective topic, lists of the

necessary materials and reagents, step-by-step, readily reproducible laboratory protocols and tips on troubleshooting and avoiding known pitfalls. Comprehensive and authoritative, *Yeast Metabolic Engineering: Methods and Protocols* aims to familiarize researchers with the current state of these vital and increasingly useful technologies.

For decades biology has focused on decoding cellular processes one gene at a time, but many of the most pressing biological questions, as well as diseases such as cancer and heart disease, are related to complex systems involving the interaction of hundreds, or even thousands, of gene products and other factors. How do we begin to understand this complexity? *Fundamentals of Systems Biology: From Synthetic Circuits to Whole-cell Models* introduces students to methods they can use to tackle complex systems head-on, carefully walking them through studies that comprise the foundation and frontier of systems biology. The first section of the book focuses on bringing students quickly up to speed with a variety of modeling methods in the context of a synthetic biological circuit. This innovative approach builds intuition about the strengths and weaknesses of each method and becomes critical in the book's second half, where much more complicated network models are addressed—including transcriptional, signaling, metabolic, and even integrated multi-network models. The approach makes the work much more accessible to novices (undergraduates, medical students, and biologists new to mathematical modeling) while still having much to offer experienced modelers—whether their interests are microbes, organs, whole organisms, diseases, synthetic biology, or just about any field that investigates living systems.

Synthetic biology aims to make biology easier to engineer and to program. Thanks to advances in computing power, the ability to make long tracts of DNA, new tools like CRISPR that can be used to edit genomes, and the enthusiasm of young scientists and even amateurs who want to enter the field, synthetic biology is poised to change the future of medicine, agriculture, and manufacturing. Yet, while this new field promises vast opportunities and benefits, there are also risks. There are biosecurity risks that these technologies will be deliberately used for harm; safety risks to people and the environment; ethical and social considerations for how to apply these technologies; and there are risks to the competitiveness of nations that do not invest in these technologies that are likely to spur economic growth. This volume is dedicated to a discussion of what can be done to minimize risks and maximize the benefits of synthetic biology.

*Praise for Synthetic Biology: Safety, Security, and Promise* "There can be no doubt that advances in the life sciences, including new insights and tools provided by synthetic biology, place us in a position to create exciting and novel products and approaches for patients in need. Gigi Gronvall describes that promise but also lays forth critical policy concerns that need to be addressed so that we don't risk safety, security, or the competitiveness of US science." - Margaret Hamburg, MD, Former FDA Commissioner and Foreign Secretary, National Academy of Medicine "Synthetic biology gives us tools that can help tackle global problems that affect humanity—but for that to happen, the risks of bioterror or bio-error need to be dealt with and managed, as well. Gronvall clearly describes the policy challenges that must be addressed and concludes with steps to enhance US leadership and competitiveness in the global bio-economy." - J. Craig Venter, PhD, founder, chairman, and CEO of the J. Craig Venter Institute and co-founder, executive chairman and co-chief scientist of Synthetic Genomics, Inc. "For those of us working in the lab, it is important to embrace conversations with those who aren't - including strategies for biological security, to create new synthetic biology products - with respect for facts about GMO risk/benefit balances, creating a culture of safe lab practices and norms worldwide. Gigi Gronvall dissects such issues at stake in synthetic biology and presents a pragmatic and scientifically responsive path forward for anyone in a position to influence, regulate, decide upon, or benefit from the science to follow." - George Church, PhD, Professor of Genetics Harvard Medical School and Director of PersonalGenomes.org "Synthetic biology presents some of the greatest challenges and opportunities of the 21st Century. Gigi Gronvall navigates a path to follow, to make sure risks are addressed and opportunities are not squandered. It should be read by all concerned about national security." - The Honorable Andrew Weber, head of global partnerships for Metabiota and former Assistant Secretary of Defense for Nuclear, Chemical, and Biological Defense Programs

This second edition of a very successful book is thoroughly updated with existing chapters completely rewritten while the content has more than doubled from 16 to 36 chapters. As with the first edition, the focus is on industrial pharmaceutical research, written by a team of industry experts from around the world, while quality and safety management, drug approval and regulation, patenting issues, and biotechnology fundamentals are also covered. In addition, this new edition now not only includes biotech drug development but also the use of biopharmaceuticals in diagnostics and vaccinations. With a foreword by Robert Langer, Kenneth J. Germeshausen Professor of Chemical and Biomedical Engineering at MIT and member of the National Academy of Engineering and the National Academy of Sciences.

A review of the interdisciplinary field of synthetic biology, from genome design to spatial engineering. Written by an international panel of experts, *Synthetic Biology* draws from various areas of research in biology and engineering and explores the current applications to provide an authoritative overview of this burgeoning field. The text reviews the synthesis of DNA and genome engineering and offers a discussion of the parts and devices that control protein expression and activity. The authors include information on the devices that support spatial engineering, RNA switches and explore the early applications of synthetic biology in protein synthesis, generation of pathway libraries, and immunotherapy. Filled with the most recent research, compelling discussions, and unique perspectives, *Synthetic Biology* offers an important resource for understanding how this new branch of science can improve on applications for industry or biological research.

In the final years of the twentieth century, emigres from mechanical and electrical engineering and computer science resolved that if the aim of biology was to understand life, then making life would yield better theories than experimentation. Sophia Roosth, a cultural anthropologist, takes us into the world of these self-named synthetic biologists who, she shows, advocate not experiment but manufacture, not reduction but construction, not analysis but synthesis. Roosth reveals how synthetic biologists make new living things in order to understand better how life works. What we see through her careful questioning is that the biological features, theories, and limits they fasten upon are determined circularly by their own experimental tactics. This is a story of broad interest, because the active, interested making of the synthetic biologists is endemic to the sciences of our time."

In the fall of 1980, Genentech, Inc., a little-known California genetic engineering company, became the overnight darling of Wall Street, raising over \$38 million in its initial public stock offering. Lacking marketed products or substantial profit, the firm nonetheless saw its share price escalate from \$35 to \$89 in the first few minutes of trading, at that point the largest gain in stock market history. Coming at a time of economic recession and declining technological competitiveness in the United States, the event provoked banner headlines and ignited a period of



speculative frenzy over biotechnology as a revolutionary means for creating new and better kinds of pharmaceuticals, untold profit, and a possible solution to national economic malaise. Drawing from an unparalleled collection of interviews with early biotech players, Sally Smith Hughes offers the first book-length history of this pioneering company, depicting Genentech's improbable creation, precarious youth, and ascent to immense prosperity. Hughes provides intimate portraits of the people significant to Genentech's science and business, including cofounders Herbert Boyer and Robert Swanson, and in doing so sheds new light on how personality affects the growth of science. By placing Genentech's founders, followers, opponents, victims, and beneficiaries in context, Hughes also demonstrates how science interacts with commercial and legal interests and university research, and with government regulation, venture capital, and commercial profits. Integrating the scientific, the corporate, the contextual, and the personal, Genentech tells the story of biotechnology as it is not often told, as a risky and improbable entrepreneurial venture that had to overcome a number of powerful forces working against it.

Written primarily for mid-to-upper level undergraduates, this primer will introduce students to topics at the forefront of the subject that are being applied to probe biological problems, or to address the most pressing issues facing society. These topics will include those that form the cornerstone of contemporary research, helping students to make the transition to active researcher. This primer introduces the challenges and opportunities of applying synthetic biological techniques to mammalian cells, tissues, and organisms. It covers the special features that make engineering mammalian systems different from engineering bacteria, fungi, and plants, and provides an overview of current techniques. A variety of cutting-edge examples illustrate the different purposes of mammalian synthetic biology, including pure biomedical research, drug production, tissue engineering, and regenerative medicine.

"Scientific advances over the past several decades have accelerated the ability to engineer existing organisms and to potentially create novel ones not found in nature. Synthetic biology, which collectively refers to concepts, approaches, and tools that enable the modification or creation of biological organisms, is being pursued overwhelmingly for beneficial purposes ranging from reducing the burden of disease to improving agricultural yields to remediating pollution. Although the contributions synthetic biology can make in these and other areas hold great promise, it is also possible to imagine malicious uses that could threaten U.S. citizens and military personnel. Making informed decisions about how to address such concerns requires a realistic assessment of the capabilities that could be misused. To that end, the U.S. Department of Defense, working with other agencies involved in biodefense, asked the National Academies of Sciences, Engineering, and Medicine to develop a framework to guide an assessment of the security concerns related to advances in synthetic biology, to assess the levels of concern warranted for such advances, and to identify options that could help mitigate those concerns"--Summary.

Synthetic Biology - a Primer (revised Edition) World Scientific Synthetic Biology A Primer

Erwin Schrödinger's 1944 classic *What Is Life?* is a small book that occupies a large place among the great written works of the twentieth century. It is said that it helped launch the modern revolution in biology and genetics, and inspired a generation of scientists, including Watson and Crick, to explore the riddle of life itself. Now, more than sixty years later, science writer Ed Regis offers an intriguing look at where this quest stands today. Regis ranges widely here, illuminating many diverse efforts to solve one of science's great mysteries. He examines the genesis of Schrödinger's great book--which first debuted as three public lectures in Dublin--and details the fantastic reception his ideas received, both in Europe and America. Regis also introduces us to the work of a remarkable group of scientists who are attempting literally to create life from scratch, starting with molecular components that they hope to assemble into the world's first synthetic living cell. The book also examines how scientists have unlocked the "three secrets of life," describes the key role played by ATP ("the ultimate driving force of all life"), and outlines the many attempts to explain how life first arose on earth, a puzzle that has given birth to a wide range of theories (which Francis Crick dismissed as "too much speculation running after too few facts"), from the primordial sandwich theory, to the theory that life arose in clay, in deep-sea vents, or in oily bubbles at the seashore, right up to Freeman Dyson's "theory of double origins." Written in a lively and accessible style, and bringing together a wide range of cutting-edge research, *What is Life?* makes an illuminating contribution to this ancient and ever-fascinating debate.

A groundbreaking examination of the implications of synthetic biology for biodiversity conservation Nature almost everywhere survives on human terms. The distinction between what is natural and what is human-made, which has informed conservation for centuries, has become blurred. When scientists can reshape genes more or less at will, what does it mean to conserve nature? The tools of synthetic biology are changing the way we answer that question. Gene editing technology is already transforming the agriculture and biotechnology industries. What happens if synthetic biology is also used in conservation to control invasive species, fight wildlife disease, or even bring extinct species back from the dead? Conservation scientist Kent Redford and geographer Bill Adams turn to synthetic biology, ecological restoration, political ecology, and de-extinction studies and propose a thoroughly innovative vision for protecting nature.

*Synthetic Biology — A Primer* gives a broad overview of the emerging field of synthetic biology and the foundational concepts on which it is built. It will be of interest to final year undergraduates, postgraduates and established researchers who are interested in learning about this exciting new field. The book introduces readers to fundamental concepts in molecular biology and engineering and then explores the two major themes for synthetic biology, namely 'bottom-up' and 'top-down' engineering approaches. 'Top-down' engineering utilises a conceptual framework of engineering and systematic design to build new biological systems by integrating robustly characterised biological parts into an existing system through the use of extensive mathematical modelling. The 'bottom-up' approach involves the design and building of synthetic protocells using basic chemical and biochemical building blocks from scratch. Exemplars of cutting-edge applications designed using synthetic biology principles are presented, including the production of novel biofuels from renewable feedstocks, microbial synthesis of pharmaceuticals and fine chemicals, and the design and implementation of biosensors to detect infections and environmental waste. The book also uses the Internationally Genetically Engineered Machine (iGEM) competition to illustrate the power of synthetic biology as an innovative research and training science. Finally, the primer includes a chapter on the ethical, legal and societal issues surrounding synthetic biology, illustrating the integration of social sciences in synthetic biology research.

Praise for the first edition: ... superb, beautifully written and organized work that takes an engineering approach to systems biology. Alon provides nicely written appendices to explain the basic mathematical and biological concepts clearly and succinctly without interfering with the main text. He starts with a mathematical description of transcriptional activation and then describes some basic transcription-network motifs (patterns) that can be combined to form larger networks. – Nature [This text deserves] serious attention from any quantitative scientist who hopes to learn about modern biology ... It assumes no prior knowledge of or even interest in biology ... One final aspect that must be mentioned is the wonderful set of exercises that accompany each chapter. ... Alon's book should become a standard part of the training of graduate students. – Physics Today Written for students and researchers, the second edition of this best-selling textbook continues to offer a clear presentation of design principles that govern the structure and behavior of biological systems. It highlights simple, recurring circuit elements that make up the regulation of cells and tissues. Rigorously classroom-tested, this edition includes new chapters on exciting advances made in the last decade. Features: Includes seven new chapters The new edition has 189 exercises, the previous edition had 66 Offers new examples relevant to human physiology and disease

This textbook has been conceptualized to provide a detailed description of the various aspects of Systems and Synthetic Biology, keeping the requirements of M.Sc. and Ph.D. students in mind. Also, it is hoped that this book will mentor young scientists who are willing to contribute to this area but do not know from where to begin. The book has been divided into two sections. The first section will deal with systems biology – in terms of the foundational understanding, highlighting issues in biological complexity, methods of analysis and various aspects of modelling. The second section deals with the engineering concepts, design strategies of the biological systems ranging from simple DNA/RNA fragments, switches and oscillators, molecular pathways to a complete synthetic cell will be described. Finally, the book will offer expert opinions in legal, safety, security and social issues to present a well-balanced information both for students and scientists.

Synthetic Biology — A Primer (Revised Edition) presents an updated overview of the field of synthetic biology and the foundational concepts on which it is built. This revised edition includes new literature references, working and updated URL links, plus some new figures and text where progress in the field has been made. The book introduces readers to fundamental concepts in molecular biology and engineering and then explores the two major themes for synthetic biology, namely 'bottom-up' and 'top-down' engineering approaches. 'Top-down' engineering uses a conceptual framework of systematic design and engineering principles focused around the Design-Build-Test cycle and mathematical modelling. The 'bottom-up' approach involves the design and building of synthetic protocells using basic chemical and biochemical building blocks from scratch exploring the fundamental basis of living systems. Examples of cutting-edge applications designed using synthetic biology principles are presented, including: the production of novel, microbial synthesis of pharmaceuticals and fine chemicals the design and implementation of biosensors to detect infections and environmental waste. The book also describes the Internationally Genetically Engineered Machine (iGEM) competition, which brings together students and young researchers from around the world to carry out summer projects in synthetic biology. Finally, the primer includes a chapter on the ethical, legal and societal issues surrounding synthetic biology, illustrating the integration of social sciences into synthetic biology research. Final year undergraduates, postgraduates and established researchers interested in learning about the interdisciplinary field of synthetic biology will benefit from this up-to-date primer on synthetic biology. Contents: List of Contributors Preface Introduction to Biology Basic Concepts in Engineering Biology Foundational Technologies Minimal Cells and Synthetic Life Parts, Devices and Systems Modelling Synthetic Biology Systems Applications of Designed Biological Systems iGEM The Societal Impact of Synthetic Biology Appendices: Proforma of Common Laboratory Techniques Glossary Index Readership: Students, professionals, researchers in biotechnology and bioengineering. Keywords: Synthetic Biology; Engineering Principles; Biosociety; Biological Engineering; Biotechnology Key Features: The book is written in a way that is accessible to students and researchers from different disciplines The authors are part of the internationally recognised Centre for Synthetic Biology and Innovation and are among the leaders in this field Technology is a process and a body of knowledge as much as a collection of artifacts. Biology is no different—and we are just beginning to comprehend the challenges inherent in the next stage of biology as a human technology. It is this critical moment, with its wide-ranging implications, that Robert Carlson considers in *Biology Is Technology*. He offers a uniquely informed perspective on the endeavors that contribute to current progress in this area—the science of biological systems and the technology used to manipulate them. In a number of case studies, Carlson demonstrates that the development of new mathematical, computational, and laboratory tools will facilitate the engineering of biological artifacts—up to and including organisms and ecosystems. Exploring how this will happen, with reference to past technological advances, he explains how objects are constructed virtually, tested using sophisticated mathematical models, and finally constructed in the real world. Such rapid increases in the power, availability, and application of biotechnology raise obvious questions about who gets to use it, and to what end. Carlson's thoughtful analysis offers rare insight into our choices about how to develop biological technologies and how these choices will determine the pace and effectiveness of innovation as a public good.

*Calculations for Molecular Biology and Biotechnology: A Guide to Mathematics in the Laboratory, Second Edition*, provides an introduction to the myriad of laboratory calculations used in molecular biology and biotechnology. The book begins by discussing the use of scientific notation and metric prefixes, which require the use of exponents and an understanding of significant digits. It explains the mathematics involved in making solutions; the characteristics of cell growth; the multiplicity of infection; and the quantification of nucleic acids. It includes chapters that deal with the mathematics involved in the use of radioisotopes in nucleic acid research; the synthesis of oligonucleotides; the polymerase chain reaction (PCR) method; and the development of recombinant DNA technology. Protein quantification and the assessment of protein activity are also discussed, along with the centrifugation method and applications of PCR in forensics and paternity testing. Topics range from basic scientific notations to complex subjects like nucleic acid chemistry and recombinant DNA technology Each chapter includes a brief explanation of the concept and covers necessary definitions, theory and rationale for each type of calculation Recent applications of the procedures and computations in clinical, academic, industrial and basic research laboratories are cited throughout the text New to this Edition: Updated and increased coverage of real time PCR and the mathematics used to measure gene expression More sample problems in every chapter for readers to practice concepts

“Bold and provocative... Regenesi s tells of recent advances that may soon yield endless supplies of renewable energy, increased longevity and the return of long-extinct species.”—New Scientist In *Regenesi s*, Harvard biologist George Church and science writer Ed Regis explore the possibilities—and perils—of the emerging field of synthetic biology. Synthetic biology, in which living organisms are selectively altered by modifying substantial portions of their genomes, allows for the creation of entirely new species of organisms. These technologies—far from the out-of-control nightmare depicted in science fiction—have the power to improve human and animal health, increase our intelligence, enhance our memory, and even extend our life span. A breathtaking look at the potential of this world-changing technology, *Regenesi s* is nothing less than a guide to the future of life.

*Zero to Genetic Engineering Hero* is made to provide you with a first glimpse of the inner-workings of a cell. It further focuses on skill-building for genetic engineering and the Biology-as-a-Technology mindset (BAAT). This book is designed and written for hands-on learners who have little knowledge of biology or genetic engineering. This book focuses on the reader mastering the necessary skills of genetic engineering while learning about cells and how they function. The goal of this book is to take you from no prior biology and genetic engineering knowledge toward a basic understanding of how a cell functions, and how they are engineered, all while building the skills needed to do so.

Modern biotechnologies give us unprecedented control of the fundamental building blocks of life. For designers, across a range of disciplines, emerging fields such as synthetic biology offer the promise of new sustainable materials and structures which may be grown, are self-assembling, self-healing and adaptable to change. While there is a thriving speculative discourse on the future of design in the age of biotechnology, there are few realized design applications. This book, the first in the Bio Design series, acts as a bridge between design speculation and scientific reality and between contemporary design thinking, in areas such as architecture, product design and fashion design, and the traditional engineering approaches which currently dominate biotechnologies. Filled with real examples, *Living Construction* reveals how living cells construct and transform materials through methods of fabrication and assembly at multiple scales and how designers can utilize these processes.

Written primarily for 16-19 year old students, this primer aims to extend students' knowledge and inspire them to take their school-level learning further. It explores topics that are familiar from the curriculum and also introduces new ideas, giving students a first taste of the study of biology beyond school-level and demonstrating how concepts frequently encountered at school are relevant to and applied in current research. This is the ideal text to support students who are considering making the transition from studying biology at school to university. This is a concise, stimulating introduction to the fundamental



biomolecules in cells and organisms, and the exciting ways biochemistry could be used to solve global problems, both now and in the future.

As synthetic biology transforms living matter into a medium for making, what is the role of design and its associated values? Synthetic biology manipulates the stuff of life. For synthetic biologists, living matter is programmable material. In search of carbon-neutral fuels, sustainable manufacturing techniques, and innovative drugs, these researchers aim to redesign existing organisms and even construct completely novel biological entities. Some synthetic biologists see themselves as designers, inventing new products and applications. But if biology is viewed as a malleable, engineerable, designable medium, what is the role of design and how will its values apply? In this book, synthetic biologists, artists, designers, and social scientists investigate synthetic biology and design. After chapters that introduce the science and set the terms of the discussion, the book follows six boundary-crossing collaborations between artists and designers and synthetic biologists from around the world, helping us understand what it might mean to 'design nature.' These collaborations have resulted in biological computers that calculate form; speculative packaging that builds its own contents; algae that feeds on circuit boards; and a sampling of human cheeses. They raise intriguing questions about the scientific process, the delegation of creativity, our relationship to designed matter, and, the importance of critical engagement. Should these projects be considered art, design, synthetic biology, or something else altogether? Synthetic biology is driven by its potential; some of these projects are fictions, beyond the current capabilities of the technology. Yet even as fictions, they help illuminate, question, and even shape the future of the field.

*Synthetic Biology: A Lab Manual* is the first manual for laboratory work in the new and rapidly expanding field of synthetic biology. Aimed at non-specialists, it details protocols central to synthetic biology in both education and research. In addition, it provides all the information that teachers and students from high schools and tertiary institutions need for a colorful lab course in bacterial synthetic biology using chromoproteins and designer antisense RNAs. As a bonus, practical material is provided for students of the annual international Genetically Engineered Machine (iGEM) competition. The manual is based upon a highly successful course at Sweden's Uppsala University and is coauthored by one of the pioneers of synthetic biology and two bioengineering postgraduate students. An inspiring foreword is written by another pioneer in the field, Harvard's George Church: "Synthetic biology is to early recombinant DNA as a genome is to a gene. Is there anything that SynBio will not impact? There was no doubt that the field of SynBio needed 'A Lab Manual' such as the one that you now hold in your hands."

Today's synthetic biologists are in the early stages of engineering living cells to help treat diseases, sense toxic compounds in the environment, and produce valuable drugs. With this manual, you can be part of it. Based on the BioBuilder curriculum, this valuable book provides open-access, modular, hands-on lessons in synthetic biology for secondary and post-secondary classrooms and laboratories. It also serves as an introduction to the field for science and engineering enthusiasts. Developed at MIT in collaboration with award-winning high school teachers, BioBuilder teaches the foundational ideas of the emerging synthetic biology field, as well as key aspects of biological engineering that researchers are exploring in labs throughout the world. These lessons will empower teachers and students to explore and be part of solving persistent real-world challenges. Learn the fundamentals of biodesign and DNA engineering Explore important ethical issues raised by examples of synthetic biology Investigate the BioBuilder labs that probe the design-build-test cycle Test synthetic living systems designed and built by engineers Measure several variants of an enzyme-generating genetic circuit Model "bacterial photography" that changes a strain's light sensitivity Build living systems to produce purple or green pigment Optimize baker's yeast to produce  $\beta$ -carotene

Developments in synthetic biology are raising significant security concerns: Will they enable the creation of dangerous viruses from scratch? Will scientific advances enable radically new pathogens not found in nature to be designed? Is synthetic biology breaking down the boundary between experts and non-experts to such an extent that anyone will be able to develop a biological weapon? Drawing on years of experience working with synthetic biologists, the established team of social scientists behind this book tackle these questions head on in their assessment of whether the misuse potential of synthetic biology is realistic or exaggerated. Through an accessible and engaging narrative that highlights key messages, questions for discussion and classroom exercises, readers are expertly led through the complex technical, historical, social, political and legal landscape at the intersection of synthetic biology and security.

How can we accelerate the development of vaccines? How do we feed three billion people when 12 million died of hunger in 2019? Does synthetic biology hold the answer? With all the advances in science in the last century, why are there still so many infectious diseases? Why haven't we found cures for difficult cancers? Why hasn't any major progress been made in the treatment of mental illness? And how do we intend to stop, and not only that but reverse, global warming and the climate crisis? In *Saved by Science*, scientist Mark Poznansky examines the many crises facing humanity while encouraging us with the promise of an emerging solution: synthetic biology. This is the science of building simple organisms, or "biological apps," to make manufacturing greener energy production more sustainable, agriculture more robust, and medicine more powerful and precise. Synthetic biology is the marriage of the digital revolution with a revolution in biology and genomics; some have even called it "the fourth industrial revolution." Accessible and informative, *Saved by Science* provides readers with hope for the future if we trust in and support the future of science.

This text offers a fresh, distinctive approach to the teaching of molecular biology that reflects the challenge of teaching a subject that is in many ways unrecognizable from the molecular biology of the 20th century - a discipline in which our understanding has advanced immeasurably, but about which many questions remain to be answered. With a focus on key principles, this text emphasizes the commonalities that exist between the three kingdoms of life, giving students an accurate depiction of our current understanding of the nature of molecular biology and the differences that underpin biological diversity.

Bill Gates recently told *Wired* that if he were a teenager today, he would be hacking biology. "If you want to change the world in some big way," he says, "that's where you should start-biological molecules." The most disruptive force on the planet resides in DNA. Biotech companies and academic researchers are just beginning to unlock the potential of

piecing together life from scratch. Champions of synthetic biology believe that turning genetic code into Lego-like blocks to build never-before-seen organisms could solve the thorniest challenges in medicine, energy, and environmental protection. But as the hackers who cracked open the potential of the personal computer and the Internet proved, the most revolutionary discoveries often emerge from out-of-the-way places, forged by brilliant outsiders with few resources besides boundless energy and great ideas. In *Biopunk*, Marcus Wohlsen chronicles a growing community of DIY scientists working outside the walls of corporations and universities who are committed to democratizing DNA the way the Internet did information. The "biohacking" movement, now in its early, heady days, aims to unleash an outbreak of genetically modified innovation by making the tools and techniques of biotechnology accessible to everyone. Borrowing their idealism from the worlds of open-source software, artisanal food, Internet startups, and the Peace Corps, biopunks are devoted advocates for open-sourcing the basic code of life. They believe in the power of individuals with access to DNA to solve the world's biggest problems. You'll meet a new breed of hackers who aren't afraid to get their hands wet, from entrepreneurs who aim to bring DNA-based medical tools to the poorest of the poor to a curious tinkerer who believes a tub of yogurt and a jellyfish gene could protect the world's food supply. These biohackers include: -A duo who started a cancer drug company in their kitchen -A team who built an open-source DNA copy machine -A woman who developed a genetic test in her apartment for a deadly disease that had stricken her family Along with the potential of citizen science to bring about disruptive change, Wohlsen explores the risks of DIY bioterrorism, the possibility of genetic engineering experiments gone awry, and whether the ability to design life from scratch on a laptop might come sooner than we think.

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