

BB 101

Module 3: Biomedical Engineering (BME)

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Course Overview

Module		Faculty	Quiz	Mid-Sem	End-Sem	Total
Module - 1	Molecular & Cell Biology (MCB)	Prof. Sanjeeva Srivastava	5	20	0	25
		Prof. Rahul Purwar	5	20	0	25
Module - 2	Physical Biology	Prof. Ambarish Kunwar	5	0	20	25
Module - 3	Biomedical Engineering (BME)	Prof. Neeta Kanekar	5	0	20	25

Module - 1	50 marks
Module - 2	25 marks
Module - 3	25 marks
	100 marks

Mid-Sem	40 marks
End-Sem	40 marks
Quiz	20 marks
	100 marks

Minimum 30 %

BME module: Lecture - Tutorial - Quiz Schedule

D1 + D2			Lecture - Tutorial - Quiz No.	D3 + D4		
DATE	DAY	TIME		DATE	DAY	TIME
27/05/21	THU	08:00 AM - 09:30 AM	L 1	28/05/21	FRI	03:30 PM - 05:00 PM
01/06/21	TUE	11:30 AM – 01:00 PM	L 2 + Q 1	01/06/21	TUE	03:30 PM - 05:00 PM
03/06/21	THU	08:00 AM - 09:30 AM	L 3 + Q 2	04/06/21	FRI	03:30 PM - 05:00 PM
08/06/21	TUE	11:30 AM – 01:00 PM	L 4 + Q 3	08/06/21	TUE	03:30 PM - 05:00 PM
09/06/21	WED	04:00 PM – 05:00 PM	T 1	09/06/21	WED	02:00 PM – 03:00 PM
10/06/21	THU	08:00 AM - 09:30 AM	L 5 + Q 4	11/06/21	FRI	03:30 PM - 05:00 PM
15/06/21	TUE	11:30 AM – 01:00 PM	L 6 + Q 5	15/06/21	TUE	03:30 PM - 05:00 PM
16/06/21	WED	04:00 PM – 05:00 PM	T 2	16/06/21	WED	02:00 PM – 03:00 PM
17/06/21	THU	08:00 AM - 09:00 AM	T 3 + Q 6	18/06/21	FRI	03:30 PM - 04:30 PM

Note:

- Instead of a lecture, Tutorial 3 (+ Quiz 6) will be conducted in the last lecture slot (17/06 for D1, D2 and 18/06 for D3, D4).
- Quiz – 5 marks: Each quiz will be based on the previous lecture (not tutorial) and will be for 1 mark. 6 quizzes will be conducted and 5 best scores will be chosen.

BME module: Instructions

1. Online Platforms

- a. Course Announcements: Moodle
- b. Lectures – live teaching: Zoom (use same lecture links as given for the Physical Biology module)
- c. Lecture Handouts (slides) and Recordings of live lectures: Moodle and Google Drive (links shared on Moodle)
- d. Tutorials: MS Teams; each student has been assigned to a specific tutorial team “BB101_BME Tut Rm ##” and a specific channel within the team (Channel X1 >> D3, D4; Channel X3 >> D1, D2)
- e. Tutorial Material and Recordings of tutorial sessions: under “Files” of respective Teams Channels
- f. Quiz: Google Forms; accessible only via IITB Google Account; Quiz will also serve as your attendance.
- g. Queries (lecture, tutorial) + Quiz Cribs: 3 separate Google Forms (links shared on Moodle). The form will be activated after the completion of the respective session (lecture/tutorial/quiz) and will remain active till 09:00 AM of the following day.

BME module: Instructions

2. Assessments

- a. Quiz – 5 marks: Each quiz will be based on the previous lecture (not tutorial) and will be for 1 mark. 6 quizzes will be conducted and 5 best scores will be chosen.
- b. End-Sem exam – 20 marks for BME module: online and remote proctored

3. Point of Contact for general queries

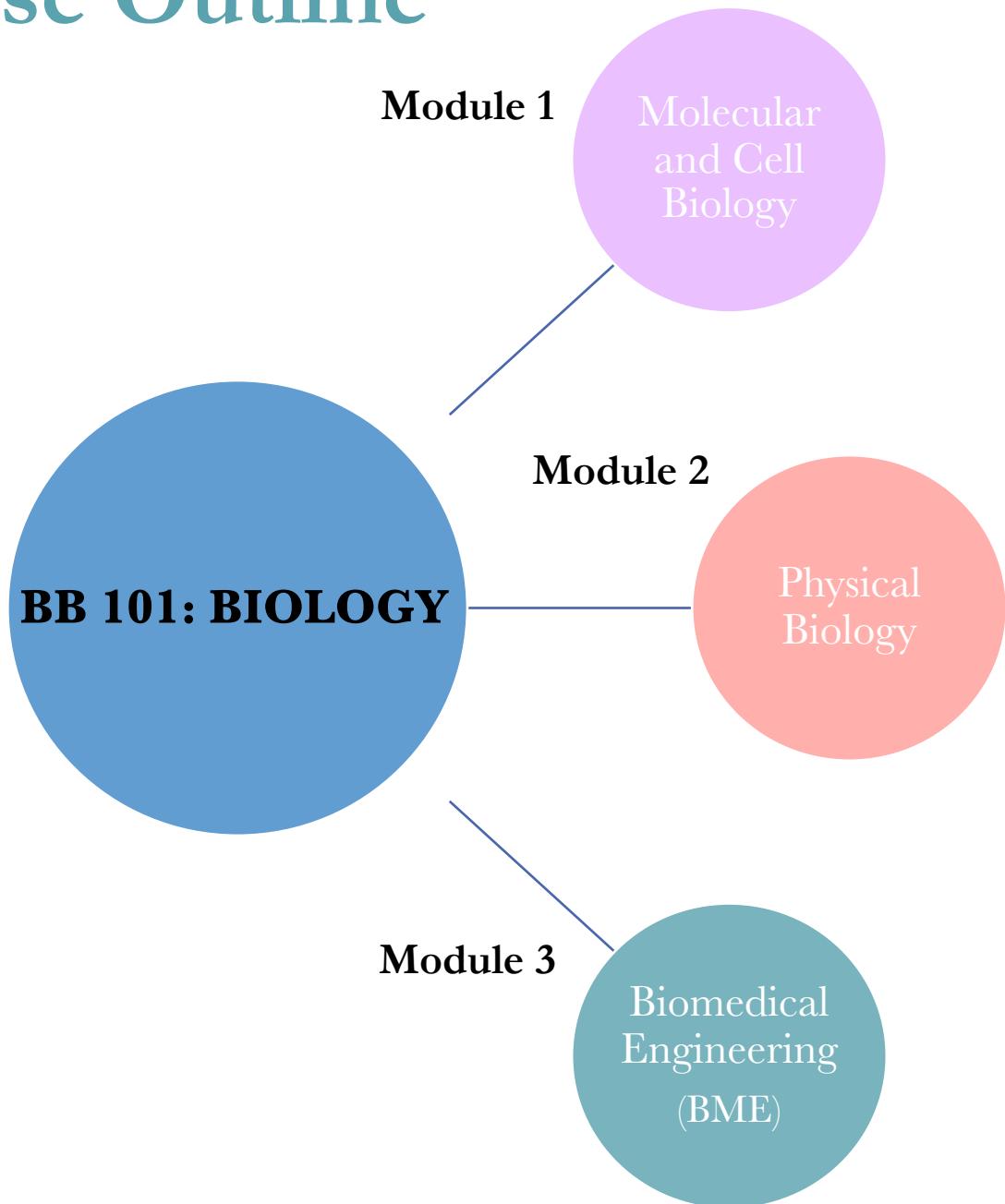
- a. Prof. Neeta Kanekar: nkanekar@iitb.ac.in
- b. Head TAs: Raj Kumari Sharma: rks.bme@iitb.ac.in
Sanjukta Bhattacharya: 163300010@iitb.ac.in

BME module: Instructions

4. Code of Honor

- a. All the course material (handouts/slides/pre-recorded content, recordings of live lecture and tutorial meetings; web links to posted course material; any other documents, etc.) is meant only for the students registered for this course. This course material or any part of it should not be shared (in any form on any platform or via any medium) with anybody without the course-module instructor's written permission.
- b. Likewise, login credentials of one's Institute LDAP account should not be shared with any unauthorized external person for any reason whatsoever.
- c. Audio, video recording, photographs, etc. of course materials and live meetings, etc. is not allowed by anyone (other than the course instructor and/or assigned TAs) without the express, written consent of the course instructor.

BB 101: Course Outline



BME module: Learning Objectives & Relevance

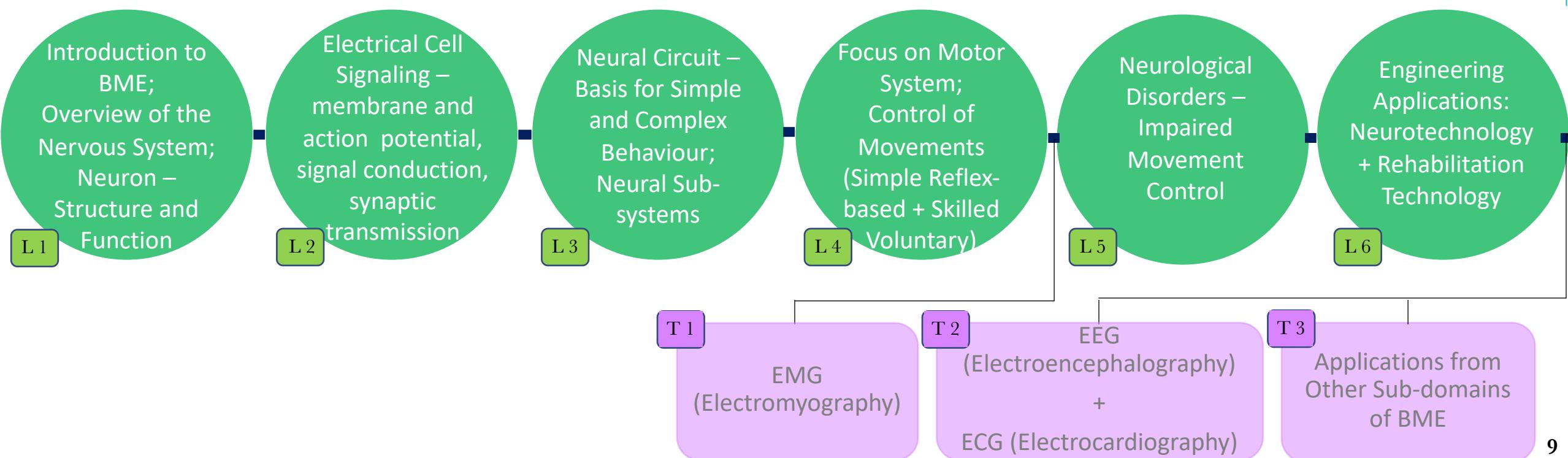
1. To describe and give an overview of the field of BME and its various sub-fields/sub-domains
2. To understand the role of engineering and sciences (concepts and methods) in advancing our knowledge of biological and physiological processes in health and disease and in developing technology-based solutions for healthcare
3. To give an in-depth example of the role of engineering in biology + medicine by focusing on the Nervous System and Neural Engineering and Rehabilitation Engineering as sub-domains of BME
4. To understand the diversity and inter-disciplinarity of various sub-domains of BME through a range of biomedical applications and the underlying engineering contributions

BME module: Course Content/Topics

Overview of Biomedical Engineering (BME) and its Various Sub-domains/Sub-fields

Nervous System – Cell >> Circuit >> System >> Behaviour
Neural Engineering – Rehabilitation Engineering

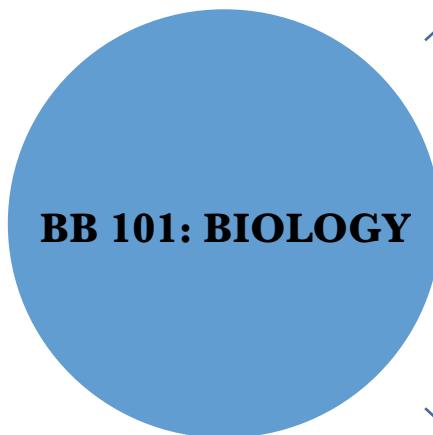
Diversity & Inter-disciplinarity in BME



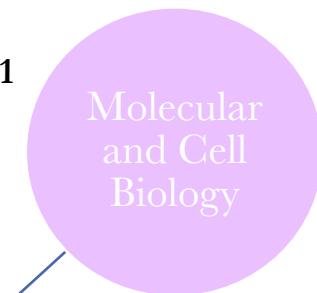
BME module: Reading Material + Reference Textbooks

1. Attending Lectures and Tutorials – most important
2. Lecture and Tutorial Slides
3. Lecture and Tutorial Recordings
4. Your own Class Notes
5. Reference Textbooks:
 - i. Dale Purves, George J. Augustine, David Fitzpatrick, William C. Hall, Anthony-Samuel LaMantia, Richard D. Mooney, Michael L. Platt, and Leonard E. White, Neuroscience, 6th Edition, Oxford University Press (Sinauer Associates), 2018, ISBN-13: 978-1605358413.
Cited in the slides as: Neuroscience, Purves D et al, 6th Ed
 - ii. Hall J, Guyton A, Textbook Of Medical Physiology, 12th Edition, Elsevier; 2011.
Cited in the slides as: Textbook of Medical Physiology, Hall & Guyton, 12th Ed

BB 101: Course Outline



Module 1



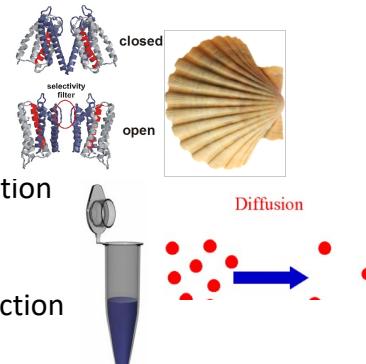
- Cell – Properties, Cycle, Metabolism
- Genome, Inheritance, DNA Tools
- Cell Communication
- Viruses and Bacteria - Applications
- Immunity
- Stem Cells - Applications



Module 2

Physical
Biology

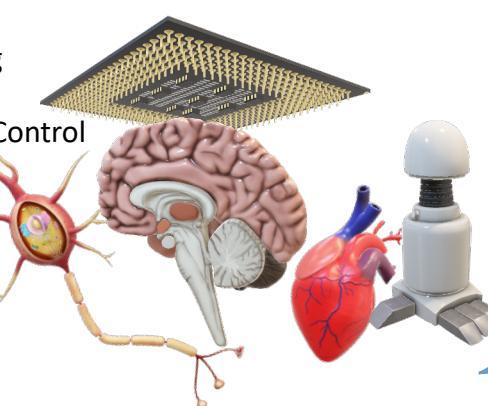
- Forces in the Microscopic World
- Viscosity of Medium > Biological Molecules
- Thermal Forces and Brownian Motion
- Diffusion, Active Transport
- Free Energy, Protein Folding
- Toy Models of Protein-DNA Interaction



Module 3

Biomedical
Engineering
(BME)

- Introduction to BME
- Neuron – Electrical Signalling
- Neural Circuits, Sub-systems
- Motor System – Movement Control
- Neuro & Rehab Engineering
- Other BME Sub-domains



Influence of Biology is All Around Us

Biology & Physiology
↓
Healthcare

Fundamental Biological Concepts

Biology & Medicine +
Physics, Math,
Chemistry &
Engineering
↓
Biomedical Research

Interweaving of Biology & Engineering
↓
Technological Solutions

BB 101

Module 3: Biomedical Engineering (BME)

Lecture 1

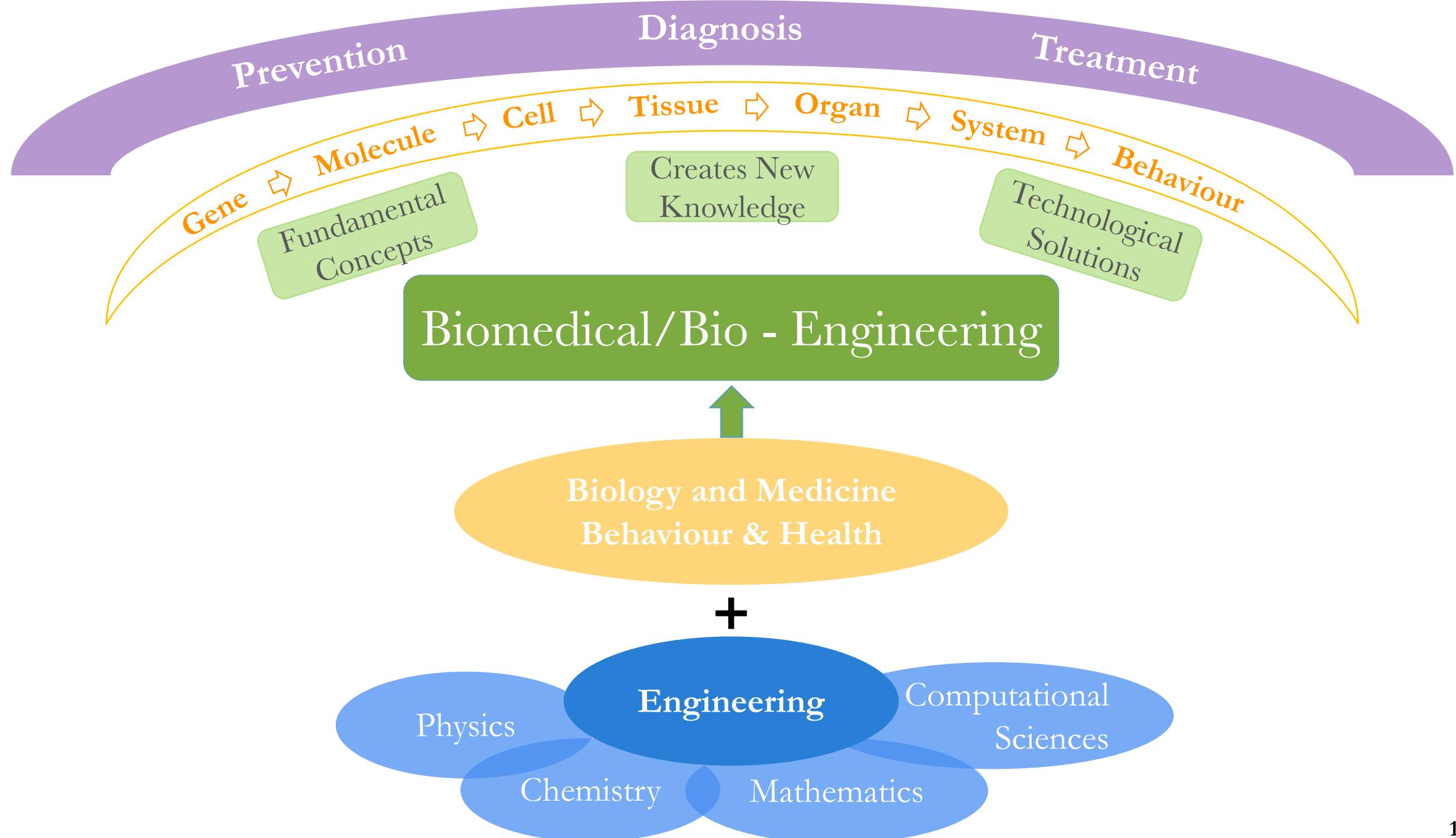
Introduction to BME

Overview of the Human Nervous System

Lecture 1 - Outline

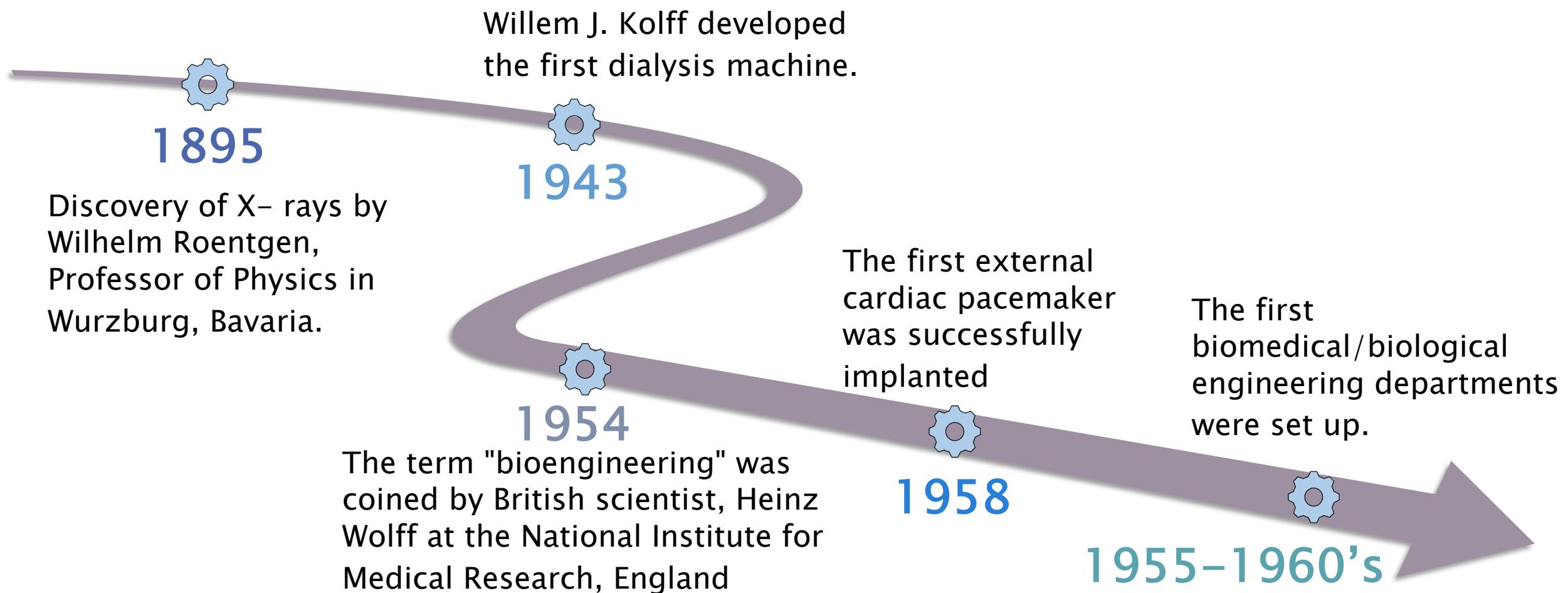
- What is Biomedical Engineering (BME)?
- Sub-domains of BME – Interdisciplinarity and Diversity
- Overview of the Human Nervous System
 - Role of the Nervous System as a Command and Coordination System: Communication at its Essence
- Levels of Organization of the Body: Chemical > Cell > Tissues > Organ > Organ Systems > Organism
- Organization of the Human Nervous System beginning with
 - Genetic diversity
 - Cells of the Nervous System: Neurons (key cells for communication) + Glial Cells (supporting cells)
 - Structure – Function Relationship

Introduction to BME



“Biomedical/Bio – Engineering integrates physical, chemical, mathematical, and computational sciences and engineering principles to study biology, medicine, behavior, and health. It advances fundamental concepts; creates knowledge from the molecular to the organ systems level; and develops innovative biologics, materials, processes, implants, devices and informatics approaches for the prevention, diagnosis, and treatment of disease, for patient rehabilitation, and for improving health.”

History of Biomedical/Bio - Engineering



Sub-domains of BME

Interdisciplinarity and Diversity

Sub-domains of Biomedical/Bio Engineering

Brain-Computer Interfaces, Biofeedback Therapy

Sensors, Medical Devices



<https://www.science.eus/en/groups/neurobiology-language>

Neuroengineering

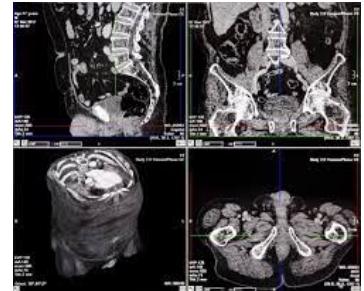
Bio-Instrumentation

Medical Imaging



<https://answers.childrenshospital.org/ventilator-training-covid-19/>

CT Scan, MRI



<https://www.medicalnewstoday.com/articles/153201>

Prosthesis, Orthosis

Rehabilitation Engineering

Clinical Engineering



<https://www.ottobockus.com/prosthetics/upper-limb-prosthetics/solution-overview/myoelectric-prosthetics/>

Implants, Artificial Heart Valves

Biomechanics

Cellular, Tissue, and Genetic Engineering

Hospital Informatics, Databases



<https://orthoinfo.aaos.org/en/treatment/total-hip-replacement>

Biomaterials

Gene Therapy, Computational Biology



<https://www.galendata.com/digital-healthcare-future-healthcare/>

<https://trialsitenews.com/technion-university-investigator-developing-next-generation-drug-delivery-platform/>



Biopolymers, Skin Grafts, Drug Delivery



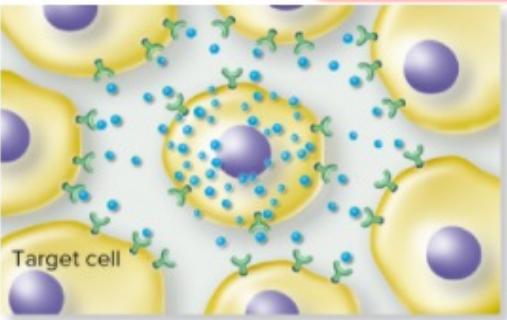
<https://www.cnet.com/news/crispr-gene-editing-explained-what-is-it-and-how-does-it-work-genetic-engineering/>

Overview of the Human Nervous System

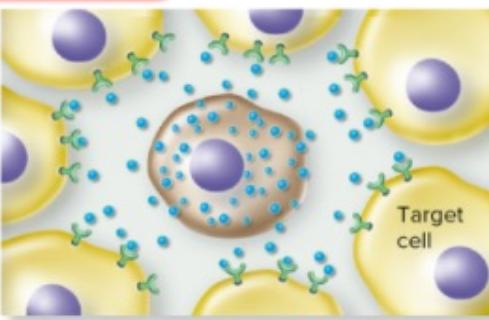
Cell to Cell Communication

Local Cell Signaling

Chemical Signaling

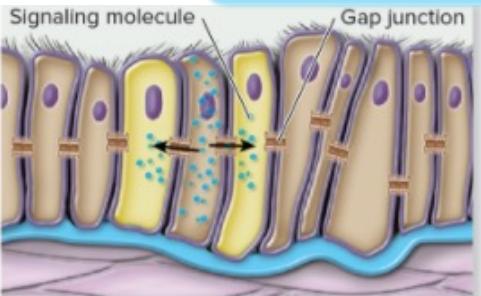


(c) **Autocrine signaling:** Cells release signals that affect themselves and nearby target cells.

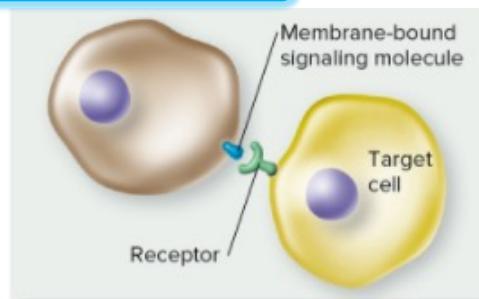


(d) **Paracrine signaling:** Cells release signals that affect nearby target cells.

Direct/Contact-based Signaling



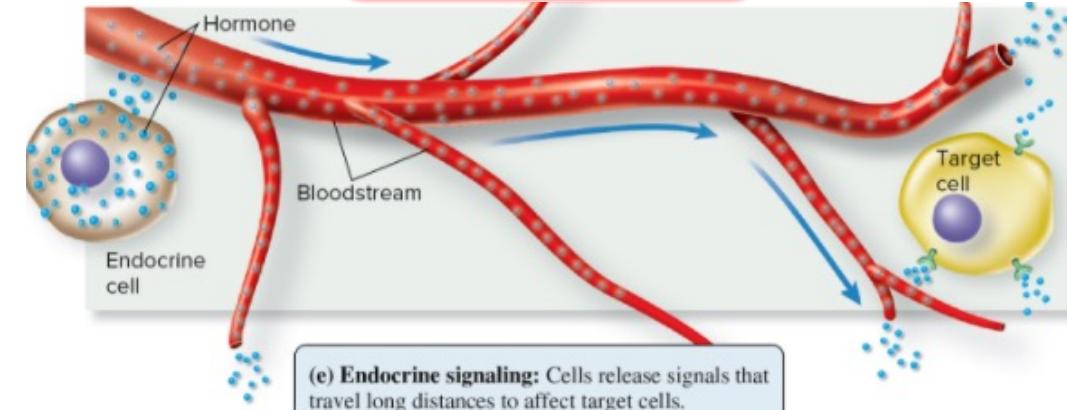
(a) **Direct intercellular signaling:** Signals pass through an intercellular channel from the cytosol of one cell to adjacent cells.



(b) **Contact-dependent signaling:** Membrane-bound signals bind to receptors on adjacent cells.

Long-Distance Cell Signaling

Chemical Signaling



(e) **Endocrine signaling:** Cells release signals that travel long distances to affect target cells.

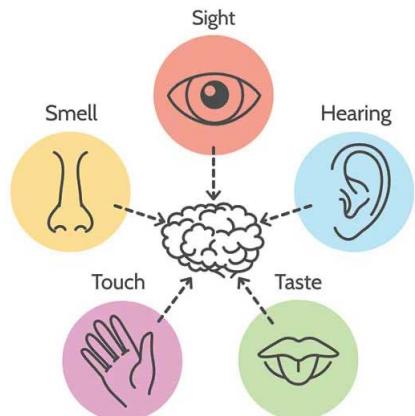
Do we need
this – for what?

Rapid Inter-Cellular Communication Over Longer Distances ???

Major Functions of The Human Nervous System

The Control and Coordination System of Our Body

Sensory Perception



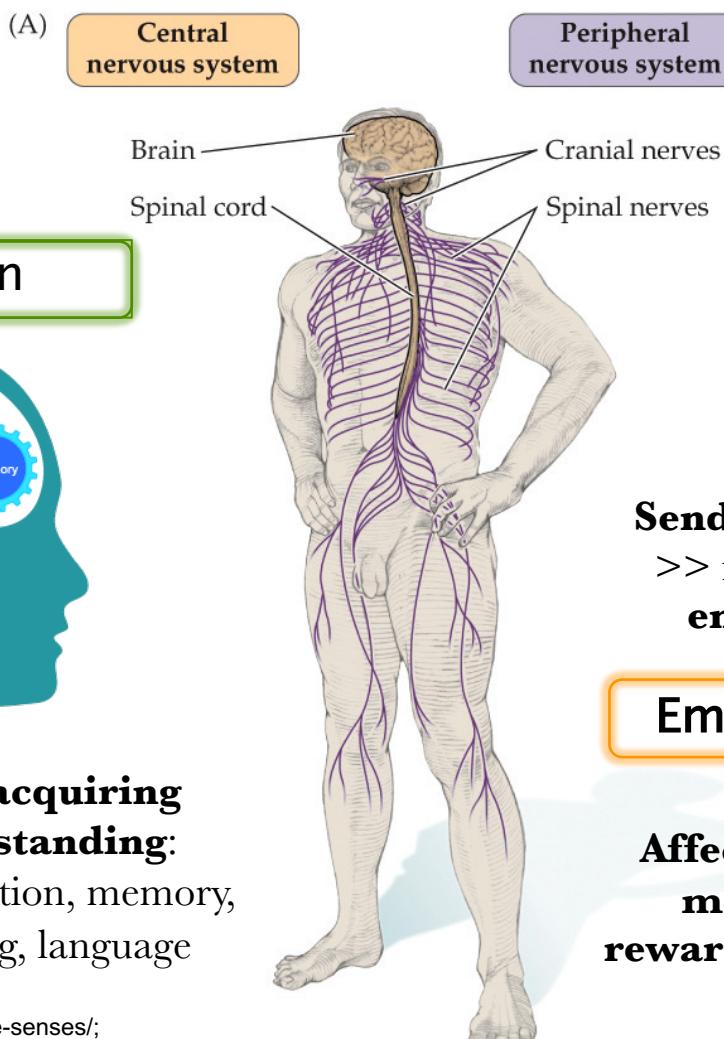
Senses and process information about the external environment and the internal status of the body

Cognition

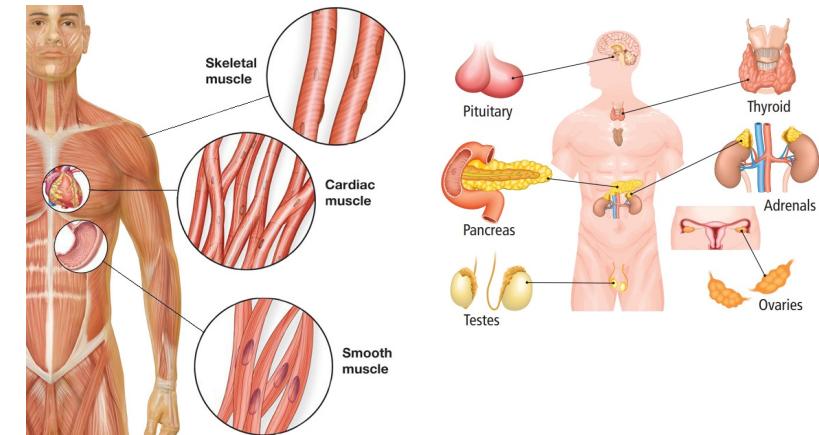


Mental processes for acquiring knowledge and understanding:

information processing, attention, memory, abstract thinking, reasoning, language



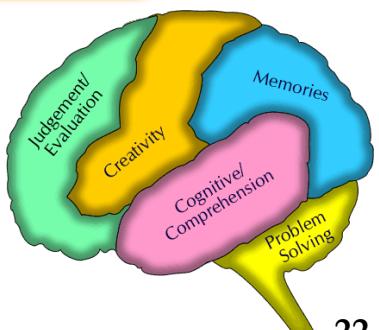
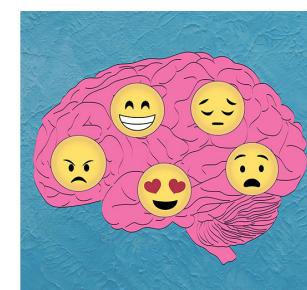
Motor/Movement Control



Sends motor outputs to two main targets: a) muscles
>> for controlling internal and external movements and **b) endocrine glands** >> to control release of hormones

Emotion Regulation and Learning

Affective states, motivation, reward, fear, stress



The Human Nervous System

Functional Requirements of the System

For Command and Coordination:

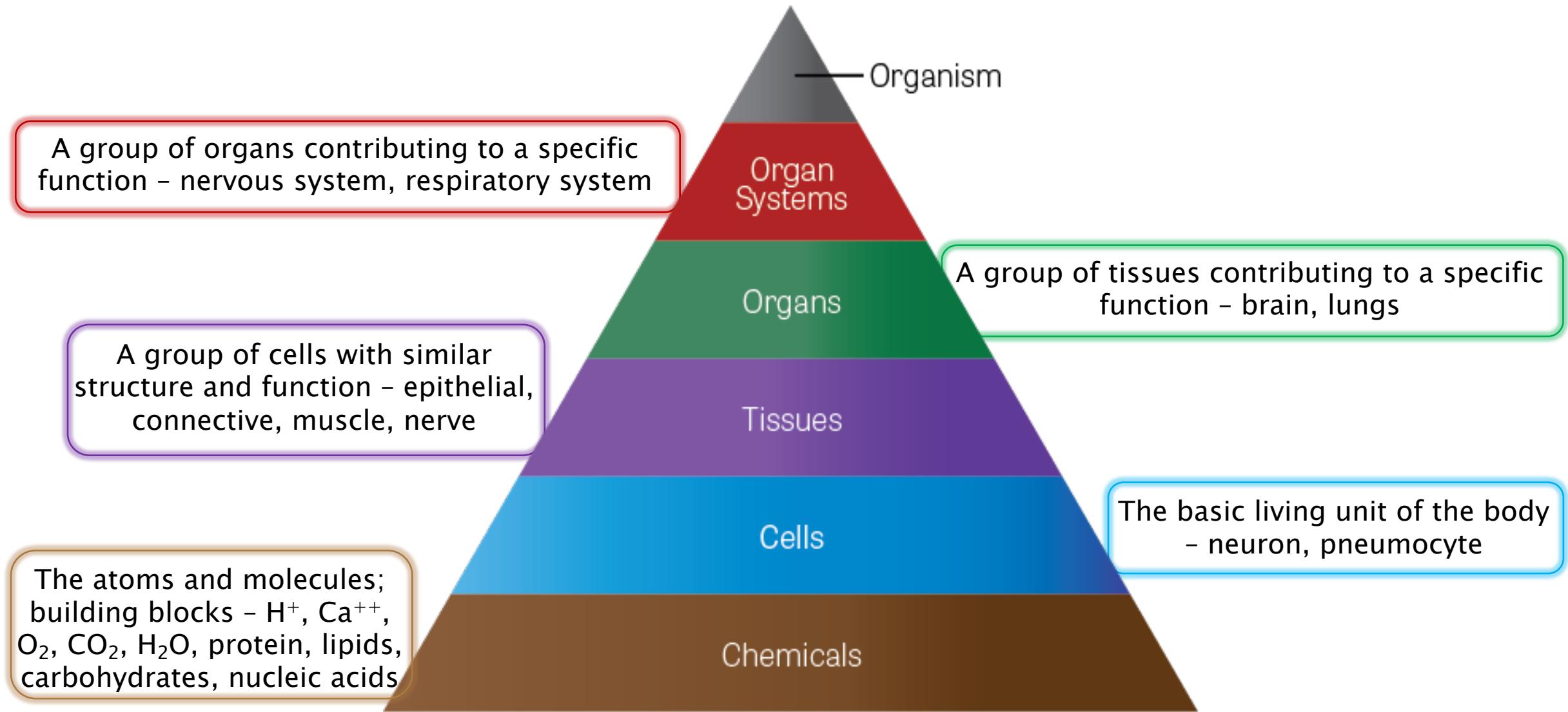
- **Communication at the heart of things** - between various organ systems and sub-systems
- Rapid transmission of information over short and long distances
- Integration and analysis of information
- Storage and recall of information
- Determining an appropriate response
- Feedback and feedforward control

Design Specifications

For Command and Coordination:

- Electrical signaling for rapid inter-cellular communication over longer distances
- Unity of function – selection of cells dedicated for a particular function
- Division of function into sub-systems and sub-modalities
- Connectivity among select regions
- Representation of information at various levels; topographic and computational mapping, diffuse distribution
- Serial and Parallel processing
- Hierarchical and Independent control

Basic Structural and Functional Organization of the Human Body



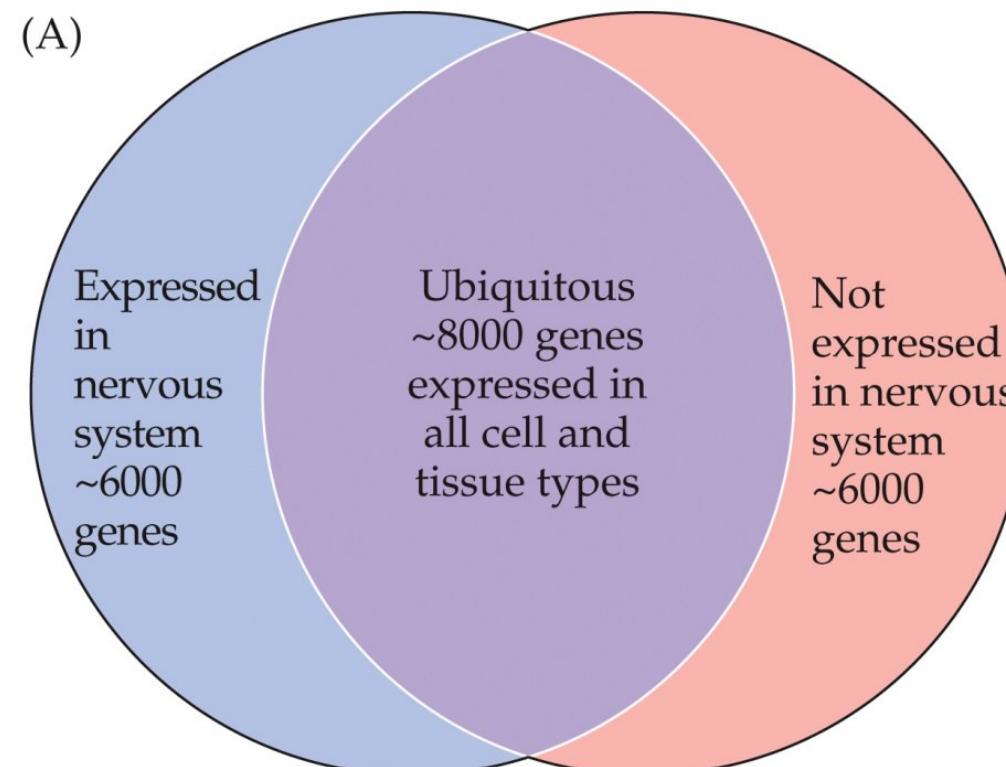
Basic Structural and Functional Organization of the Human Body

Let's look at an example

Organization of the Human Nervous System

Genes → Cells → Circuits → Sub-Systems → Systems → Behavior

Genetic Diversity in the Nervous System

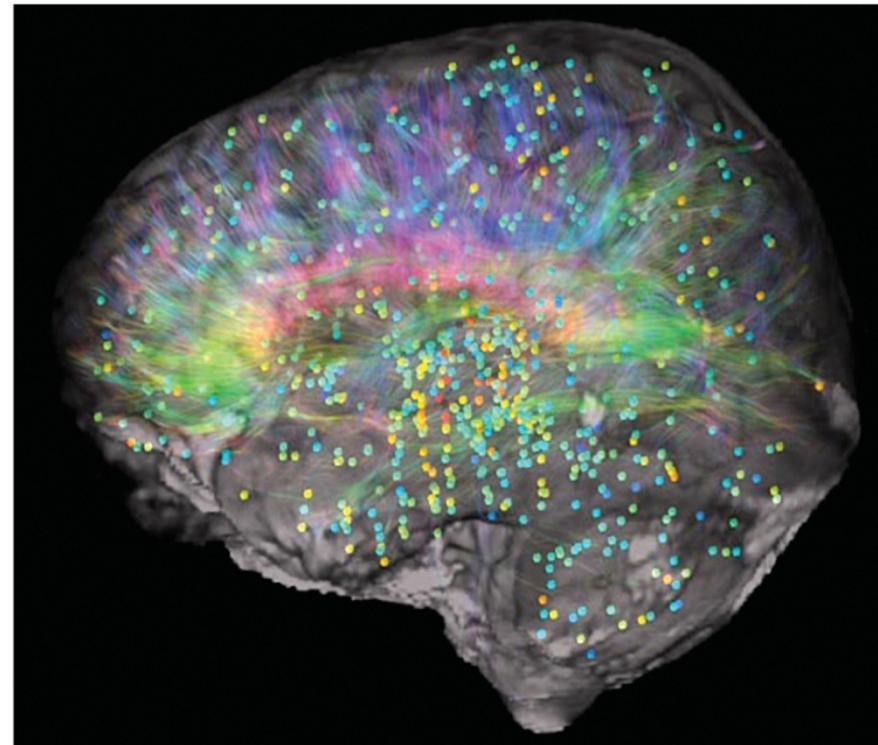


NEUROSCIENCE 6e, Figure 1.1 (Part 1)
© 2018 Oxford University Press

Data from Ramsköld et al. (2009) *PLoS* 5(12):e1000598.

Genes → Cells → Circuits → Sub-Systems → Systems → Behavior

(B)



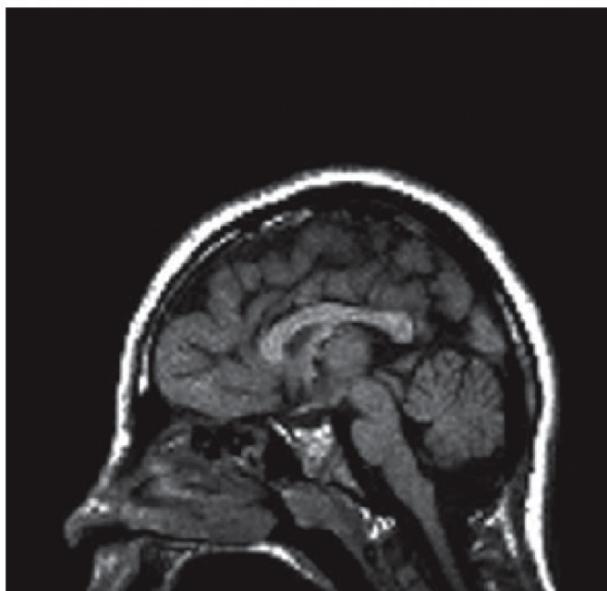
Courtesy of Allen Brain Institute, Allen Brain Atlas.

NEUROSCIENCE 6e, Figure 1.1 (Part 2)
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Location of a particular gene in the human brain and the level of gene expression at each location (blue > lower – orange > higher)

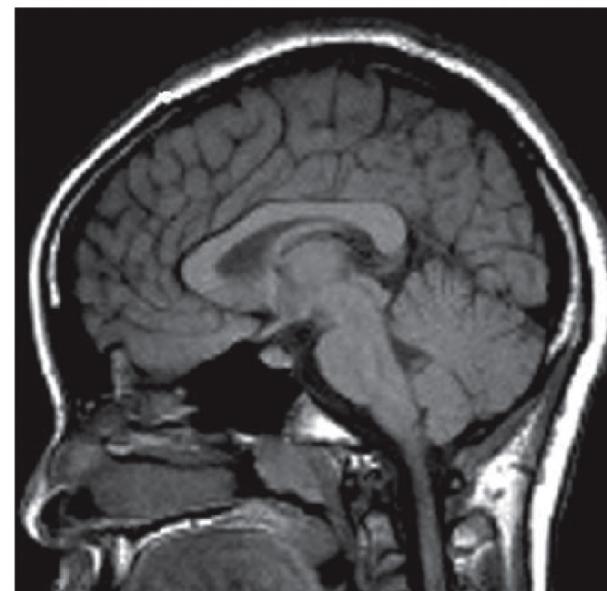
Genes → Cells → Circuits → Sub-Systems → Systems → Behavior

(C)



NEUROSCIENCE 6e, Figure 1.1 (Part 3)
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Microcephalic Brain



From Bond et al. (2002) *Nat. Genet.* 32: 316–320.

Brain of a Typical Control

Microcephaly: due to mutation in a single gene (ASPM: Abnormal Spindle-like Microcephaly-associated) important for brain development

Genes → Cells → Circuits → Sub-Systems → Systems → Behavior

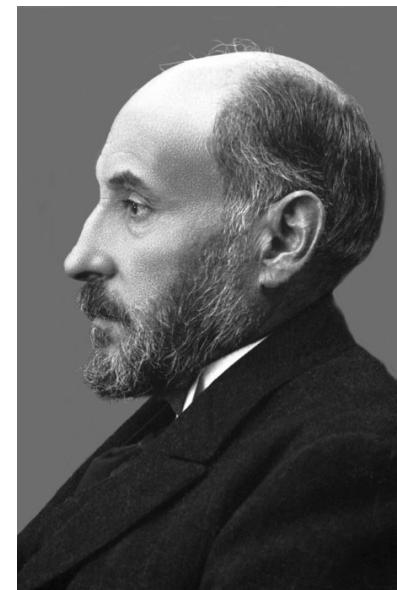
Does the nervous system have distinct unitary cells? – agreement only well into 20th century with availability of advanced tools and techniques



Camillo Golgi

Reticular theory

absence of distinct cells rather presence of a network (reticulum)



Santiago Ramón y
Cajal

“Neuron doctrine” and “Synapses”



Sir Charles
Sherrington

Using Light Microscopy and Golgi's novel staining method:

Cajal - helped establish nerve cells as distinct entities > communicating via specialized contacts > contacts not points of direct continuity between cells

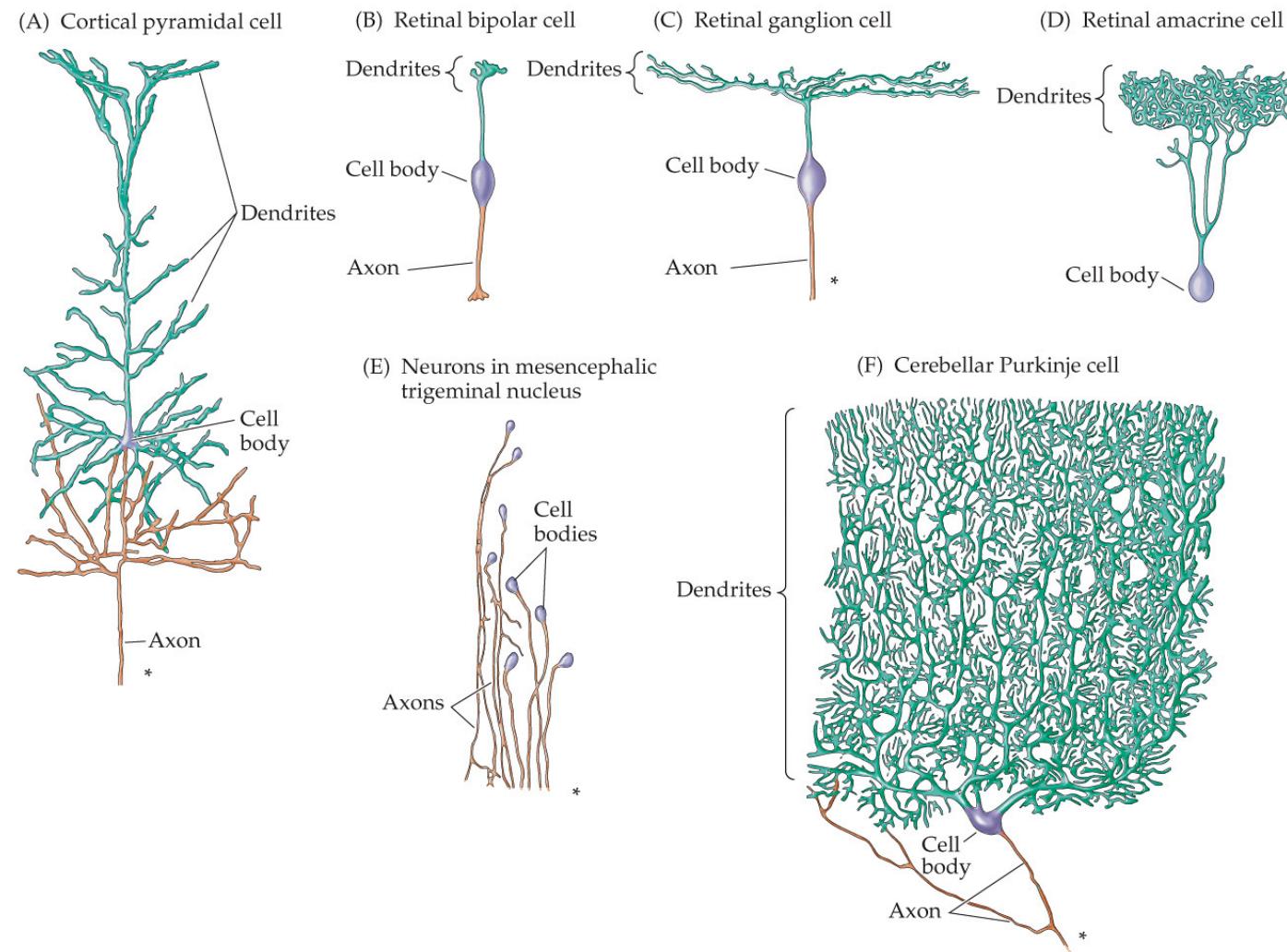
Sherrington – work on transfer of electric signals, called the specialized contacts as “synapses”

Intercellular (cytoplasmic) continuities also exist (relatively rare) between some neurons, called as “gap junctions”

Genes → Cells → Circuits → Sub-Systems → Systems → Behavior

Variations in nerve cell morphologies in the human nervous system

Tracings of nerve cells stained by impregnation with silver salts

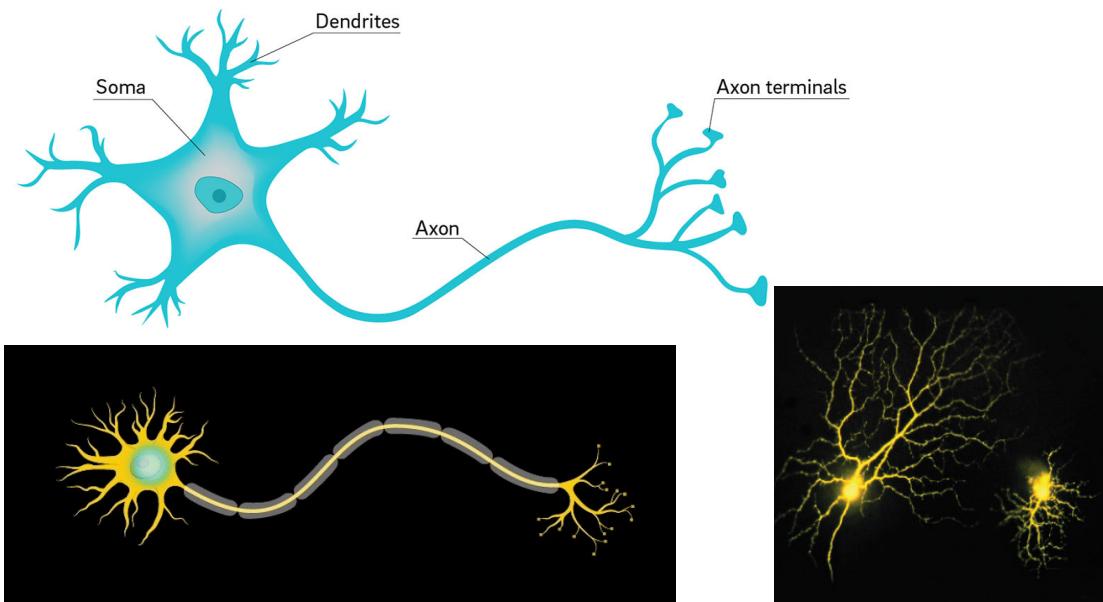


NEUROSCIENCE 6e, Figure 1.2
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Genes → Cells → Circuits → Sub-Systems → Systems → Behavior

Neurons (nerve cells)

Neuron

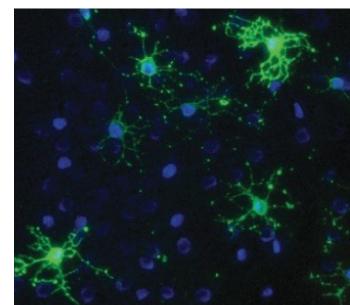
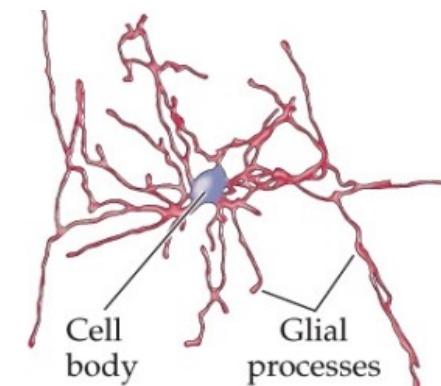


The Excitable Cells of the Nervous System

fundamental units that send and receive signals in the form of electric impulses

Glial Cells (neuroglia/glia)

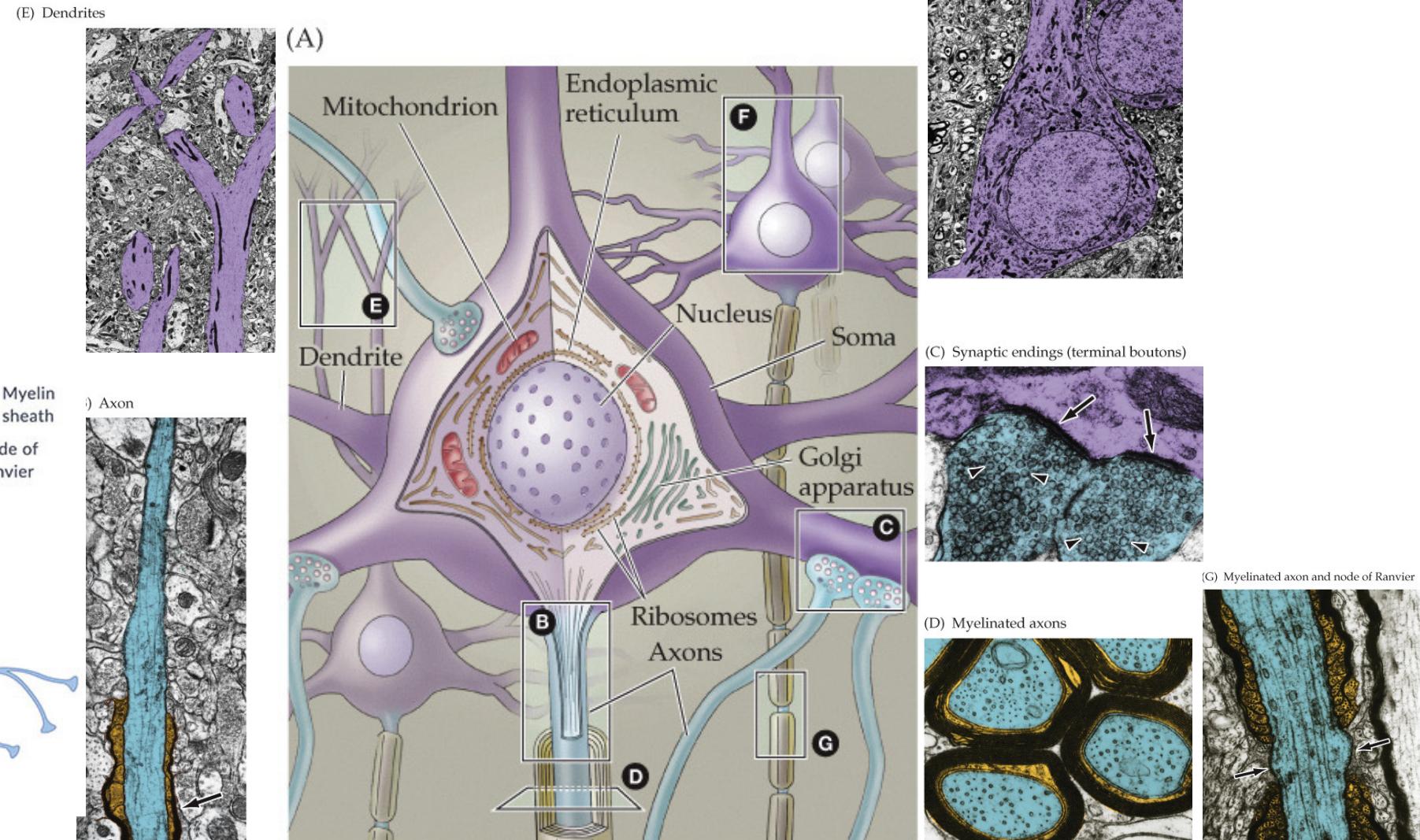
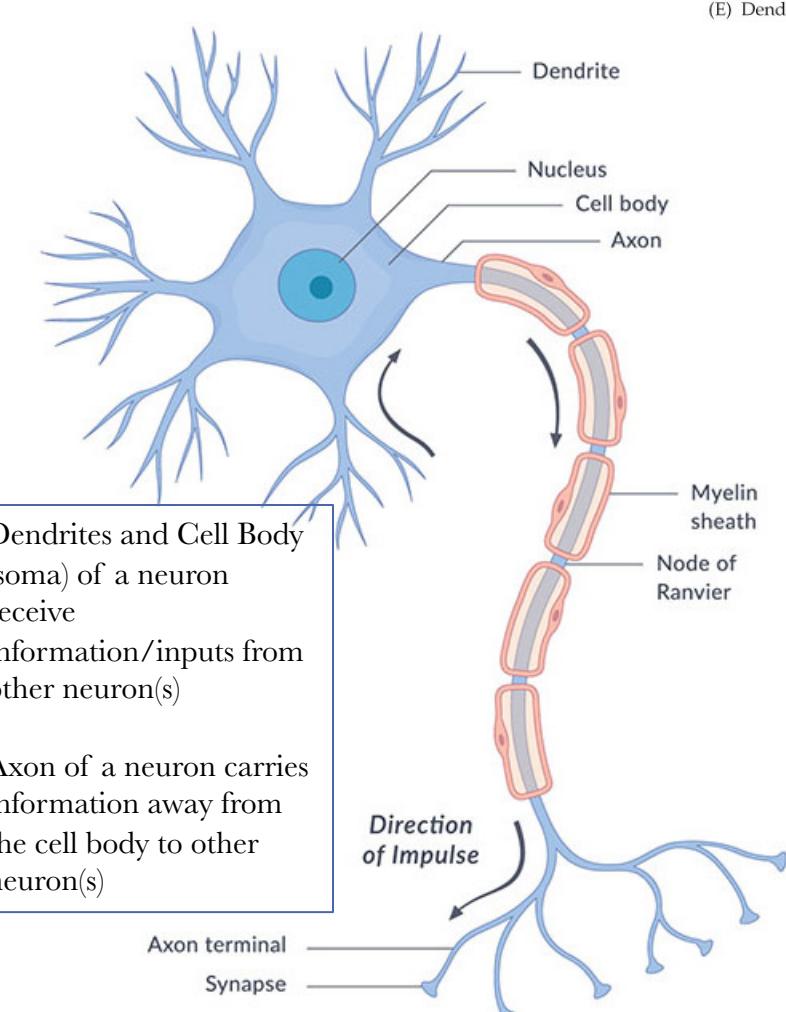
Glial Cell



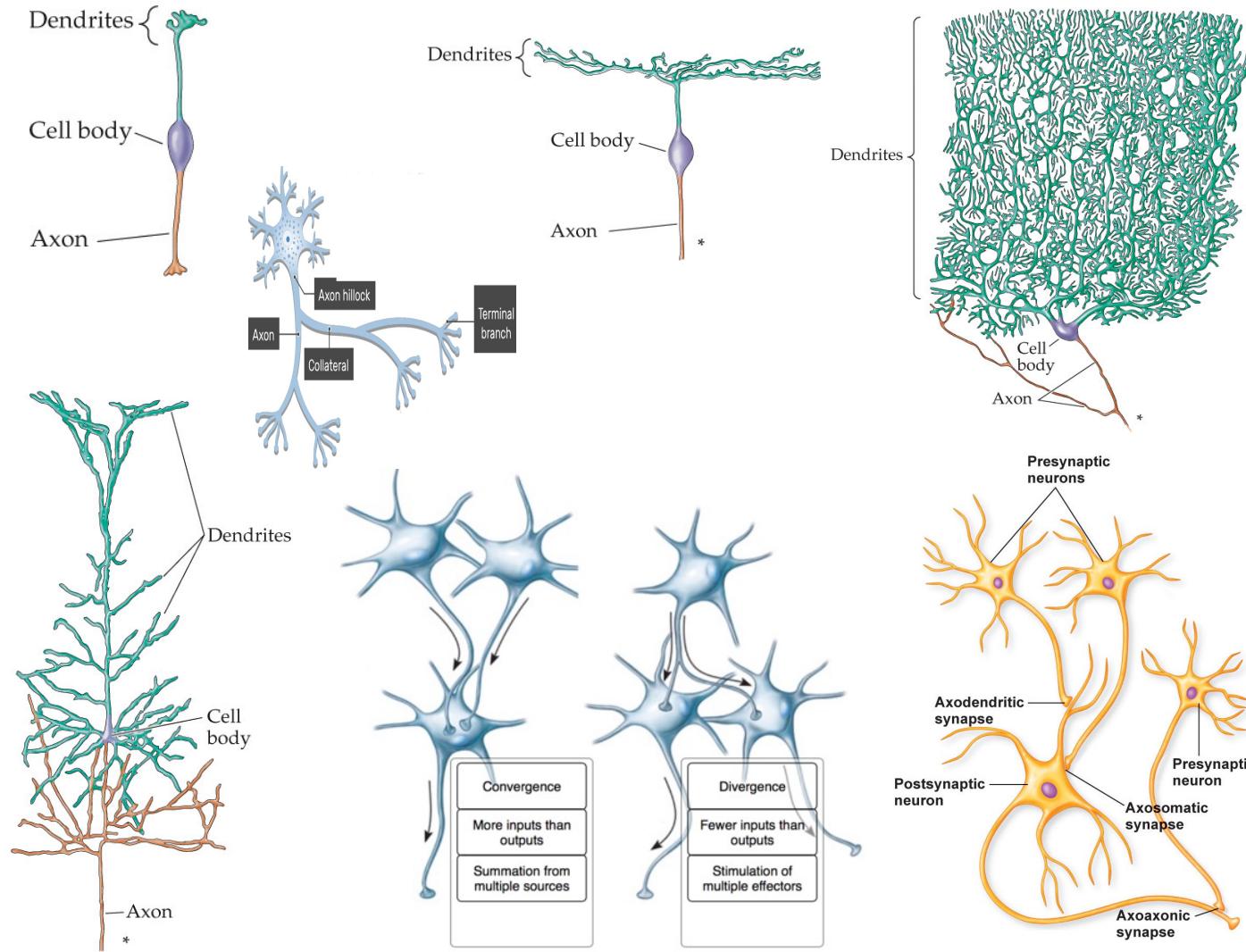
The Supporting Cells of the Nervous System

specialized for promoting development and growth, modulation of signaling, removal of cell debris

Anatomy of a Neuron



How does the structure of a neuron serve the functional essence of the nervous system >> communication and control?

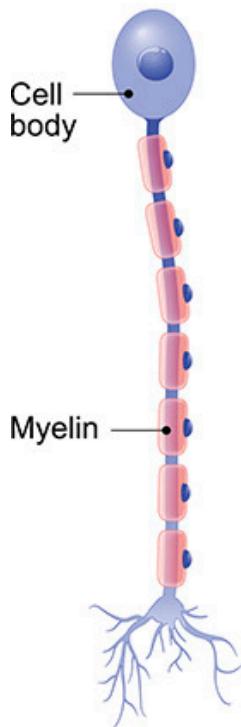


- Neuronal extensions (axons): long-distance signaling
 - Axon length – few 100 micrometer to few meters
- Extensive branching: structure needed for integration of information and communication
- Enormous variation in size and branching of dendrites and axons
 - Dendritic branching >> determines the degree of convergence of neuronal inputs
 - Axonal branching >> determines the degree of divergence of neuronal outputs
- Synapses: enable relay and transmission of information across neurons and to their final targets; sites for modulation of information
 - Information conveyed by synapses is integrated and “read out” at origin of axon
 - # of synaptic inputs received by each neuron in humans – 1 to 1,00,000

Classes of Neurons

Based on Structure

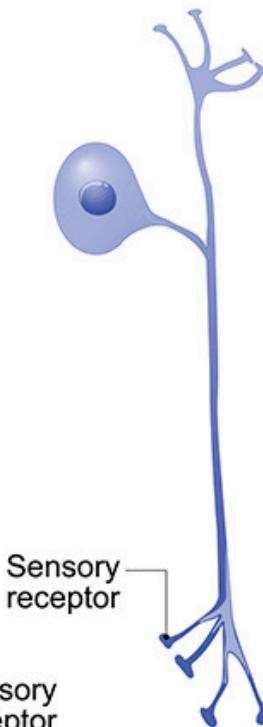
Unipolar



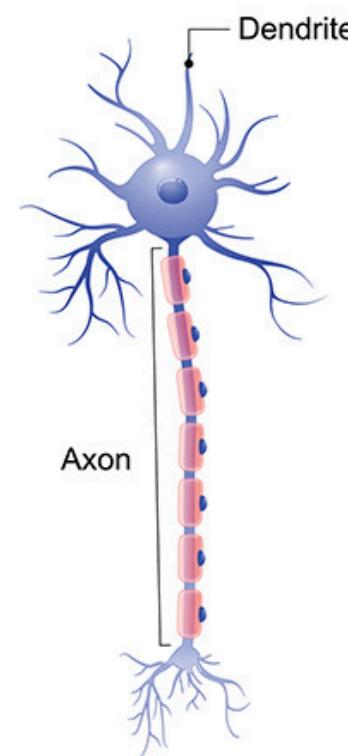
Bipolar



Pseudounipolar



Multipolar



One axon,
no dendrite

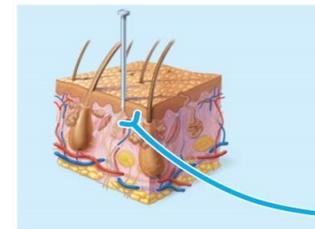
One axon,
one
dendrite

One axon splitting
into two; one branch
serves as the axon,
another as the
dendrite

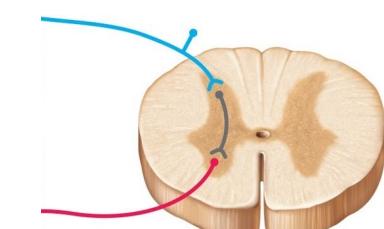
One axon,
many
dendrites

Based on Function

Sensory (afferent) neuron: carries information from periphery to the CNS (spinal cord and brain); brings in inputs; activated by physical and chemical stimuli



Motor (efferent) neuron: carries information from the CNS to the targets/effectors (muscles, glands); sends outputs



Interneuron: helps transfer signals between two neurons

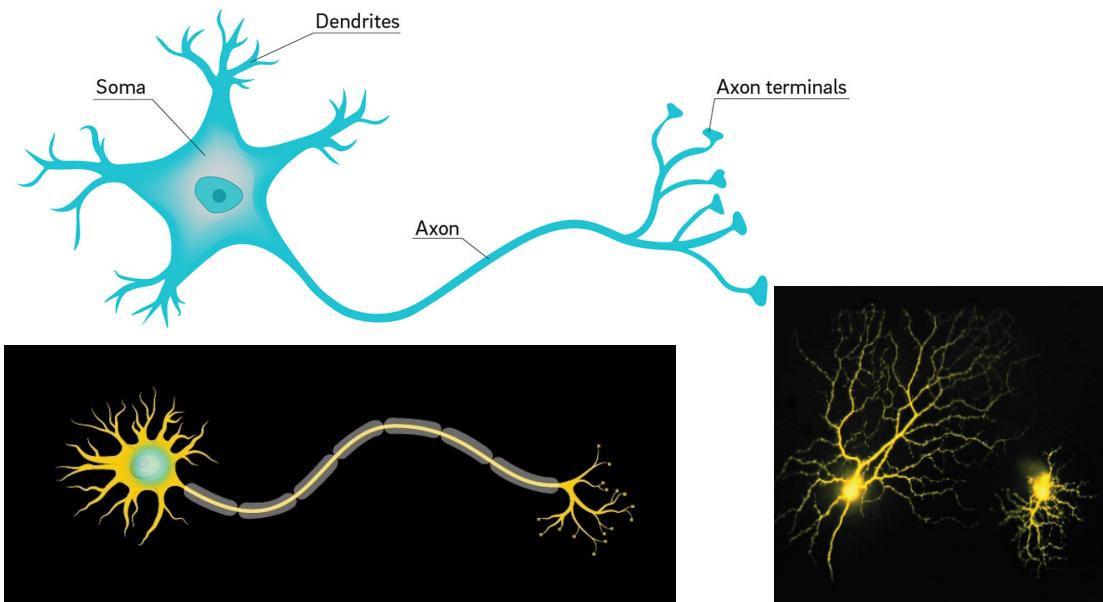
Excitatory neuron: allows impulses to flow from one neuron to another

Inhibitory neuron: slows or stops the flow of impulses from one neuron to another

Genes → Cells → Circuits → Sub-Systems → Systems → Behavior

Neurons (nerve cells)

Neuron

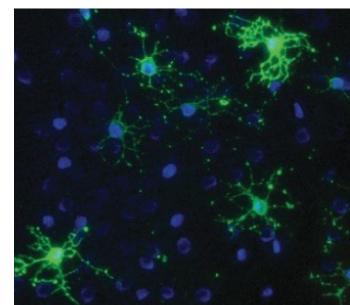
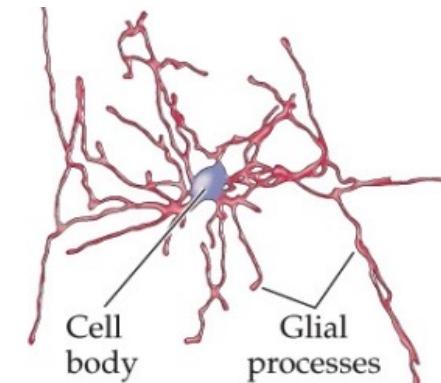


The Excitable Cells of the Nervous System

fundamental units that send and receive signals in the form of electric impulses

Glial Cells (neuroglia/glia)

Glial Cell

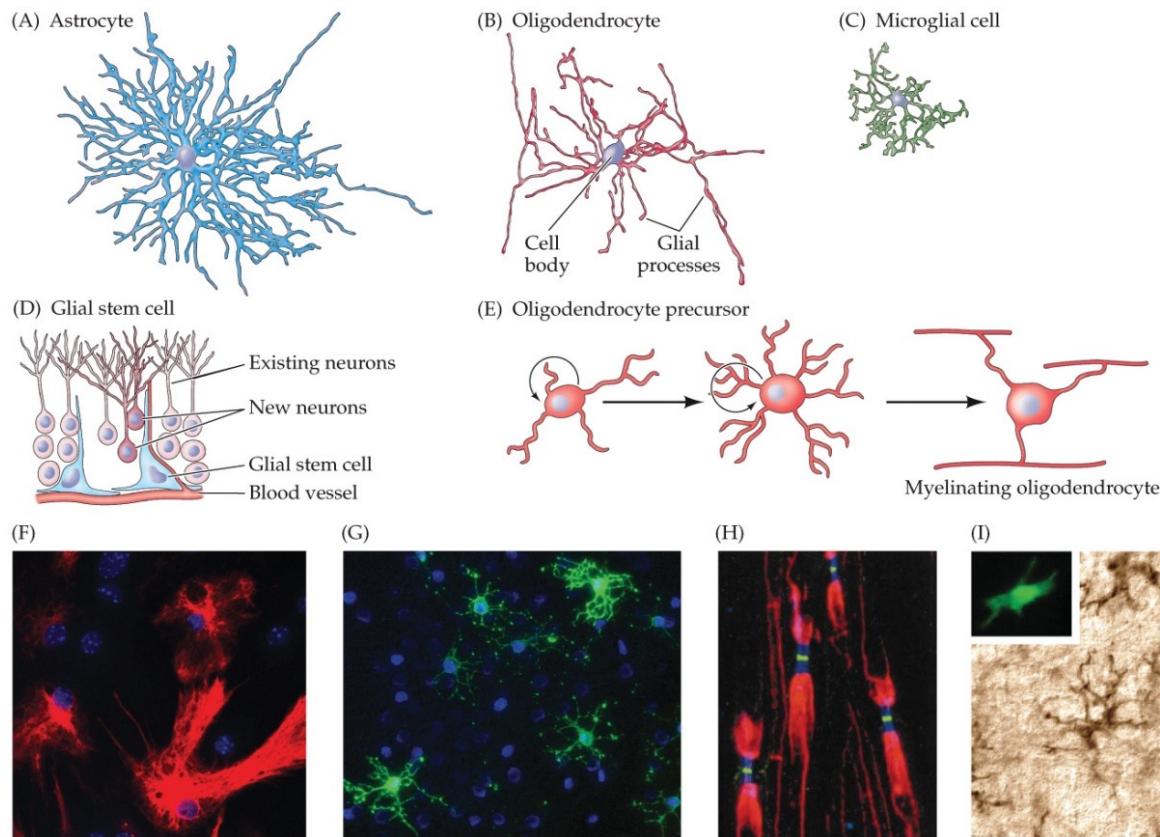


The Supporting Cells of the Nervous System

specialized for promoting development and growth, modulation of signaling, removal of cell debris

Glial Cells (neuroglia/glia)

The Supporting Cells of the Nervous System



NEUROSCIENCE 6e, Figure 1.5
© 2018 Oxford University Press

Image Source: Purves D et al, 6th Ed

- **Glial cells** – “glue”, however, they do not actually bind nerve cells; **these are non-excitable cells**
- At least as many as neurons in number
- 3 main types: astrocytes, oligodendrocytes, microglia
- Major functions:
 - Maintaining ionic milieu of neurons
 - Modulating rate of nerve signal propagation
 - Modulation synaptic action
 - Providing a scaffold for neural development
 - Aiding (or sometimes impeding) recovery from neural injury
 - Providing an interface between the immune system and the brain
 - Facilitating washing out metabolic waste during sleep

Summary of Lecture 1

• Introduction to Biomedical Engineering

- Application of Engineering + Basic Sciences to the study of Biology and Medicine >> to advance our understanding of life and disease and to develop technology-based solutions for healthcare

• Sub-domains of BME – Interdisciplinarity and Diversity

• Levels of Organization of the Body

- Chemical > Cell > Tissues > Organ > Organ Systems > Organism

• Overview of the Human Nervous System

- Major Functions of the Nervous System >> Sensory processing and perception, Movement control, Cognition, Emotion Regulation, and Learning
- Command and Coordination System >> Specialized for Communication >> Electrical Cell Signaling (+ Chemical Signaling)
- Neurons >> excitable cells, send and receive signals in the form of electric impulses; huge variety in neuronal cell type
- Parts of a Typical Neuron >> Cell body, Dendrites, Axon; Structure – Function Relationship
- Classes of Neurons >> based on structure (unipolar, bipolar, pseudounipolar, multipolar); based on function (sensory, motor, interneuron; excitatory, inhibitory)
- Glial Cells >> supporting cells, promote development, synaptic modulation, scavenging

BME module: Course Content/Topics

Overview of Biomedical Engineering (BME) and its Various Sub-domains/Sub-fields

Nervous System – Cell >> Circuit >> System >> Behaviour

Neural Engineering – Rehabilitation Engineering

Introduction to
BME;
Overview of the
Nervous System;
Neuron –
Structure and
Function

NEXT ?

L 1

L 2

Lecture 2

Neuronal Language of Communication

Neurons as Excitable Cells

Electrical Cell Signaling

Electro-Chemical Transmission of Information between Individual Neurons and between Neurons and their Targets (e.g. Muscle cells)

Thank You