Introduction

IF3211 Domain Specific Computation

School of Electrical Engineering and Informatics ITB

Lecturers

- K1 (IF): Fariska Zakhralativa Ruskanda fariska@informatika.org
- K2 (IF): Yudistira Dwi Wardhana Asnar yudis@itb.ac,id
- K3 (IF-STI): Muhammad Koyimatu koyimatu@itb.ac.id
- K4 (STI): Muhamad Koyimatu koyimatu@itb.ac.id
- K5 (STI): Beni Rio Hermanto benirio@itb.ac.id

Vision and Mission STEI ITB

Visi:

Menjadi Institusi pendidikan tinggi, pengembang ilmu pengetahuan Teknik Elektro dan Informatika yang unggul dan terkemuka di Indonesia dan diakui di dunia serta berperan aktif dalam usaha memajukan dan mensejahterakan bangsa.

Misi:

1. Menyelenggarakan pendidikan tinggi dan pendidikan berkelanjutan di bidang teknik Elektro dan Informatika dengan memanfaatkan teknologi komunikasi dan informasi
2. Mengikuti (memelihara) keterkinian (state of the art) serta mengembangkan ilmu pengetahuan Teknik Elektro dan Informatika melalui kegiatan penelitian yang inovatif.
3. Mendiseminasikan ilmu pengetahuan, teknologi dan pandangan/wawasan Teknik Elektro dan Informatika yang dimiliki kepada masyarakat baik melalui lulusannya, kemitraan dengan industri atau lembaga lainnya maupun melalui kegiatan pengabdian pada masyarakat dalam rangka membentuk masyarakat berkearifan teknologi.

Program Educational Objective IF/IST

1. Our graduates will have successful careers in their profession in informatics/IS/IT or related fields.
2. Our graduates will successfully pursue graduate study or engage in professional development.
3. Our graduates will demonstrate leadership and play active roles in the improvement of their community [, especially in the development of new tools, technologies and methodologies].

Student Outcome – IF/IST

Graduates of the program will have an ability to:

1. An ability to analyze a complex computing problem and to apply principles of computing and other relevant disciplines to identify solutions.
2. An ability to design, implement, and evaluate a computing-based solution to meet a given set of computing requirements in the context of the program's discipline.
3. An ability to communicate effectively in a variety of professional contexts.
4. An ability to recognize professional responsibilities and make informed judgments in computing practice based on legal and ethical principles.
5. An ability to function effectively as a member or leader of a team engaged in activities appropriate to the program's discipline.

IF

6. An ability to apply computer science theory and software development fundamentals to produce computing-based solutions.

IST

6. Support the delivery, use, and management of information systems within an information systems environment
7. Identify and analyze user needs and to take them into account in the selection, creation, integration, evaluation, and administration of computing-based systems

Objectives For Students – IF3211

1. Mahasiswa menunjukkan kemampuan menganalisis masalah komputasi dan menerapkan teori komputasi untuk mengidentifikasi solusi
2. Mahasiswa dapat merancang solusi berbasis komputing saat diberikan serangkaian kebutuhan komputing,
3. Mahasiswa dapat mengimplementasikan solusi berbasis komputing saat diberikan serangkaian kebutuhan komputing,
4. Mahasiswa mampu mengorganisasikan dan mendistribusikan hasil pekerjaannya secara efisien dan efektif

Dalam konteks Biologi

1. Mahasiswa memahami dasar dasar biologi dari makromolekul, sel, sistem organ, organisme hingga ekosistem.
2. Mahasiswa memahami bahwa ilmu biologi sangat luas dan banyak berkaitan dengan disiplin ilmu lainnya.
3. Mahasiswa mampu mengasah critical thinking terkait konsep dan fenomena biologi.

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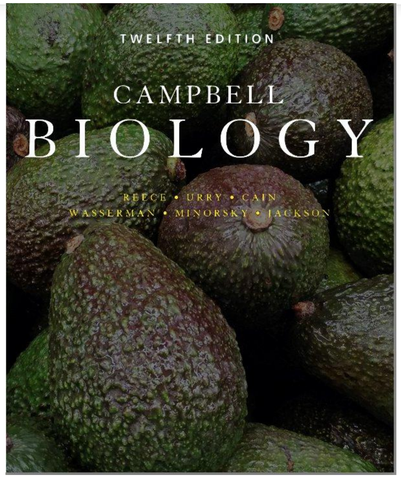
Course Description

- Credits: 2 credit points (2*45 hours/semester)
- Prerequisites: IF3170 Artificial Intelligence / IF3070 Foundation of Artificial Intelligence
- Grading Components:
  - Midterm & Final Test
  - Project Assignments
  - Exercises
- Attending classes (obligatory):
  - 2 hours/week: Wednesday 7-9, (or Friday 9-11)
- Exercises and Small Assignments
- Project assignments (groups)
- Midterm test: w8
- Final test: w16

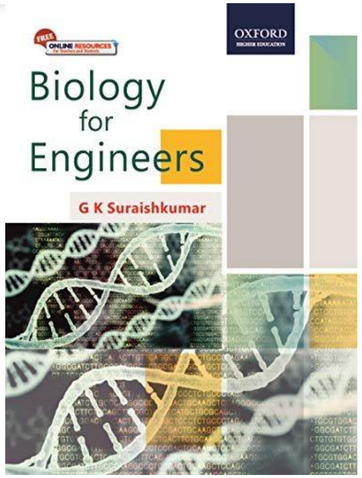
General Rules

- Midterm Test & Final Test: obligatory, if not attending grade E
  Additional test only for students who stay in hospital (doctor recommendation) / have “force majeure” proof is required (from doctor, guardian)
- Any act of cheating will result grade “E” (for all components)
  Include helping to cheat
  Include cheating for assignment: “E” for all members (for all groups involved)
  Maintain integrity between group members
- Rules for using Generative AI explicitly written in every assignment
  To pass this course, a student must have “no zero” in every component

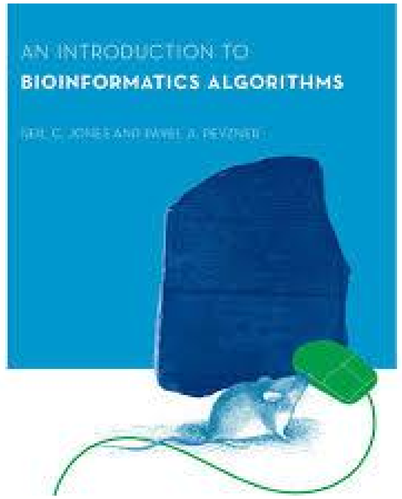
Textbooks, LMS, Communication Channel



"Biology", Neil A. Campbell, et al., Pearson, 2014



"Biology for Engineers", G. K. Suraishkumar, 2019



"An Introduction to Bioinformatics Algorithms", Jones and Pevzner, MIT Press, 2004

- Course Website: https://edunex.itb.ac.id/courses
- Modules : IF3211 Domain-Specific Computation [Parent Class]

Token: 4W12Q5 (14 March 2025)

- Communication:

  Join Ms-Teams: IF3211 – Domain-Specific Computing

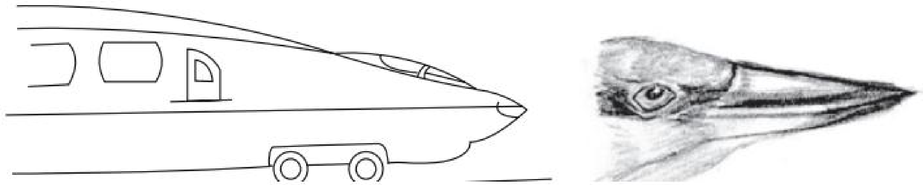
  team code: 4f53cx8

Course Contents

Biology concept and related methods in Computer Science

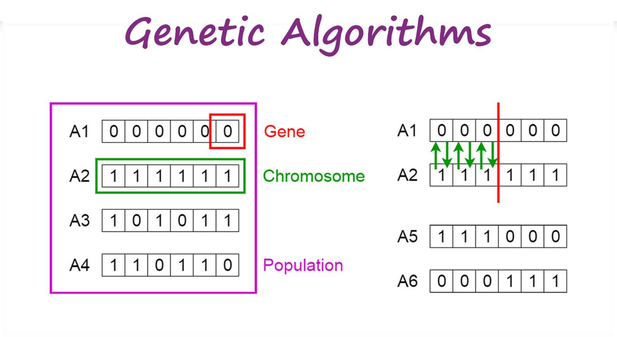
1. Introduction to Biology
2. Cell and Molecular
3. Genetics
4. Evolution
5. Biological Diversity
6. Plant form and function
7. Animal Form and Function
8. Ecology

Need for Biology



- There is no difference between learning math and learning biology.
- Shinkansen sonic boom: kingfisher's beak shaped nose of re-designed Shinkansen
- Benefit from engineering – biology coupled improve biological shortcomings, ex. Retinal prosthetic
- Bio-sensors, bio-chips, bio-pesticides, self-heal concrete

Bio-inspired Algorithms



https://medium.com/towards-data-science/introduction-to-genetic-algorithms-including-example-code-e396e98d8bf3

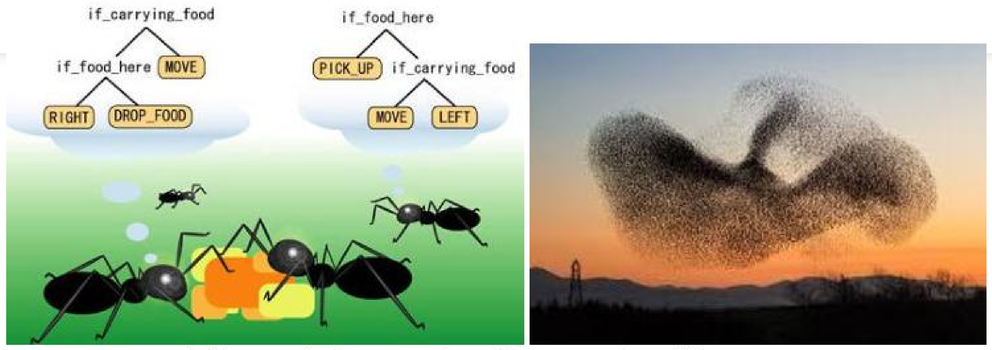
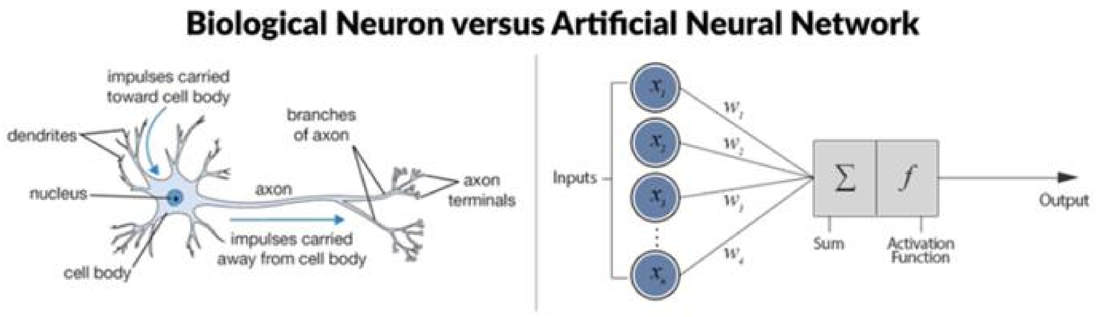


Figure 4: Example of swarm intelligence

Nemade, M.N., & Rane, M.D. (2016). A Review on Bio-Inspired Computing Algorithms and Application.



https://primo.ai/index.php/Bio-inspired_Computing

Learning Biology vs Learning Mathematics

- Learning Math: addition operation vs trigonometric functions vs log function vs Bessel function -> know/remember by using many times
- Learning Physics: use observations, then expressed mathematically for completeness.
- Learning Biology: dominated by observations, rules are not yet universal, complex system, math representation evolving
- Learning Biology is Fundamentally Not Different From Learning Mathematics

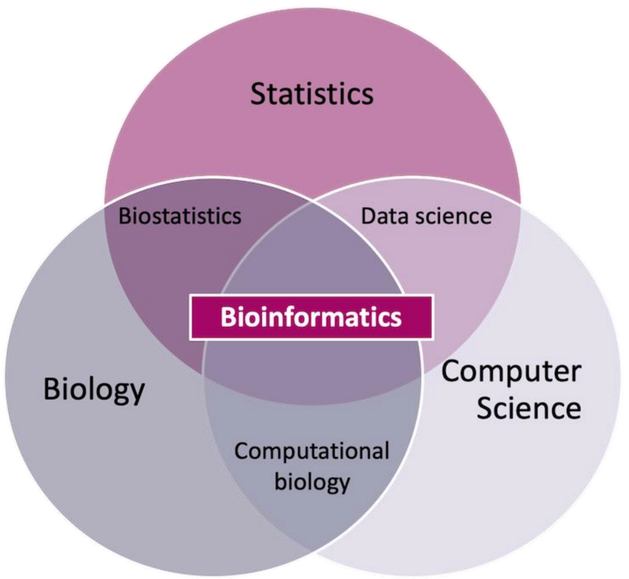
Introduction to Computational Biology

Computational Biology

- Computational biology refers to the use of techniques in computer science, data analysis, mathematical modeling and computational simulations to understand biological systems and relationships. ["NIH working definition of bioinformatics and computational biology" (PDF). Biomedical Information Science and Technology Initiative. 17 July 2000.]
- An intersection of computer science, biology, and data science, the field also has foundations in applied mathematics, molecular biology, cell biology, chemistry, and genetics.[Center for Computational Molecular Biology. Retrieved 18 August 2012.]

Bioinformatics

- Bioinformatics refers to the use of computing to understand and analyze biological data, including genetic sequences, protein structures, and other biological information.



https://python.plainenglish.io/exploring-the-interconnection-between-data-science-and-bioinformatics-future-transformations-in-2ccd1c15ffa3

Biology vs Computing

Computational Biology
using computer science, math, & statistics to understand Biology

Bioinformatics
using tech to analyze DNA, RNA, proteins & Big Data in Biology

Bio-inspired Computing
using models of Biology to solve computer science poblems

Biomedical Engineering
using engineering/computing to treat disease

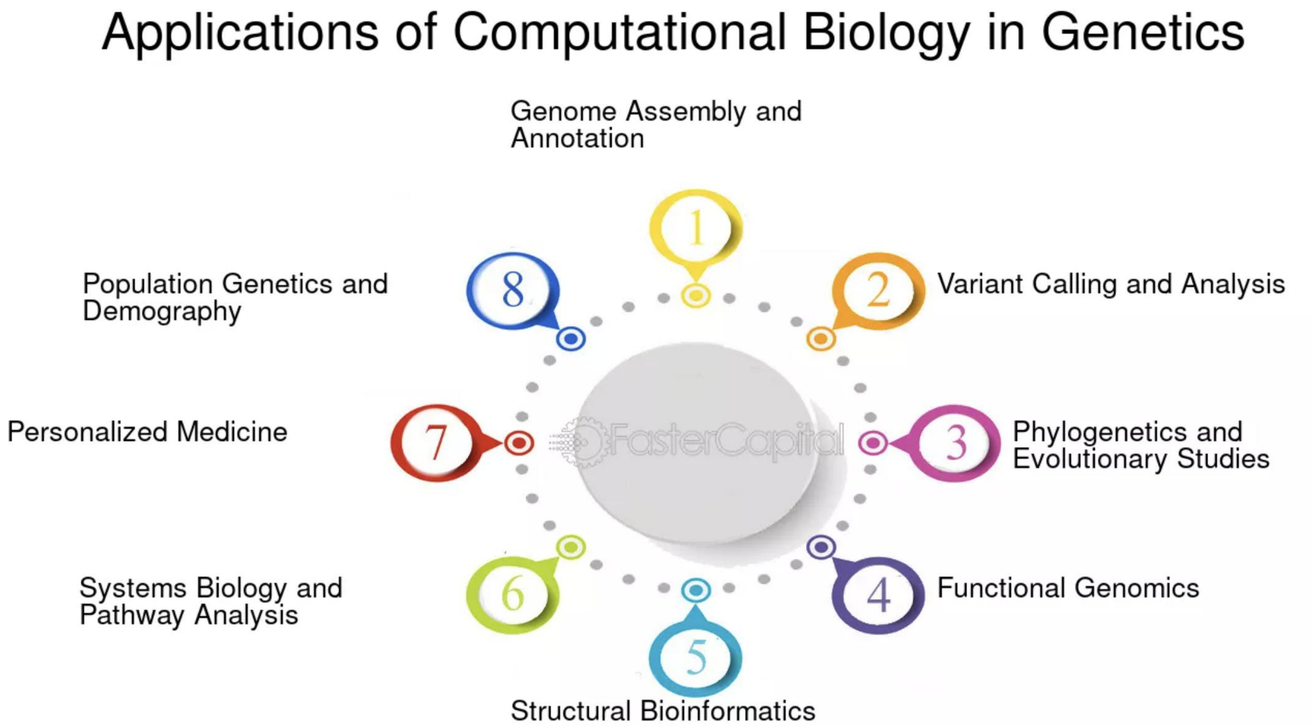
Biological Computing
using biologically derived molecule (DNA/proteins) to perform computations

In this course, Bioinformatics ≈ Computational Biology

Why Computational Biology?

- Computational biology is particularly exciting today because:
  - the problems are large enough to motivate efficient algorithms,
  - the problems are accessible, fresh and interesting,
  - biology is increasing becoming a computational science
- Computational biology is increasing of interest in both life science and computational science departments.
- Source of complex questions and real-life data.
  - Many problem ideas go from biology to CS: e.g. fragment assembly, sequence analysis, algorithms for phylogenic trees.
  - Many problem ideas go from CS to biology: e.g. sequencing by hybridization, DNA computing.

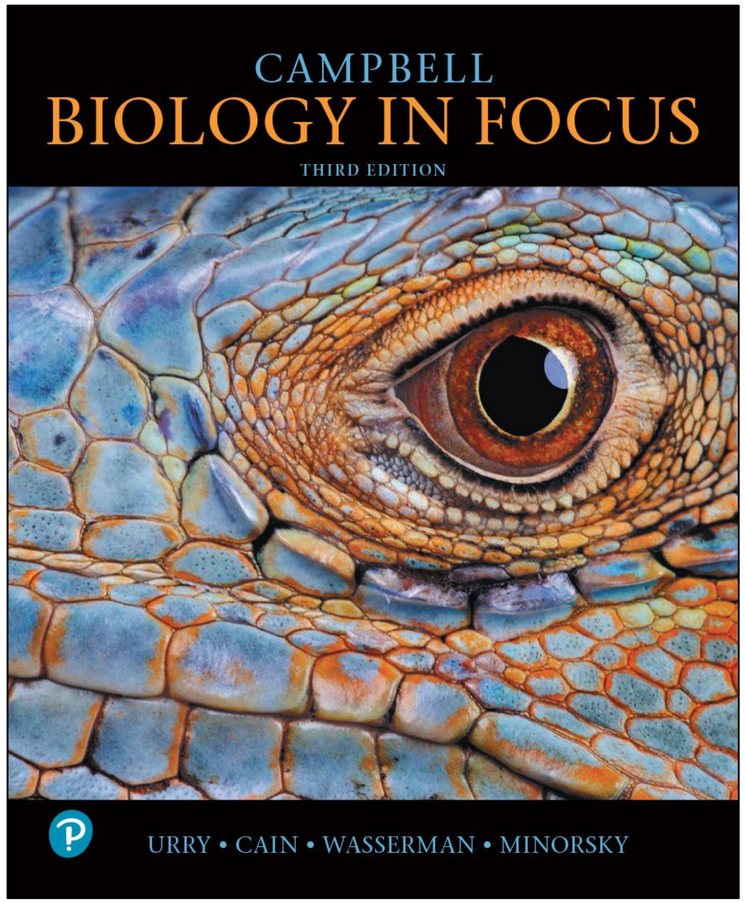
Computational Biology Applications



Introduction to Biology

Campbell Biology in Focus

Third Edition



Chapter 1

Introduction: Evolution and the Foundations of Biology

Lecture Presentations by
Kathleen Fitzpatrick and Nicole Tunbridge,
Simon Fraser University

Pearson

Overview: Inquiring About Life (1 of 2)

- An organism's adaptations to its environment are the result of evolution
  - For example, a beach mouse's light, dappled fur allows the mouse to blend into its surroundings
  - Inland mice of the same species are darker in color, matching their surroundings
- Evolution is the process of change that has resulted in the astounding array of organisms found on Earth
- It is the fundamental principle of biology

Overview: Inquiring About Life (2 of 2)

- **Biology** is the scientific study of life
- Biologists ask questions such as
  - How does a single cell develop into an organism?
  - How does the human mind work?
  - How do different forms of life in a forest interact?

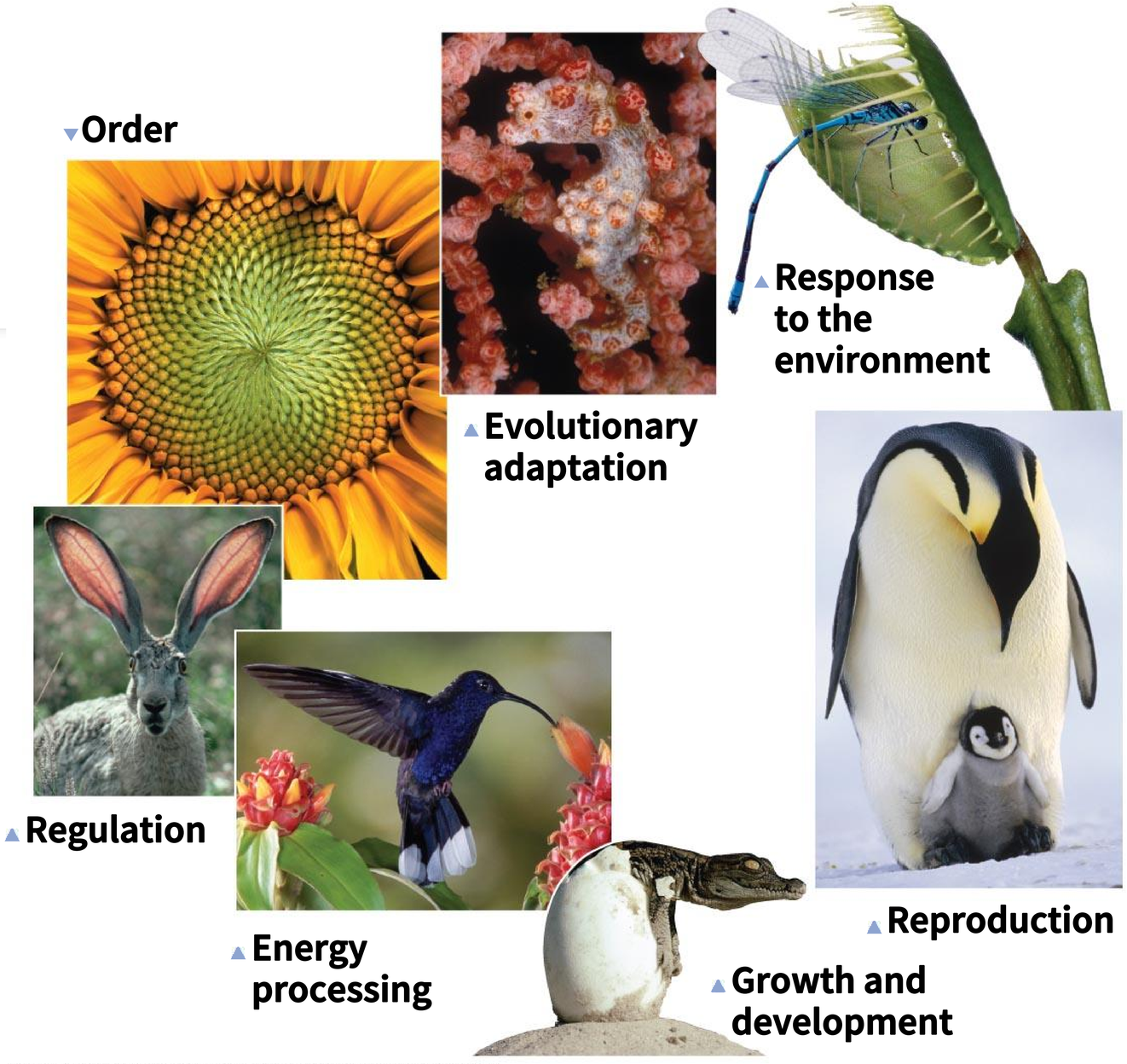
Fig. 1-2

Questions:

- How would you define what it means to be alive?
- What properties do all living things share?

- Life defies a simple, one-sentence definition
- Life is recognized by what living things do

Fig. 1-3



Concept 1.1: The Study of Life Reveals Unifying Themes

- To organize and make sense of all the information encountered in biology, focus on a few big ideas
- These unifying themes help to organize biological information:
  - Organization
  - Information
  - Energy and matter
  - Interactions
  - Evolution → paling penting

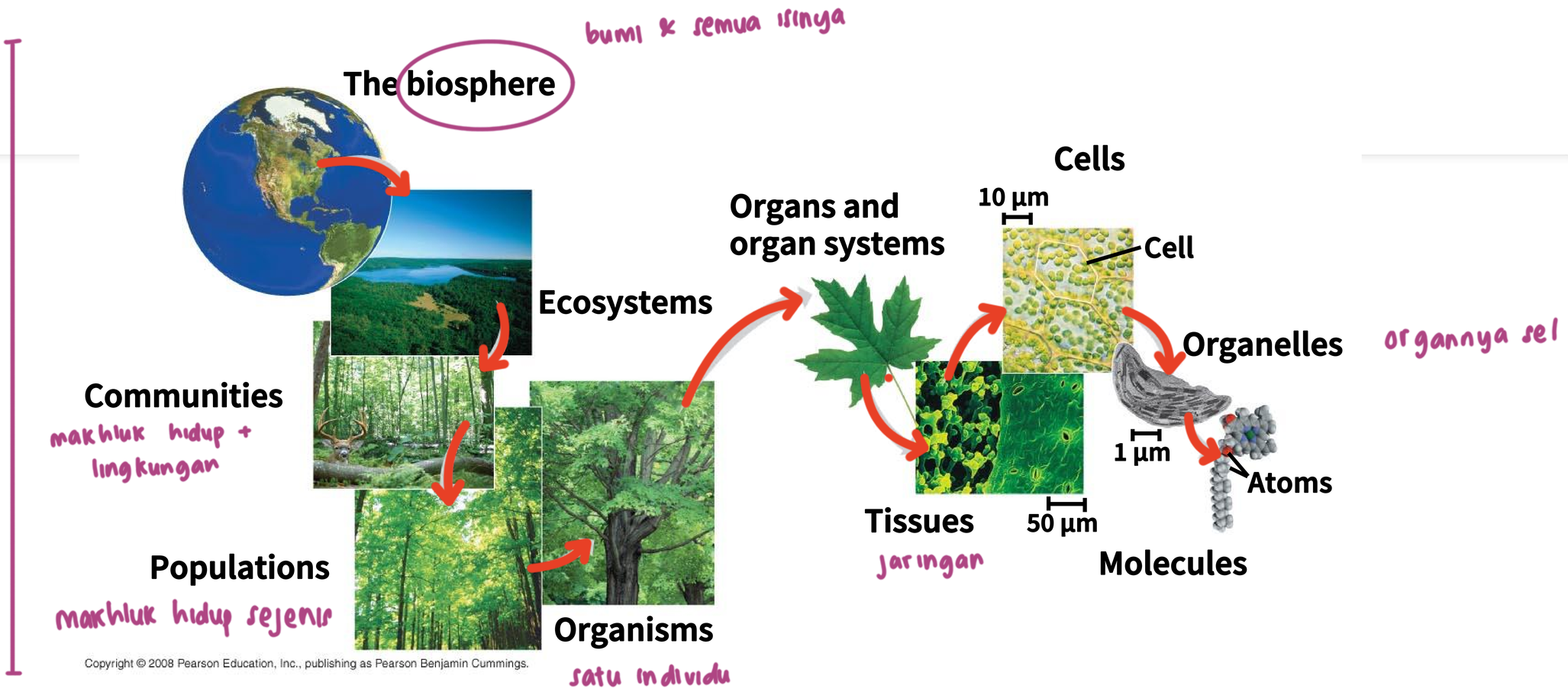
Question:

- What are three key themes (organizing principles of biology)?
- Which of these is most central to our understanding of biology?

Theme: New Properties Emerge at Successive Levels of Biological Organization

- **Life can be studied at different levels, from molecules to the entire living planet**
- **The study of life can be divided into different levels of biological organization**
- **In reductionism, complex systems are reduced to simpler components to make them more manageable to study**

Fig. 1-4


bumi & semua isinya
The biosphere
Level of Biology Organizations
Ecosystems
Communities
makhluk hidup + lingkungan
Populations
makhluk hidup sejenis
Organisms
satu individu
Organs and organ systems
Cells
10 µm
Cell
Organelles
organnya sel
1 µm
Atoms
Tissues
jaringan
50 µm
Molecules
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Structure and Function

- At each level of the biological hierarchy, we find a correlation between structure and function
- Analyzing a biological structure can give clues about what it does and how it works

The Cell: An Organism's Basic Unit of Structure and Function (1 of 2)

- The cell is the smallest unit of life that can perform all activities required for life
- All cells share certain characteristics, such as being enclosed by a membrane
- The two main forms of cells are prokaryotic and eukaryotic

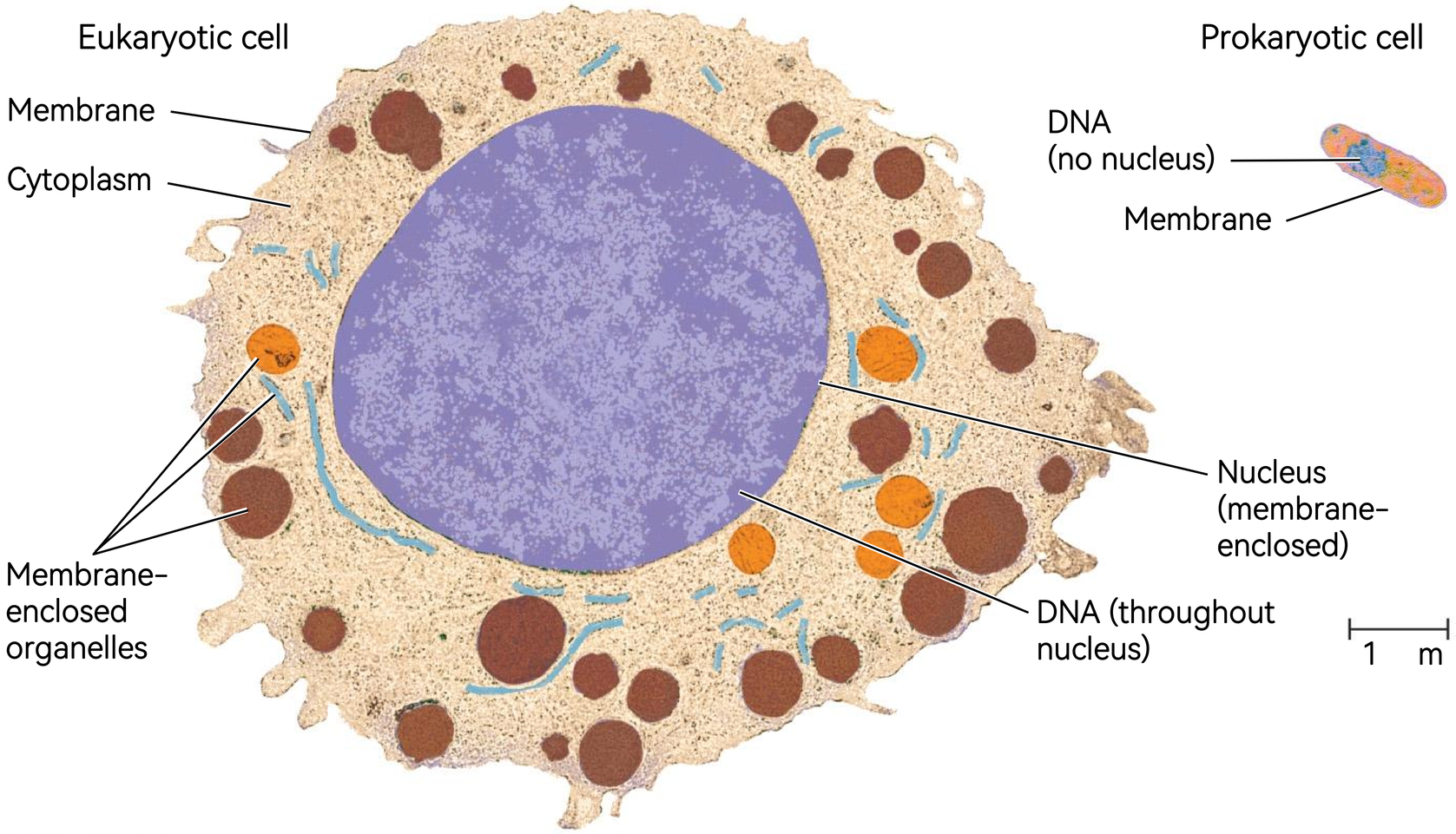
The Cell: An Organism's Basic Unit of Structure and Function (2 of 2)

- A eukaryotic cell contains membrane-enclosed organelles, including a DNA-containing nucleus
- Some organelles, such as the chloroplast, are limited only to certain cell types, that is, those that carry out photosynthesis
- Prokaryotic cells lack a nucleus or other membrane-bound organelles and are generally smaller than eukaryotic cells

eukariotik :
- punya membran
- punya nukleus
- sel besar

prokariotik :
- biasanya gapunya membran
- ga punya nukleus
- sel kecil

Figure 1.4 Contrasting Eukaryotic and Prokaryotic Cells in Size and Complexity



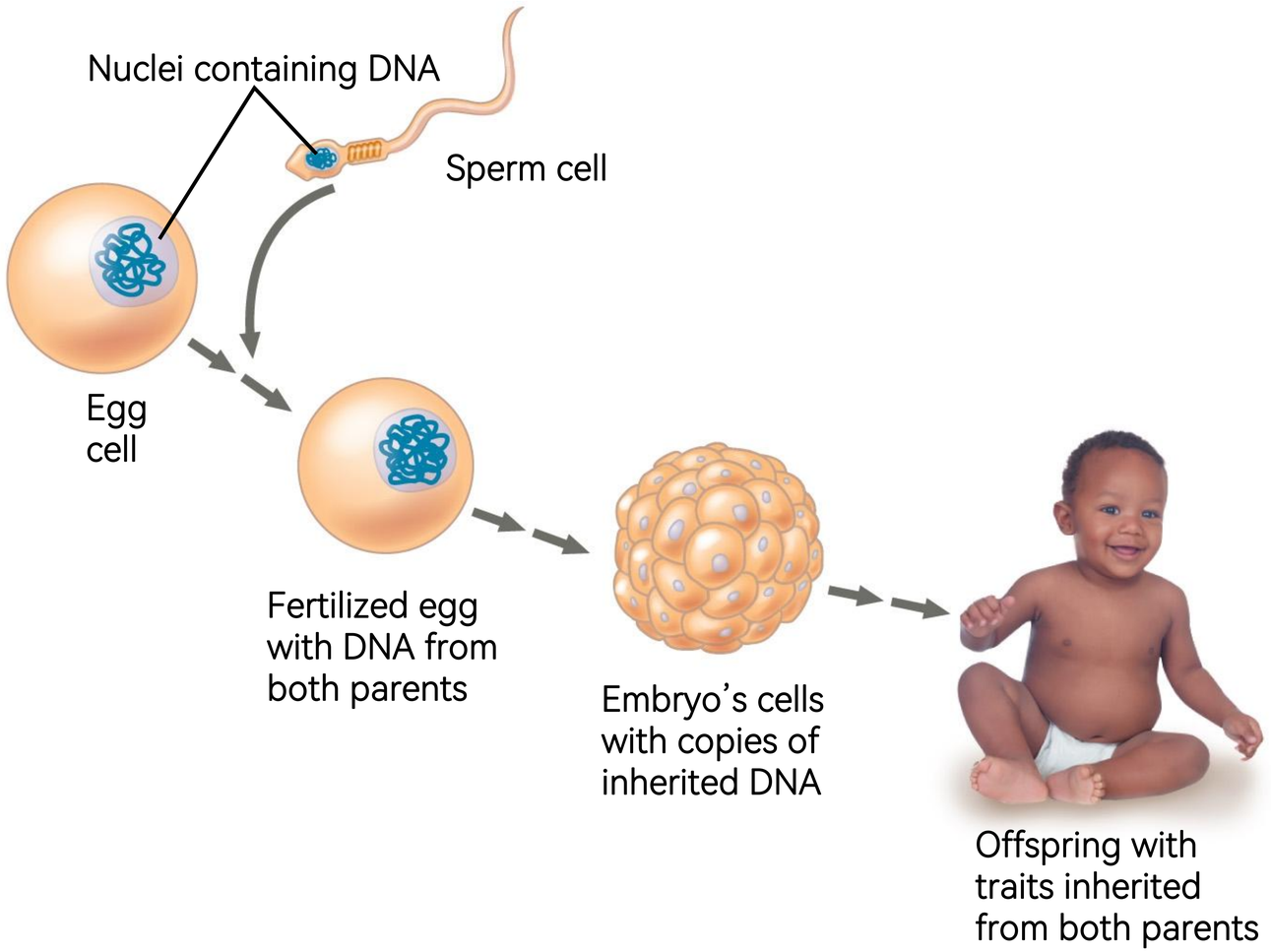
Theme: Life's Processes Involve the Expression and Transmission of Genetic Information

- Chromosomes contain a cell's genetic material in the form of **DNA** (deoxyribonucleic acid)
- DNA is the substance of genes
- **Genes** are the units of inheritance that transmit information from parents to offspring

DNA, the Genetic Material (1 of 3)

- A DNA molecule holds hundreds or thousands of genes, each a stretch of DN A along the chromosome
- **Genes** are the units of inheritance that transmit information from parents to offspring
- As cells grow and divide, the genetic information encoded by DNA directs their development

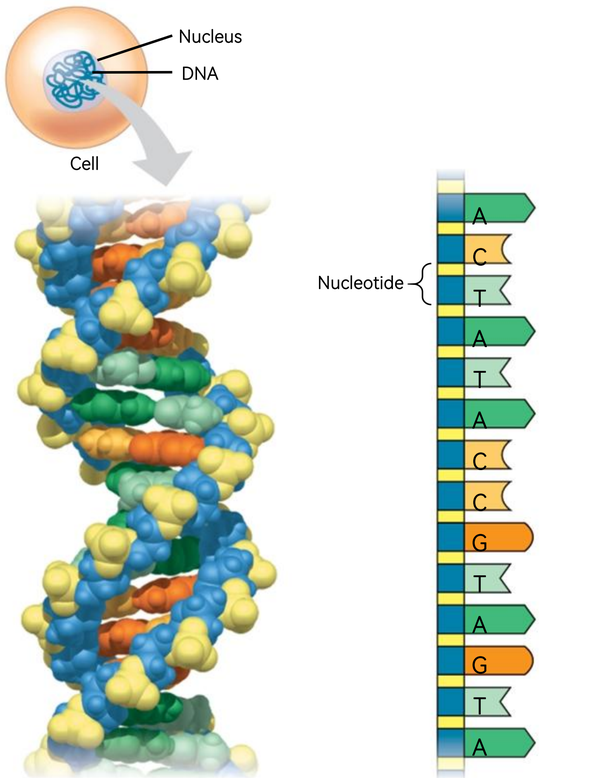
Figure 1.6 Inherited DNA Directs Development of an Organism



DNA, the Genetic Material (2 of 3)

- A DNA molecule is made of two long chains (strands) arranged in a double helix
- Each link of a chain is one of four kinds of chemical building blocks called nucleotides, abbreviated A, T, C, and G

Figure 1.7 DNA: The Genetic Material



(a) DNA double helix. This model shows the atoms in a segment of DNA. Made up of two long chains (strands) of building blocks called nucleotides, a DNA molecule takes the three-dimensional form of a double helix.

(b) Single strand of DNA. These geometric shapes and letters are simple symbols for the nucleotides in a small section of one strand of a DNA molecule. Genetic information is encoded in specific sequences of the four types of nucleotides. Their names are abbreviated A, T, C, and G.

DNA, the Genetic Material (3 of 3)

cetakan awalnya saja

- DNA provides blueprints for making proteins, the major players in building and maintaining a cell
- Genes control protein production indirectly, using RNA as an intermediary

untuk produksi proteinnya

- **Gene expression** is the process of converting information from a gene to its cellular product

Concept 1.2: The Core Theme: Evolution Accounts for the Unity and Diversity of Life

- The remarkably diverse forms of life on this planet arose by evolutionary processes
- Evolution is a process of biological change in which organisms gradually accumulate differences from their ancestors
- Similar traits in two species are explained by descent from a common ancestor
- Differences between two species indicate that heritable changes occurred after divergence from a common ancestor

pasti ada di fase kehidupan

hrs panjang & terlihat jelas bedanya

Classifying the Diversity of Life (1 of 3)

- Humans group diverse items according to their similarities and relationships to each other
- Careful analysis of form and function has been used to classify life-forms
- New methods of assessing species relationships, especially comparisons of D NA sequences, have led to a reevaluation of larger groupings

Classifying the Diversity of Life (2 of 3)

- Biologists currently divide the kingdoms of life into three domains: Bacteria, Archaea, and Eukarya
- Domains **Bacteria** and **Archaea** are prokaryotes

Classifying the Diversity of Life (3 of 3)

- Domain **Eukarya** includes all eukaryotic organisms
- Domain Eukarya includes three multicellular kingdoms: Plantae, Fungi, and Animalia
  - Plants produce their own food by photosynthesis
  - Fungi absorb nutrients from their surroundings
  - Animals obtain food by eating and digesting other organisms

Concept 1.3: In Studying Nature, Scientists Form and Test Hypotheses

dugaan awal yg hrs dibuktikan benar / tidak

- **Science** is an approach to understanding the living world
- **Inquiry** is the search for information and explanation of natural phenomena
- Science includes challenge, adventure, and luck, along with careful planning, reasoning, creativity, and persistence
- The scientific process includes making observations, forming logical hypotheses, and testing them

Exploration and Discovery

- Biology begins with careful observations
- Biologists describe natural structures and processes
- By reading about and understanding past studies, scientists can build on the foundations of existing knowledge

Gathering and Analyzing Data (1 of 2)

- Recorded observations are called **data**
- Data fall into two categories
  - Qualitative data, or descriptions rather than measurements
    - For example, Jane Goodall's observations of chimpanzee behavior
  - Quantitative data, or recorded measurements, which are sometimes organized into tables and graphs

Figure 1.18 Jane Goodall Collecting Qualitative Data on Chimpanzee Behavior

Gathering and Analyzing Data (2 of 2)

- Inductive reasoning draws conclusions through the logical process of induction

mengambil kesimpulan dr data yg dimiliki

- Through induction, generalizations are drawn from a large number of observations
  - For example, “all organisms are made of cells” was based on two centuries of microscopic observations

Forming and Testing Hypotheses (1 of 2)

- In science, a hypothesis is an explanation based on observations and assumptions that leads to a testable prediction
- It is an explanation on trial
- A scientific hypothesis must lead to predictions that can be tested with additional observations or an experiment
- An **experiment** is a scientific test, often carried out under controlled conditions

Forming and Testing Hypotheses (2 of 2)

- The initial observations may lead to multiple hypotheses to be tested
- For example
  - Observation: Your desk lamp doesn't work
  - Question: Why doesn't your lamp work?
  - Hypothesis 1: The bulb is burnt out
  - Hypothesis 2: The lamp is broken
- Both these hypotheses are testable

Hipotesis harus bisa diuji

Deductive Reasoning (1 of 2)

- Deductive reasoning extrapolates from general premises to specific predictions general → spesifik
- The hypothesis is then tested experimentally

Deductive Reasoning (2 of 2)

- A hypothesis can never be conclusively proven to be true because we can never test all the alternatives
- Testing a hypothesis in various ways can increase our confidence in its validity