

BMEG 350 – Lecture 1

The human body as an integrated system

Dr. Pawel Kudzia

January 9th, 2024

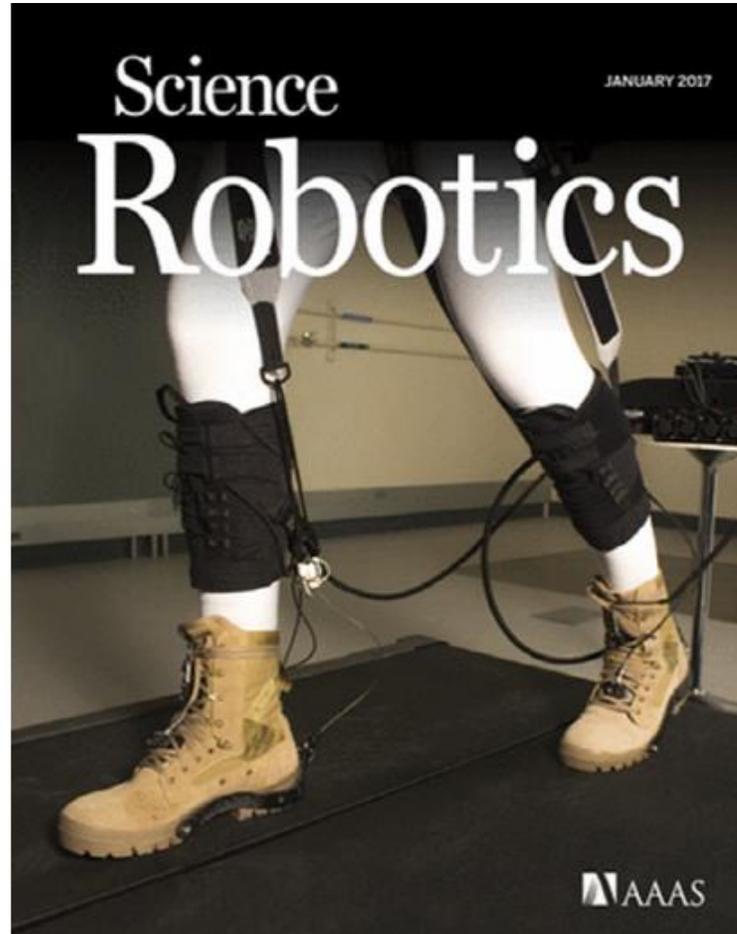
Who am I | Pawel Kudzia, PhD

Passionate engineer

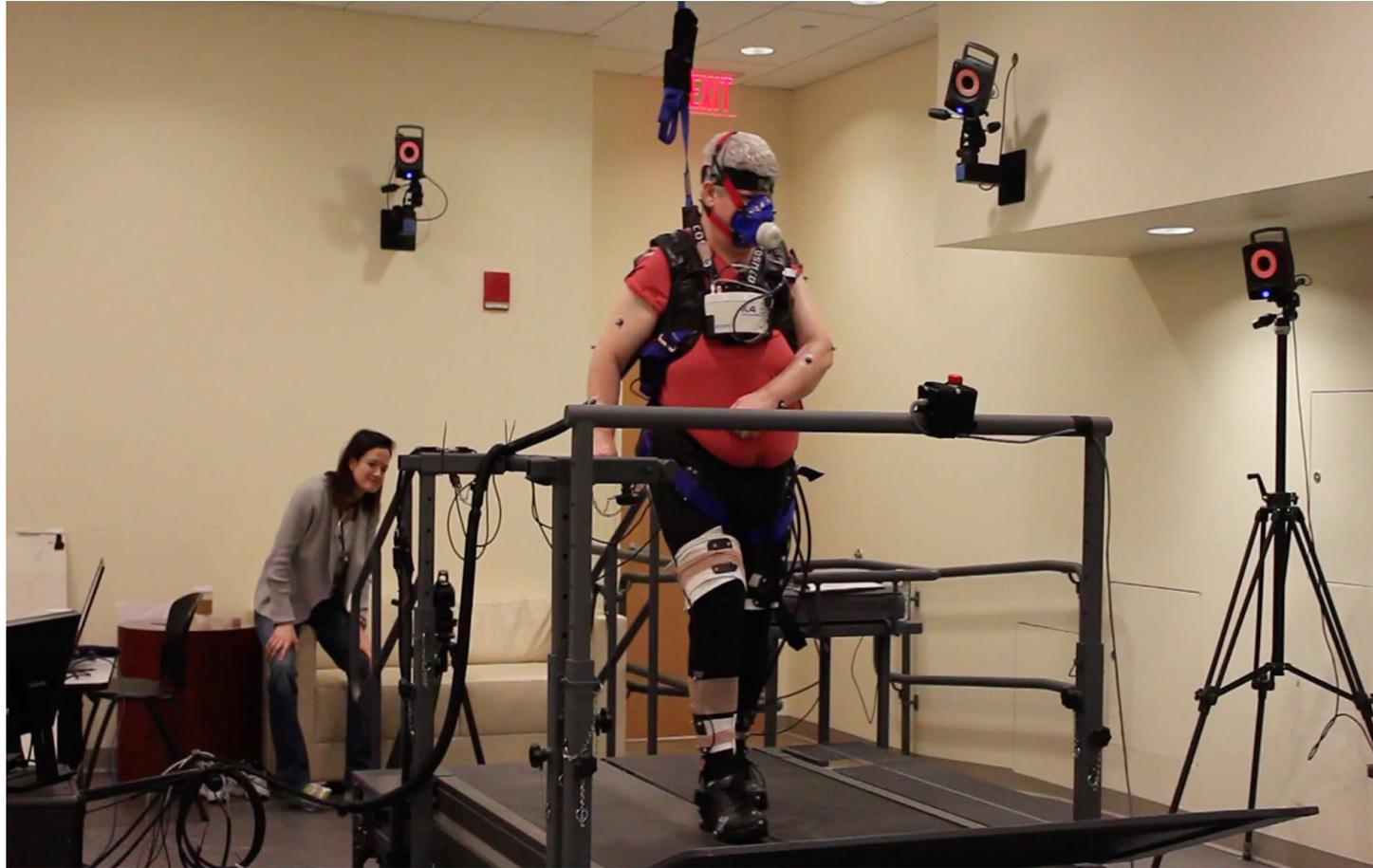
Biomechanics enthusiast

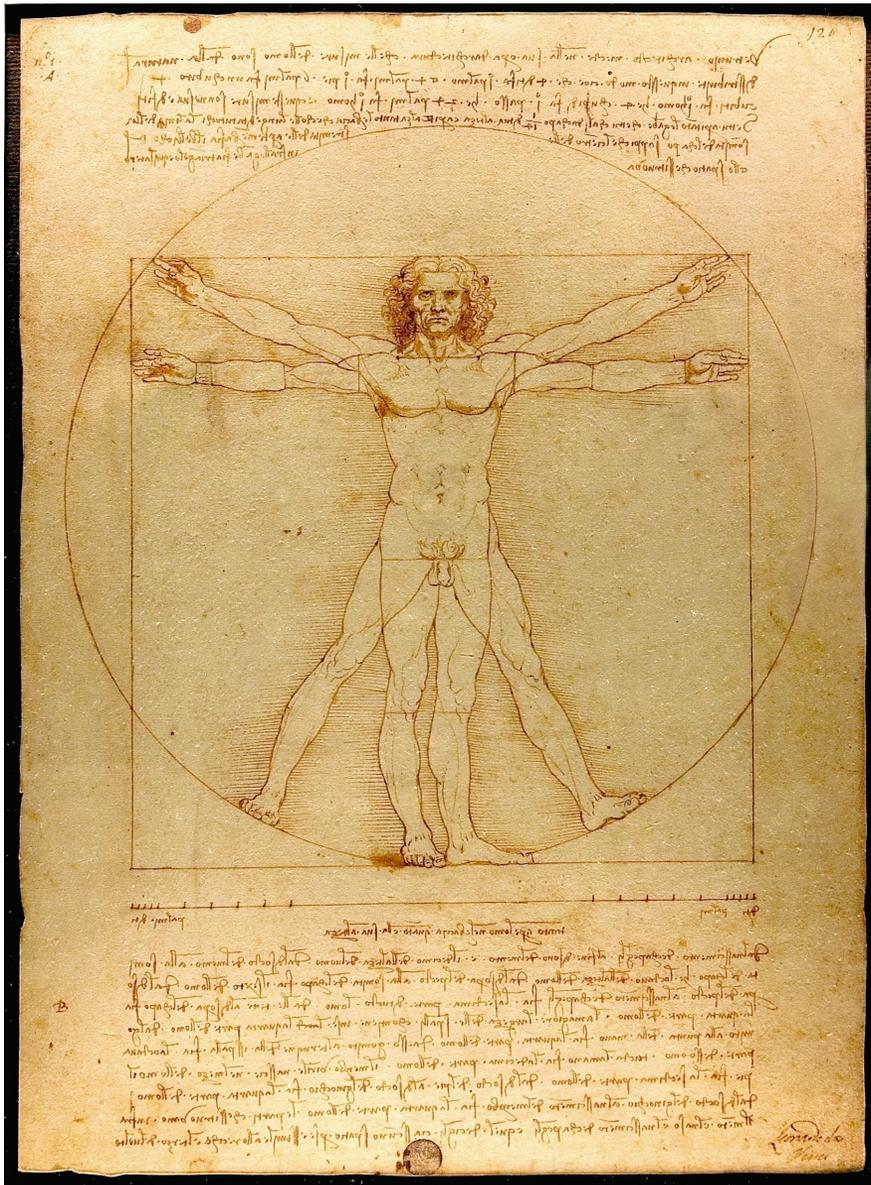
Robotics

Excited to work with you and
be a resource to you



Engineering to augment and restore





https://en.wikipedia.org/wiki/Vitruvian_Man

HUMAN 2.0

A bionic body is closer than you think

ASSISTIVE TECHNOLOGIES THAT INTERFACE WITH THE NERVOUS SYSTEM TO AUGMENT BASIC ABILITIES ARE MOVING FROM THE LAB INTO CLINICAL USE.

DEEP-BRAIN IMPLANTS
ELECTRODES DEEP WITHIN THE BRAIN CAN ADJUST CURRENT TO REGULATE ABNORMAL BRAIN ACTIVITY CAUSED BY PARKINSON'S DISEASE OR EPILEPSY.

COGNITIVE IMPLANTS
ELECTRODES ARE ALSO BEING TESTED TO STIMULATE SITES SUCH AS THE HIPPOCAMPUS TO COMPENSATE FOR LOSS OF MEMORY FROM STROKE, INJURY OR DISEASES LIKE ALZHEIMER'S.

ARTIFICIAL ARMS AND HANDS
THE LATEST MODELS CAN TRANSMIT A SENSE OF TOUCH BY STIMULATING NERVES WITH SIGNALS FROM TACTILE SENSORS.

VISUAL PROSTHESES
TINY CAMERAS RECORD IMAGES AND THEN STIMULATE THE RETINA (THE SHEET OF NEURAL TISSUE AT THE BACK OF THE EYE) TO PARTIALLY RESTORE VISION IN BLIND OR NEAR-BLIND PATIENTS.

COCHLEAR IMPLANTS
NEW DESIGNS RESTORE HEARING BY TRANSFORMING SOUND WAVES INTO DIRECT STIMULATION OF THE AUDITORY NERVE.

SPINAL CORD IMPLANTS
IMPLANTED DEVICES CAN DIRECTLY STIMULATE THE SPINAL CORD TO SOOTHE CHRONIC PAIN OR HELP BLADDER CONTROL.

GAIT STIMULATORS
SMALL DEVICES CAN APPLY CURRENT TO SPECIFIC MUSCLES TO REDUCE FOOT DROP IN PATIENTS WITH MULTIPLE SCLEROSIS OR STROKE.

EXOSKELETONS
MECHANICAL OUTER STRUCTURES POWERED BY ELECTRIC MOTORS CAN BE CONTROLLED BY BRAIN SIGNALS TO RESTORE MOBILITY IN PATIENTS WITH SPINAL CORD INJURY OR NEURODEGENERATIVE DISEASES SUCH AS AMYOTROPHIC LATERAL SCLEROSIS.

PROSTHETIC LEGS AND FEET
CURRENT MODELS NOW INCORPORATE NEURAL SIGNALS TO IMPROVE STEPPING MOTIONS.

So, are you ready for an upgrade?

BY DWAYNE GODWIN AND JORGE CHAM

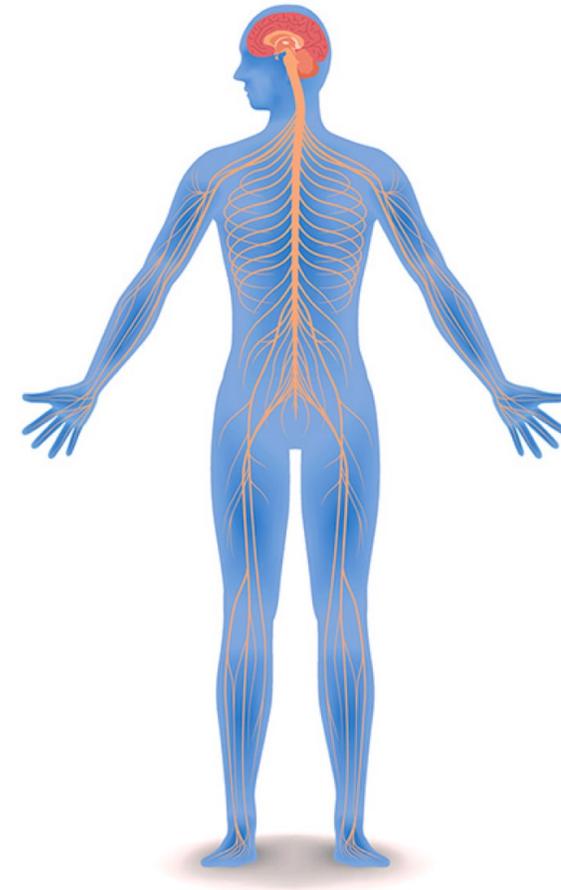
<https://www.scientificamerican.com/article/human-2-0-tech-upgrades-for-the-nervous-system-cartoon/>

Why is it important for engineers to learn about anatomy and physiology?

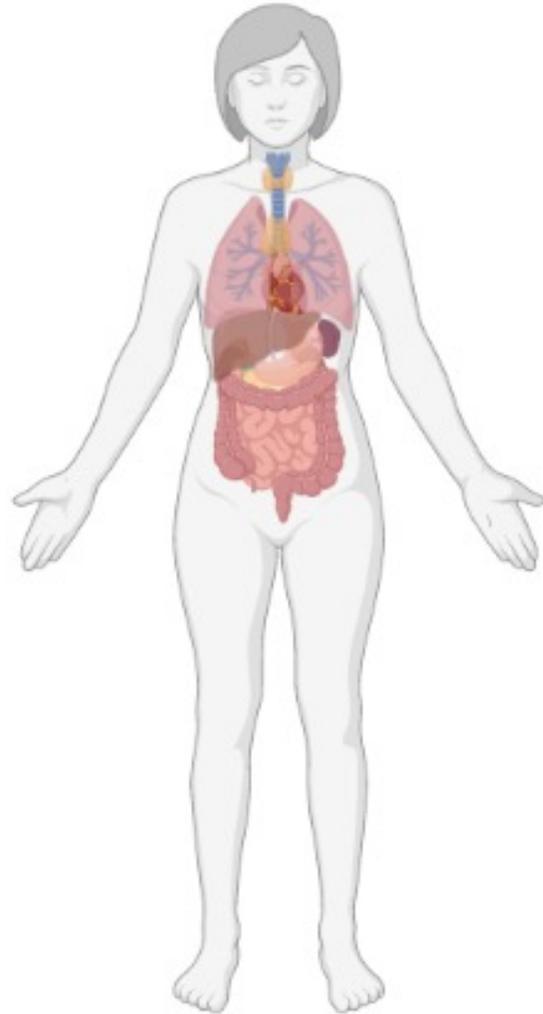
As our understanding of the human body grows, so does our ability to help repair/fix/augment or enhance it

Diagnosis, treatment, and enhancement

Holistic understanding



Body Systems



- 11 body systems “designed” to serve specific functions, but which are also integrated

Skeletal System

Muscular System

Nervous System

Endocrine System

Respiratory System

Cardiovascular System

Digestive System (GI)

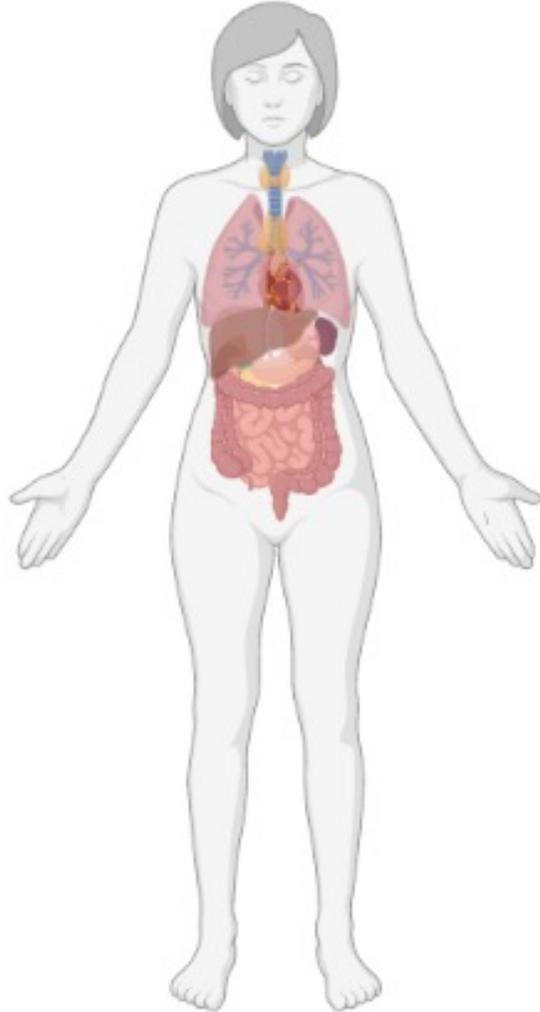
Urinary System (Renal)

Reproductive System

Immune System

Integumentary System

Body Systems



- Will cover systems in blue throughout the term

Skeletal System

Muscular System

Nervous System

Endocrine System

Respiratory System

Cardiovascular System

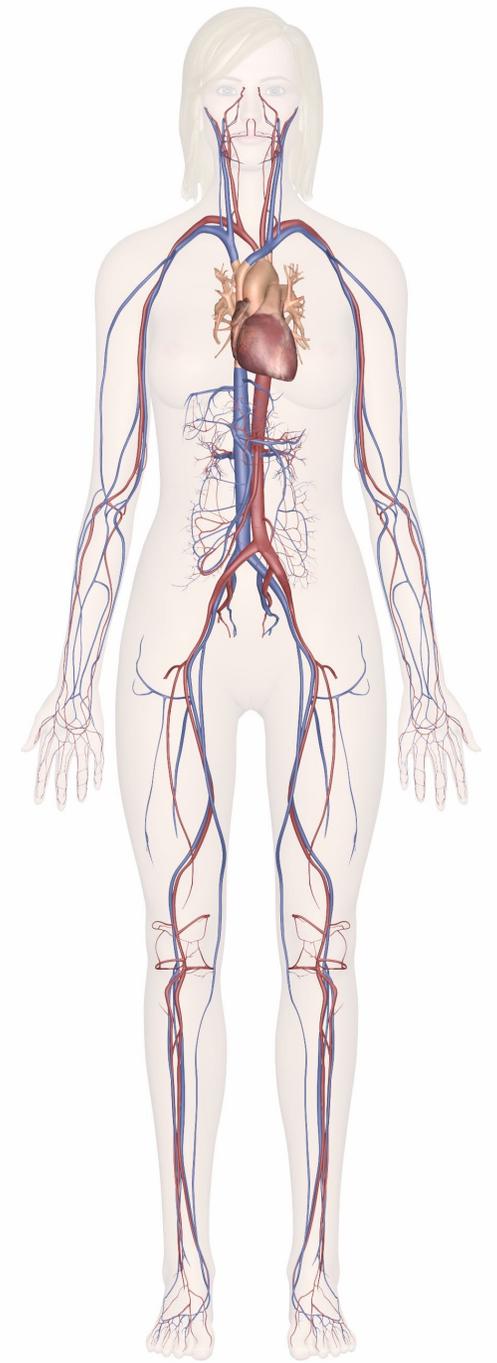
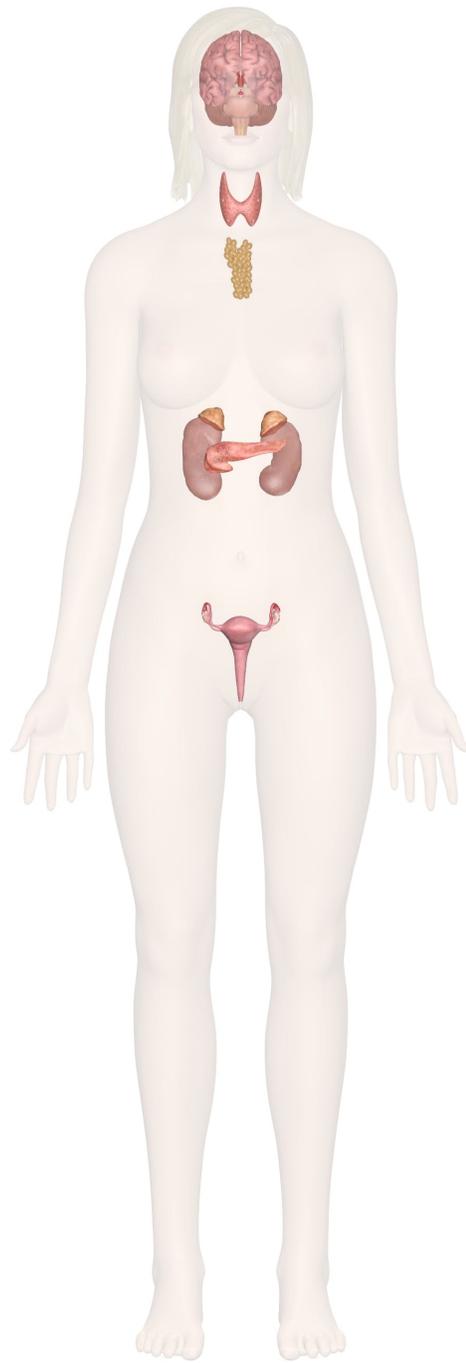
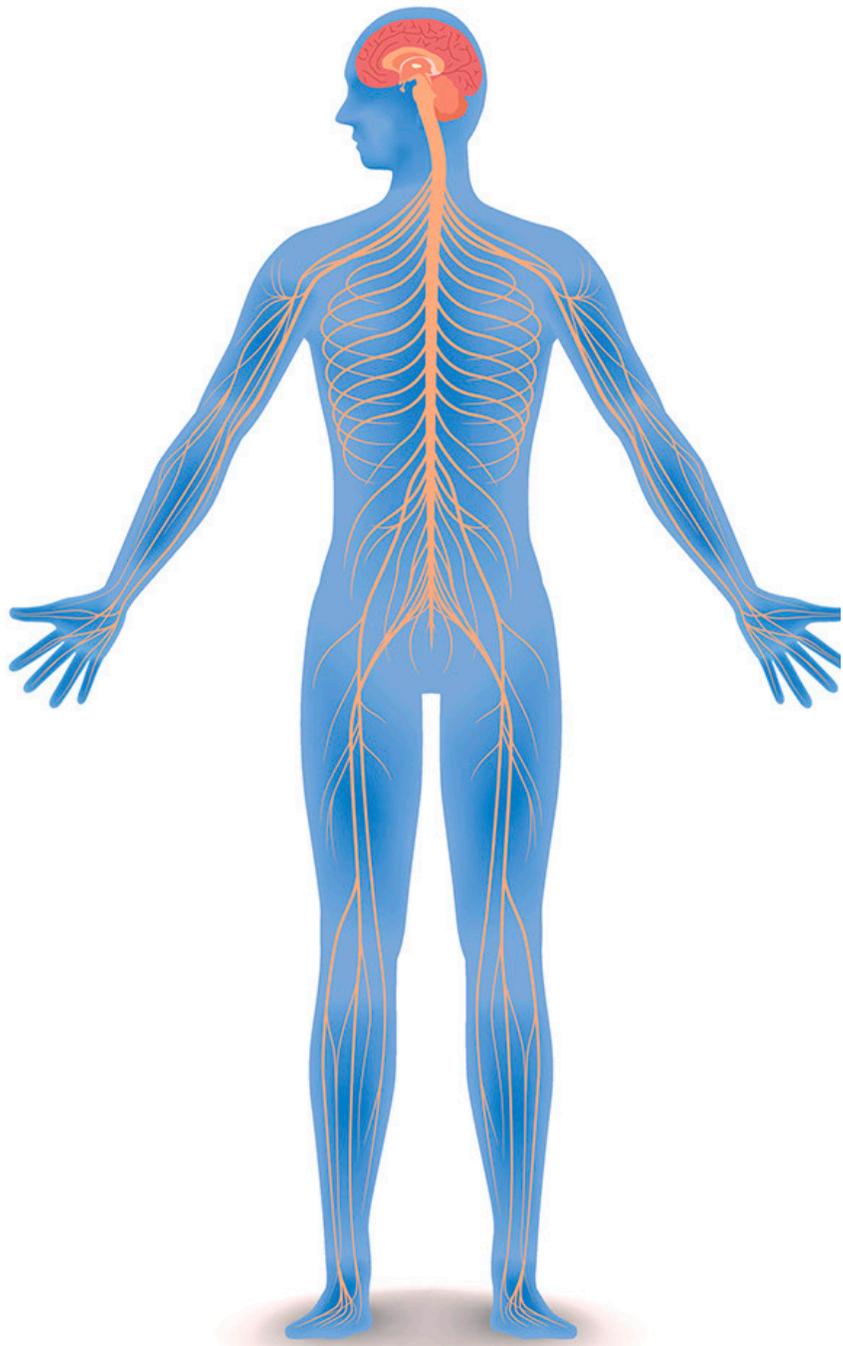
Digestive System (GI)

Urinary System (Renal)

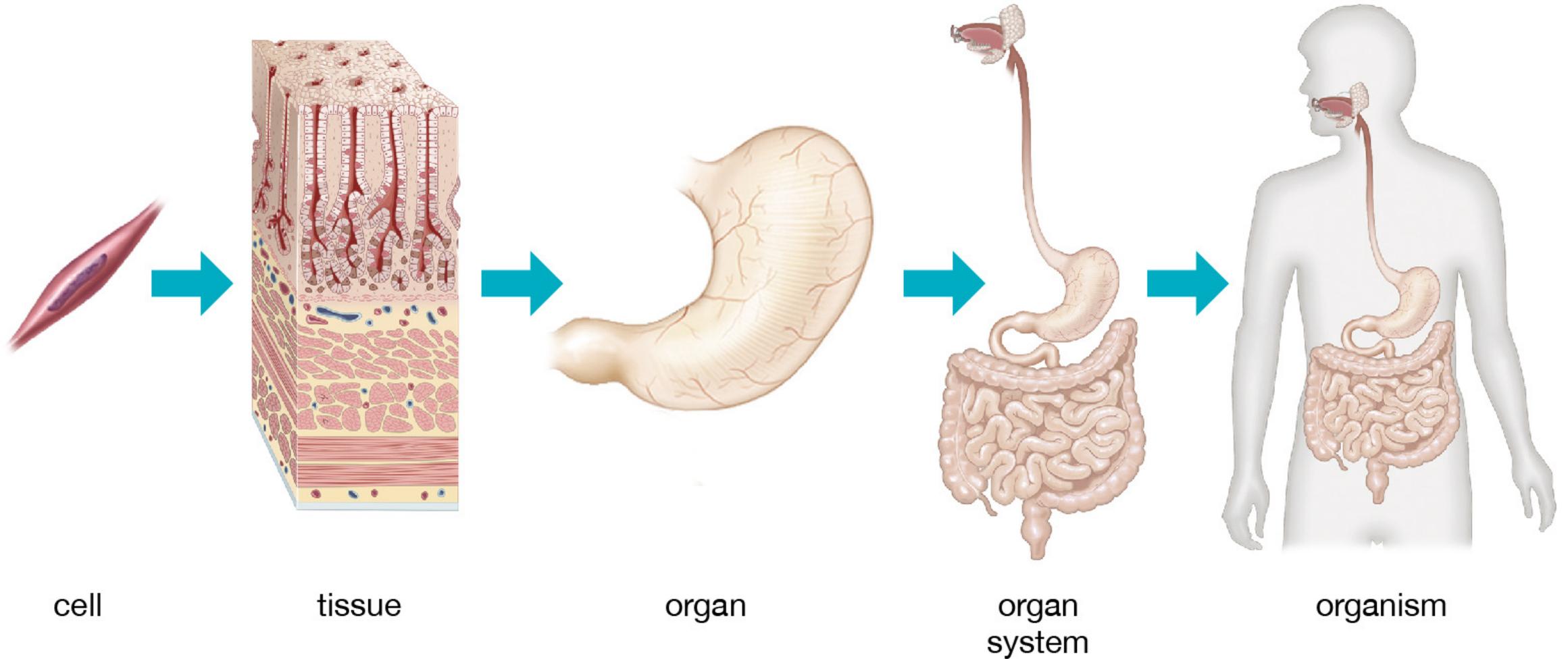
Reproductive System

Immune System

Integumentary System

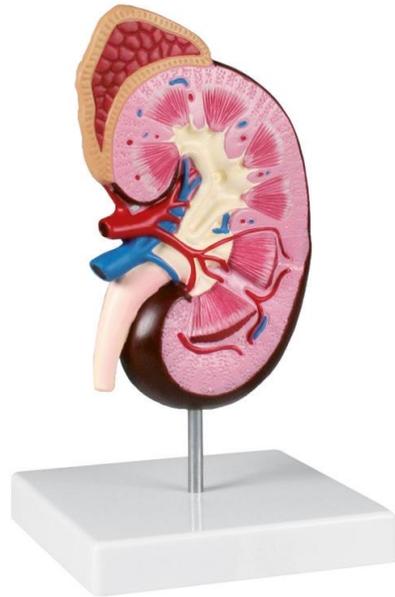


How is the human body organized?



Engineering Group* Project

Choose a tissue / system of the body to repair, replace or augment from one of the systems being discussed in the class. This could be to fix an impairment or defect caused by injury or disease, or to enhance/augment biological function.



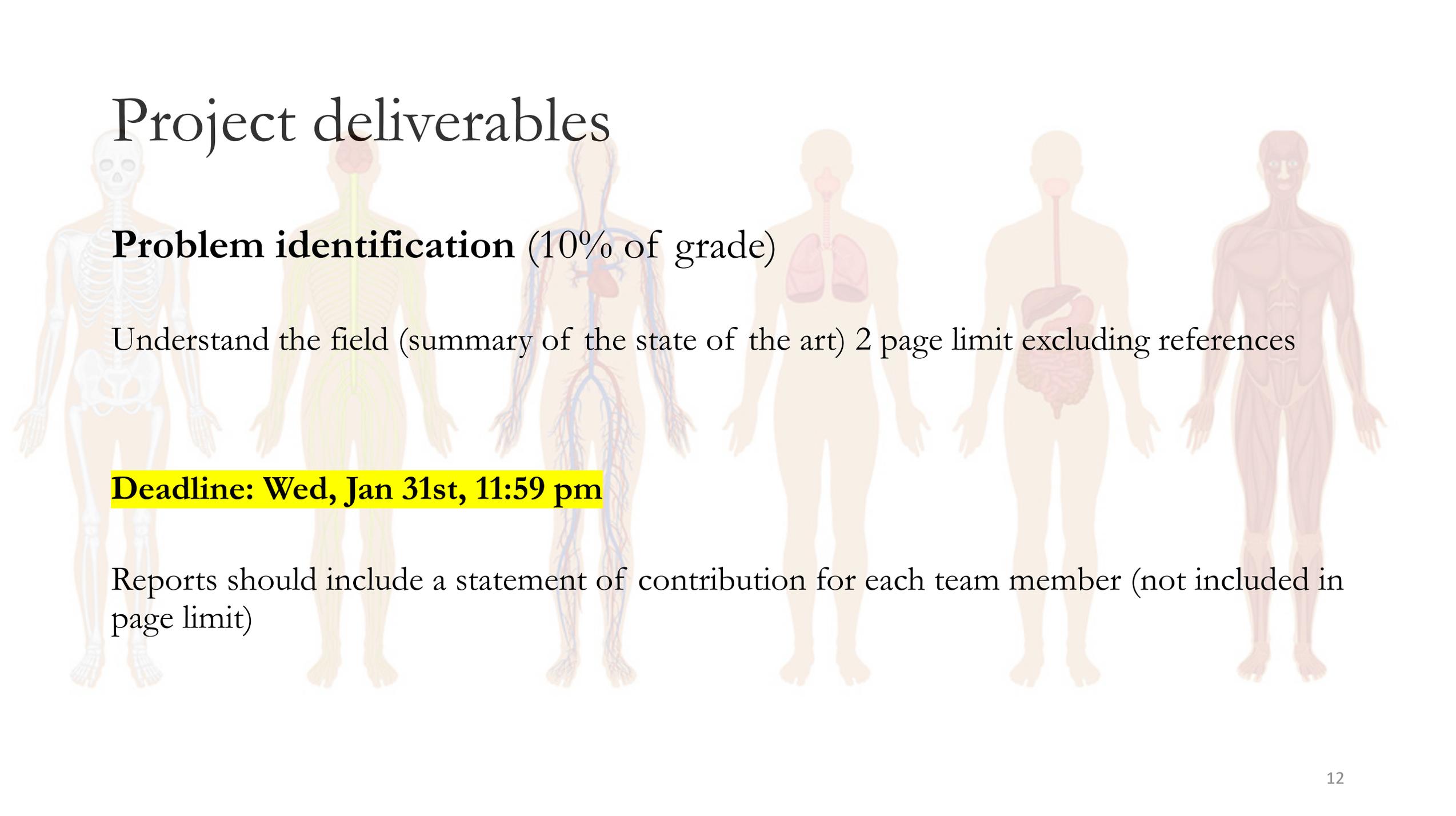
*Teams of 3, self-assigned; **Up to concept selection

Engineering Group* Project

- Identify the problem and the physiological system it affects.
- Research the state-of-the-art in biomedical approaches
- Design** a novel biomedical approach to solve the problem.
- Consider the requirements, concerns and ethical implications for the designed approach.
- Pitch the design and receive peer feedback.

*Teams of 3, self-assigned; **Up to concept selection

Project deliverables



Problem identification (10% of grade)

Understand the field (summary of the state of the art) 2 page limit excluding references

Deadline: Wed, Jan 31st, 11:59 pm

Reports should include a statement of contribution for each team member (not included in page limit)

Project deliverables

Design Requirements concerns and ethical implications

(10% of grade)

2 page limit excluding references

Deadline: Feb 28th, 11:59 pm

Reports should include a statement of contribution for each team member (not included in page limit)

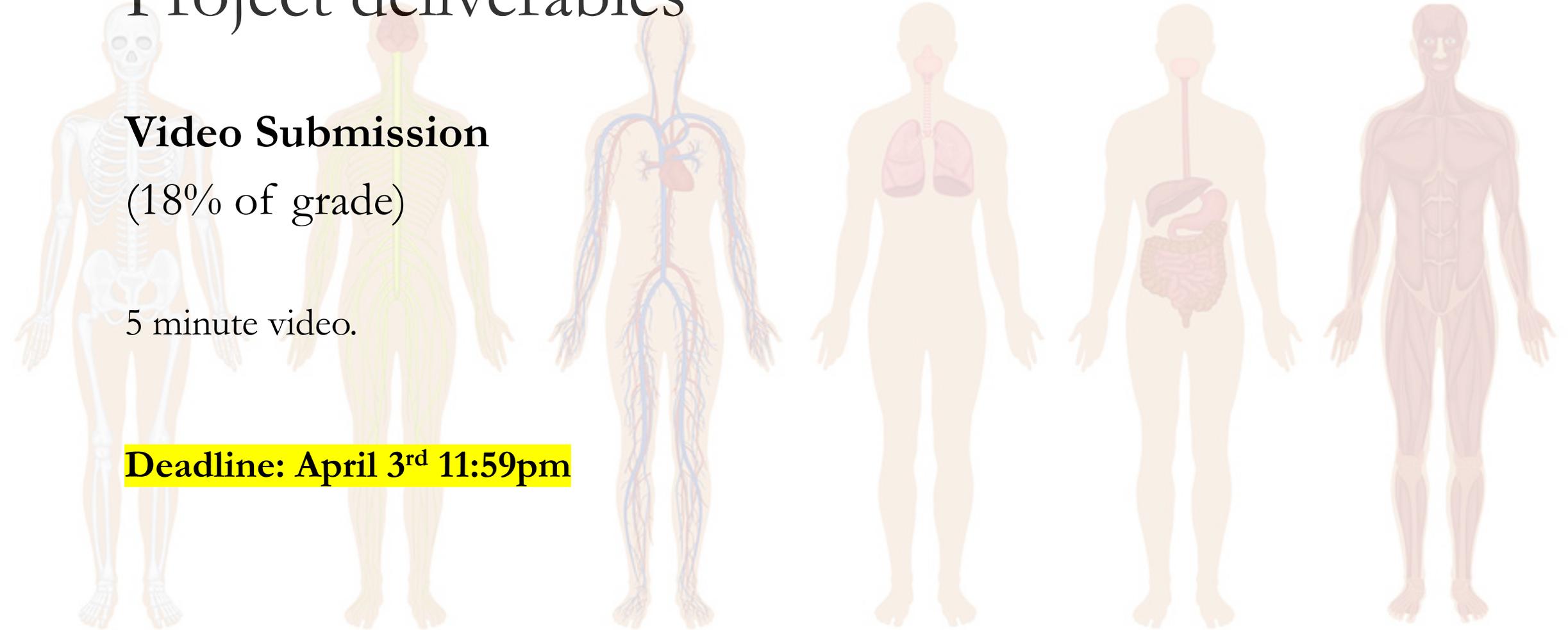
Project deliverables

Video Submission

(18% of grade)

5 minute video.

Deadline: April 3rd 11:59pm



Project deliverables

Peer evaluation (2%)

Each student in the class will be assigned 3 other team videos to evaluate using a rubric

Deadline: April 12th 11:59pm

Major life processes for an organism

Build up (anabolism) and breakdown (catabolism) of different components that create structure, enable function, and generate energy

Metabolism

Responsiveness

Detect and respond to changes in the environment

Movement at different scales (within a cell, cells, organs, organ systems, whole body)

Movement

Growth

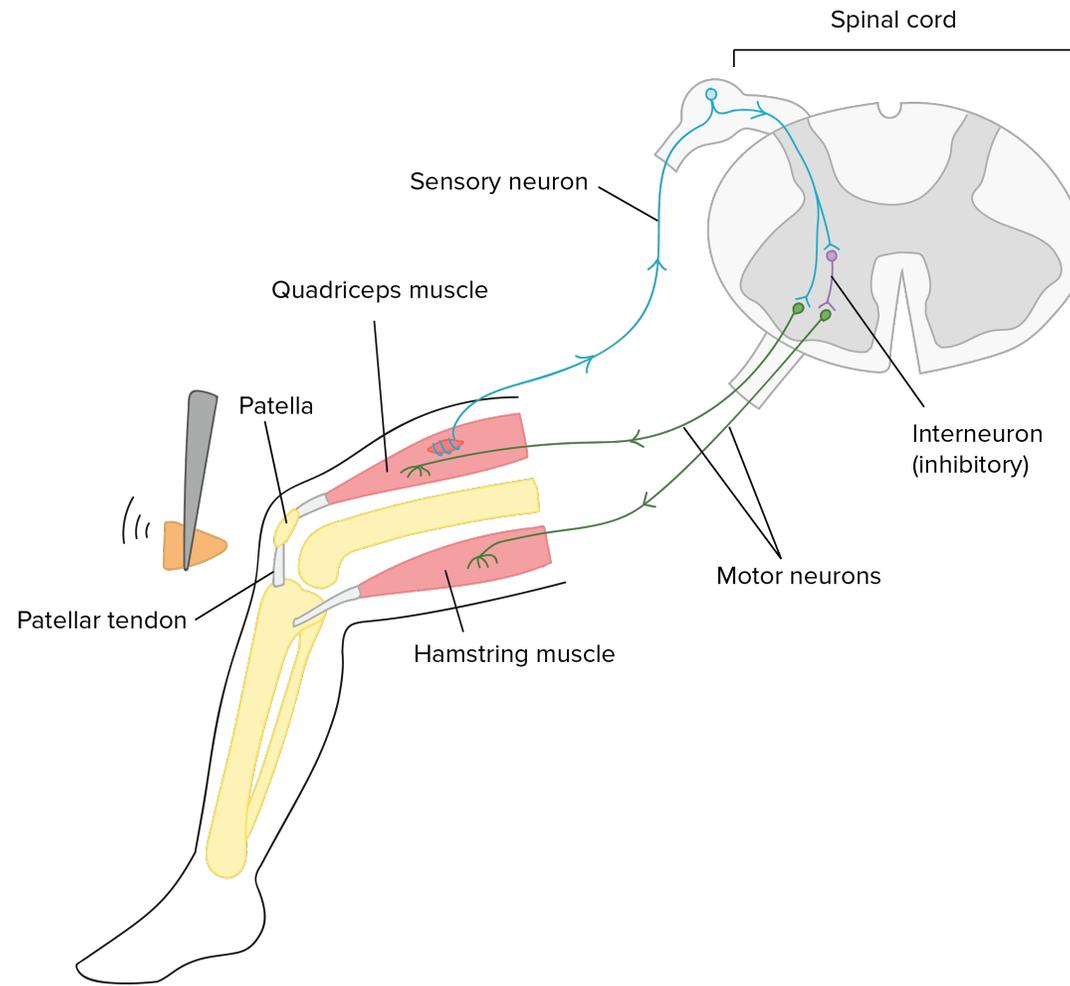
Increases in size, cell size and number, extracellular space

- Differentiation (specialization) of stem cells
- Development from an embryo

Differentiation

Reproduction

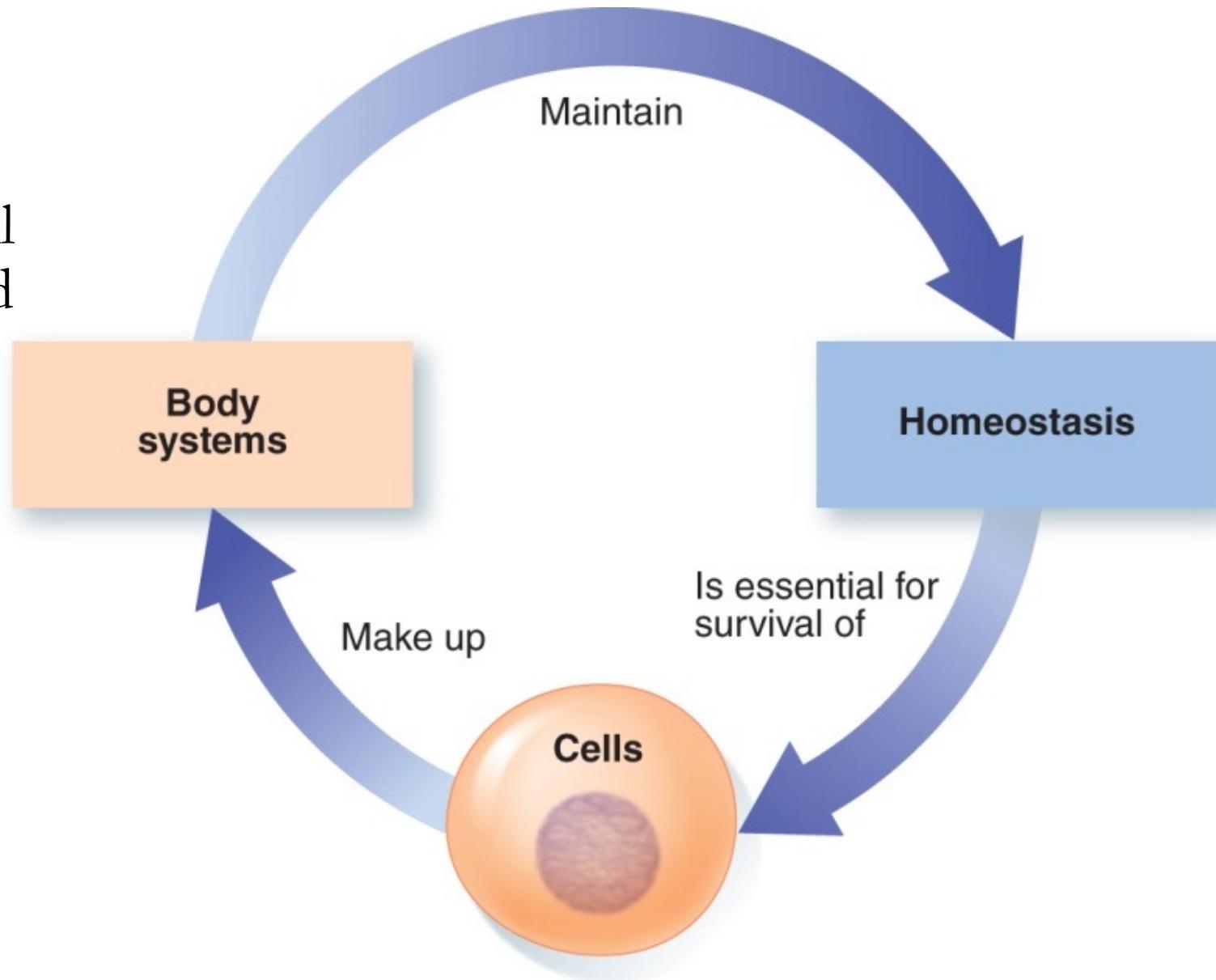
- To produce a new individual (organism)
- Create new cells for growth or repair



Viewing the human body through the lens of an engineer, it's fascinating to consider the body as a system that uses various controllers or 'algorithms' to adjust and regulate its internal processes.

Homeostasis

- Ability of an organism or cell to maintain a stable/balanced internal environment
- Homeostasis encompasses a wide range of physiological processes that regulate internal conditions like temperature, pH balance, hydration, electrolyte levels, and more.

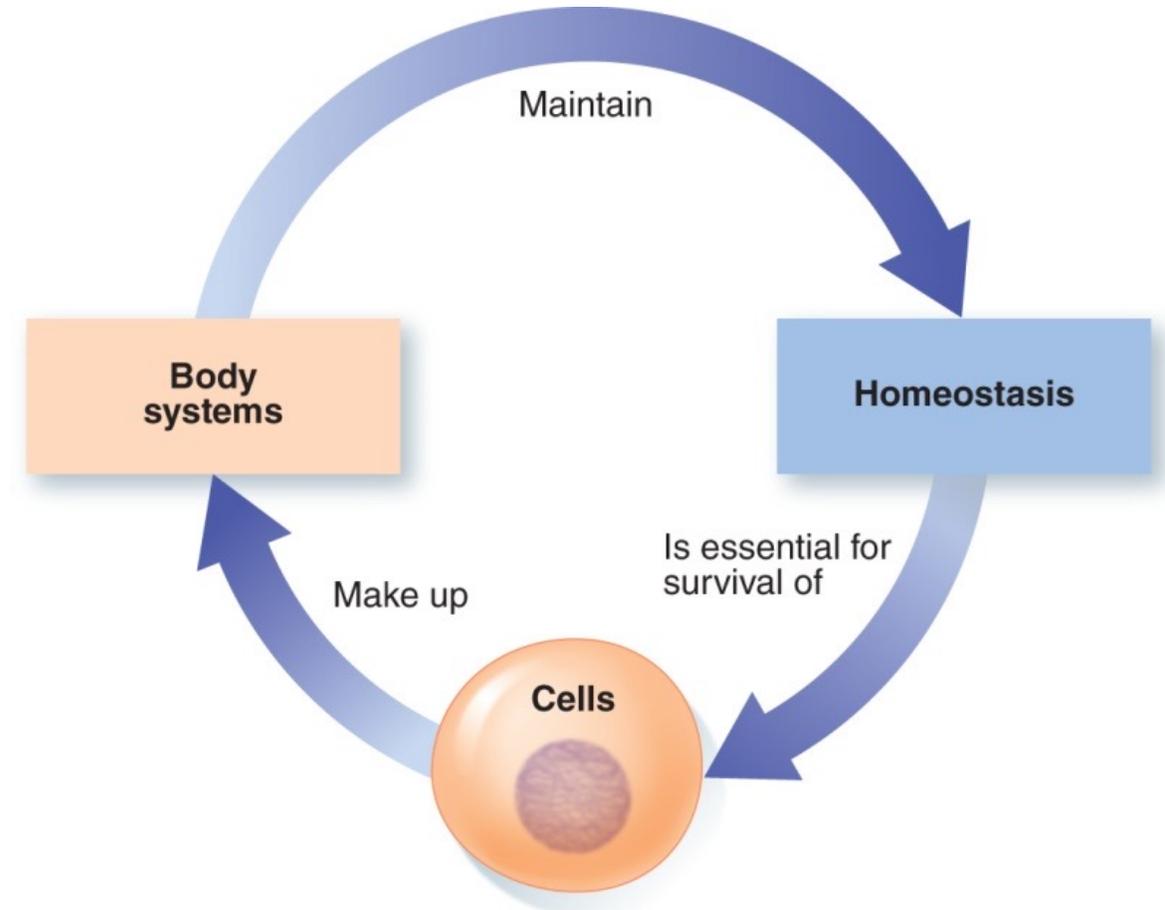


Homeostasis

An engineering control system?

In order to maintain homeostasis, a control system must be able to

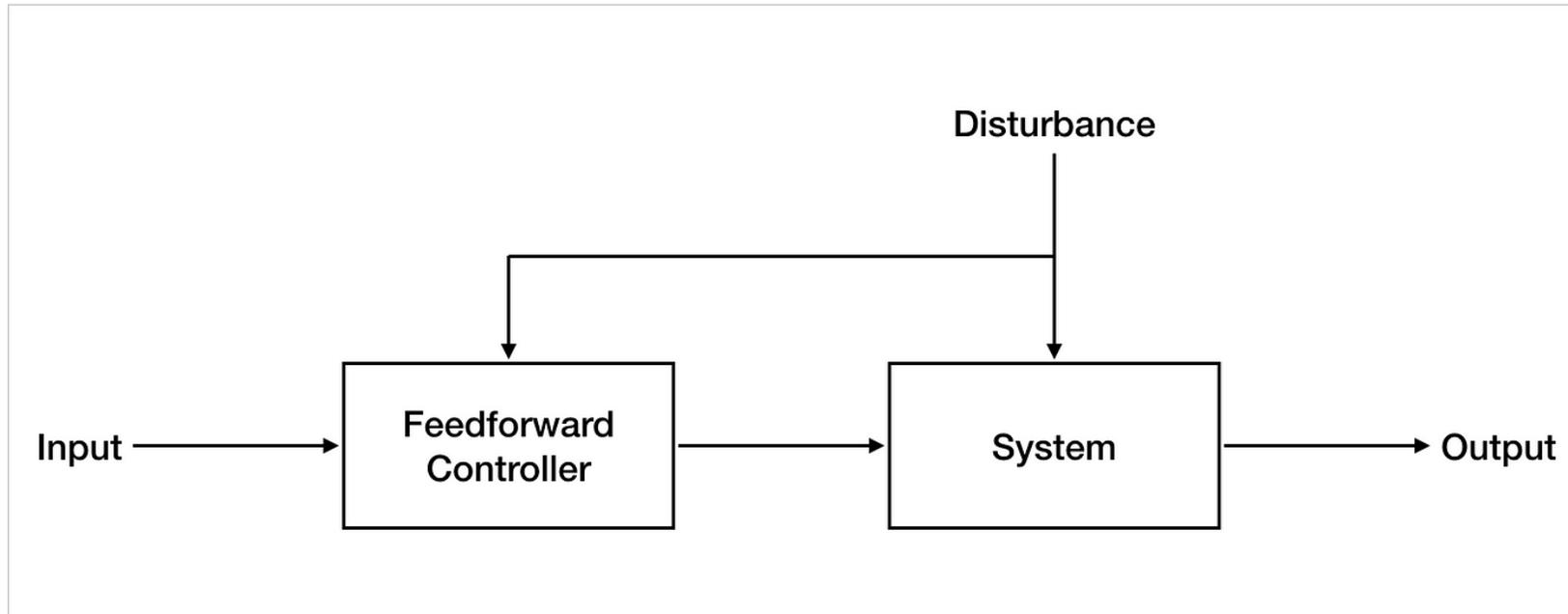
- Detect deviations from normal in the internal environment that need to be held within narrow limits (sensor)
- Integrate this information with other relevant information (control centre)
- Make appropriate adjustments in order to restore a factor to its desired value (effector)



Homeostasis

An engineering control system?

Lets consider Feedforward control first. Recap:



Example of feedforward control

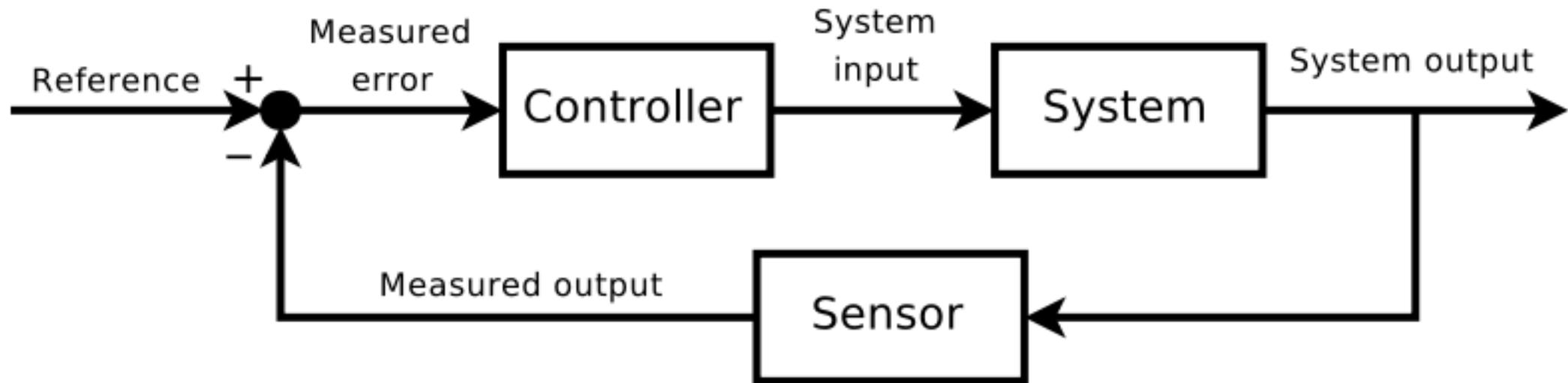


- The sight of food activates the salivary glands to release saliva in advance, preparing the digestive system for the incoming food. This pre-emptive response exemplifies a feedforward control system, where the body anticipates a future need - in this case, digestion - and takes early action to facilitate the process efficiently.
- In this example, the body's response (salivation) is triggered not by the actual process of eating but by the anticipation of it. This is a classic case of feedforward control, where the system prepares for a future event based on cues or signals, in this instance, the visual stimulus of seeing food.

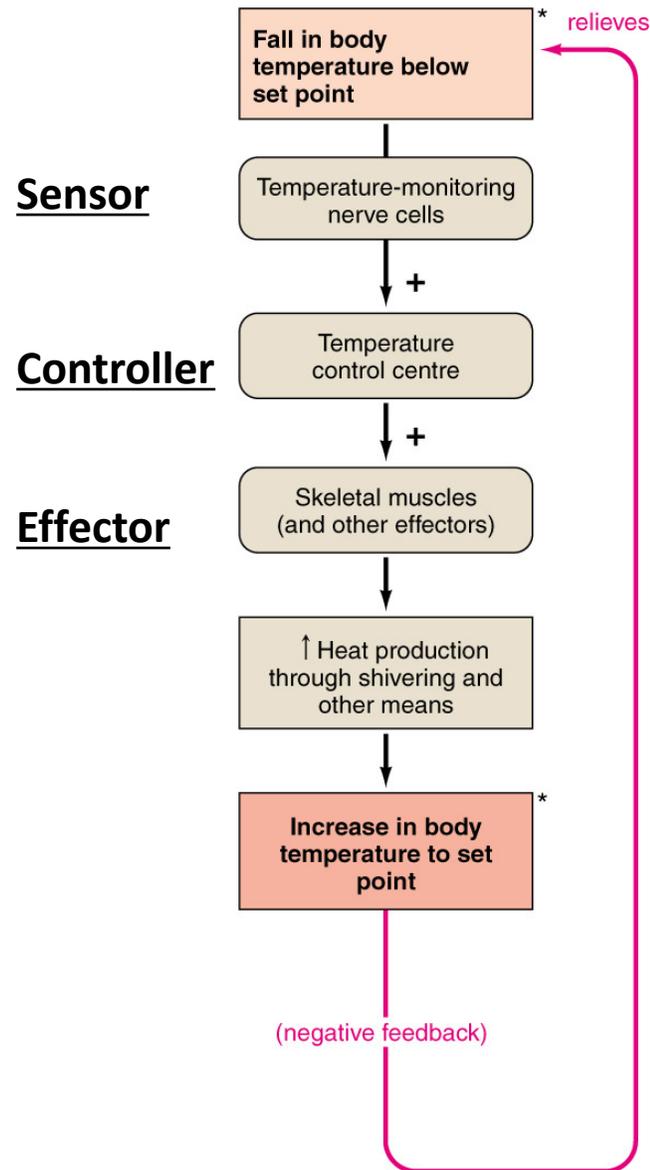
Homeostasis

An engineering control system?

Homeostasis is more like a feedback controller

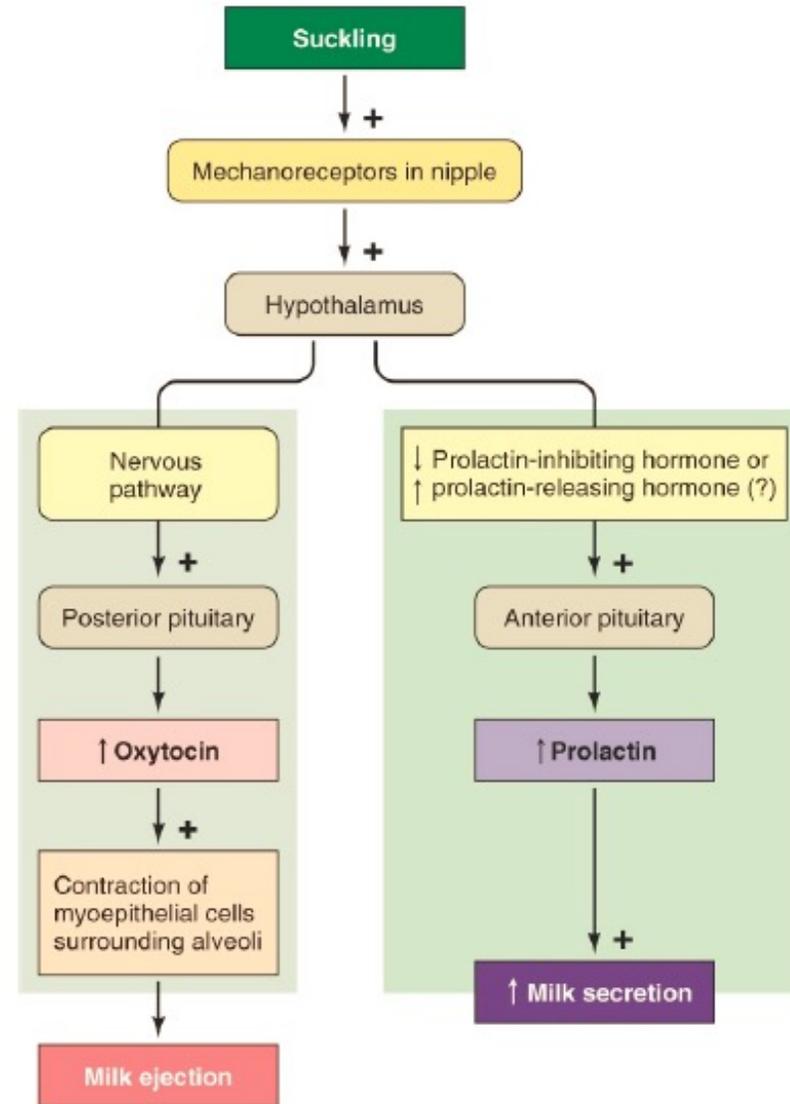


Negative Feedback



(c)

Positive Feedback



Muscle and its importance in the control system

