P524: Survey of Instrumentation and Laboratory Techniques

Instructor: Chen-Yu Liu
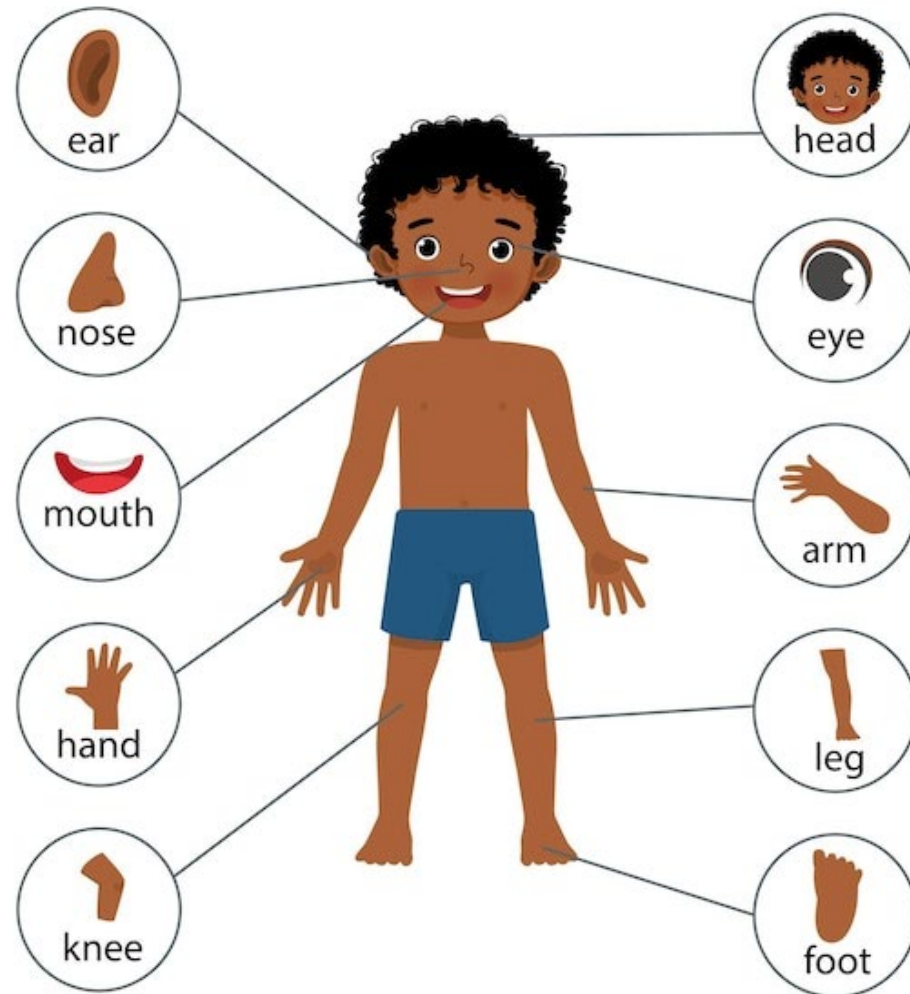
Guest lecturer: Gregory Hallewell, Brian Mercer, Tim Barklow

TA: Chad Lantz

Grader: Garrett Williams

Course designer: George Collins, who will teach P523 (projects)

Human Anatomy

Instrumentation, or building your project (could be a robot)

We will need the following:

1. A brain:

   Microprocessors (with CPU: Central Processing Unit)
   - Personal computer (running windows, mac, or linux OS)
   - Raspberry Pi (small computer, running linux OS)
   - Arduino board (microprocessor)
   - Other boards similar to Arduino boards

   https://www.sparkfun.com/standard_arduino_comparison_guide

	PC	Raspberry Pi	Arduino Uno	Arduino Mega	Feather M0	Feather M4
Processor make	Intel, AMD, Apple	ARM Cortex-A72	Atmega328P	ATmega2560	ATSAMD21G18	ATSAMD51
cores	1 to 64 (standard)	4	1	1	1	1
Speed	Up to 3.8 GHz	Up to 1.8 GHz	16 MHz	16 MHz	48 MHz	120 MHz

Arduino Boards
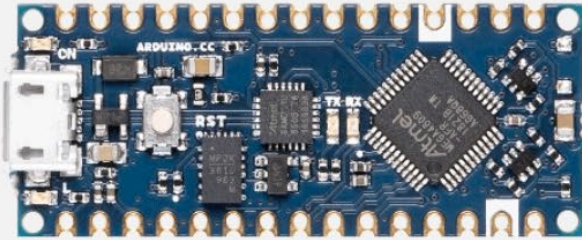
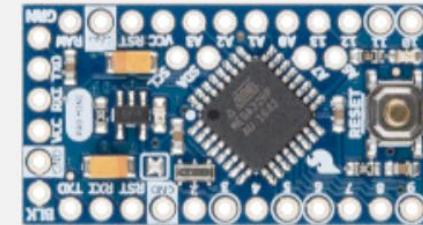**Arduino Nano Every**

Arduino Uno Rev3

Arduino Mega 2560 Rev3
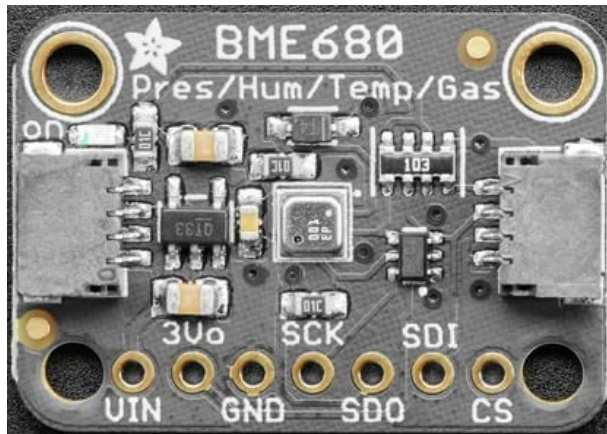

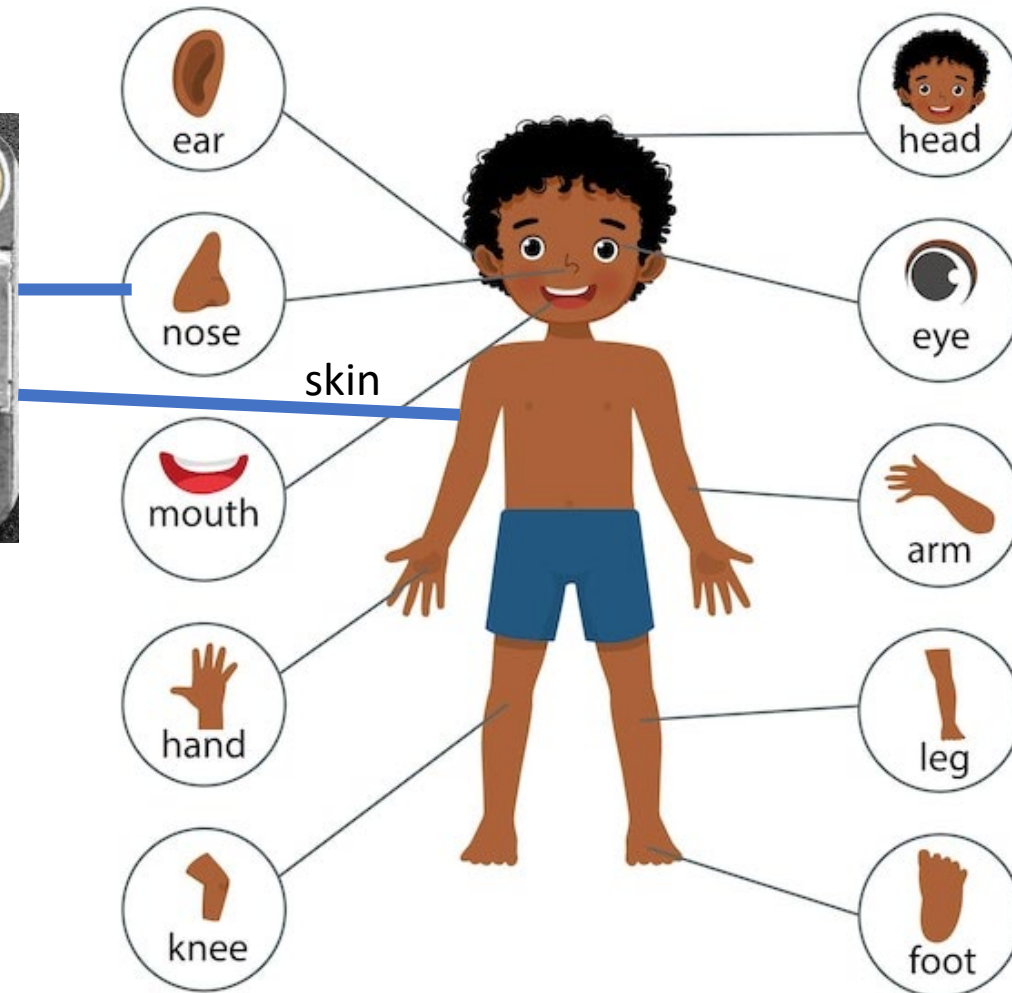**Arduino Nano 33 BLE Sense**

Arduino Zero

Arduino Pro Mini

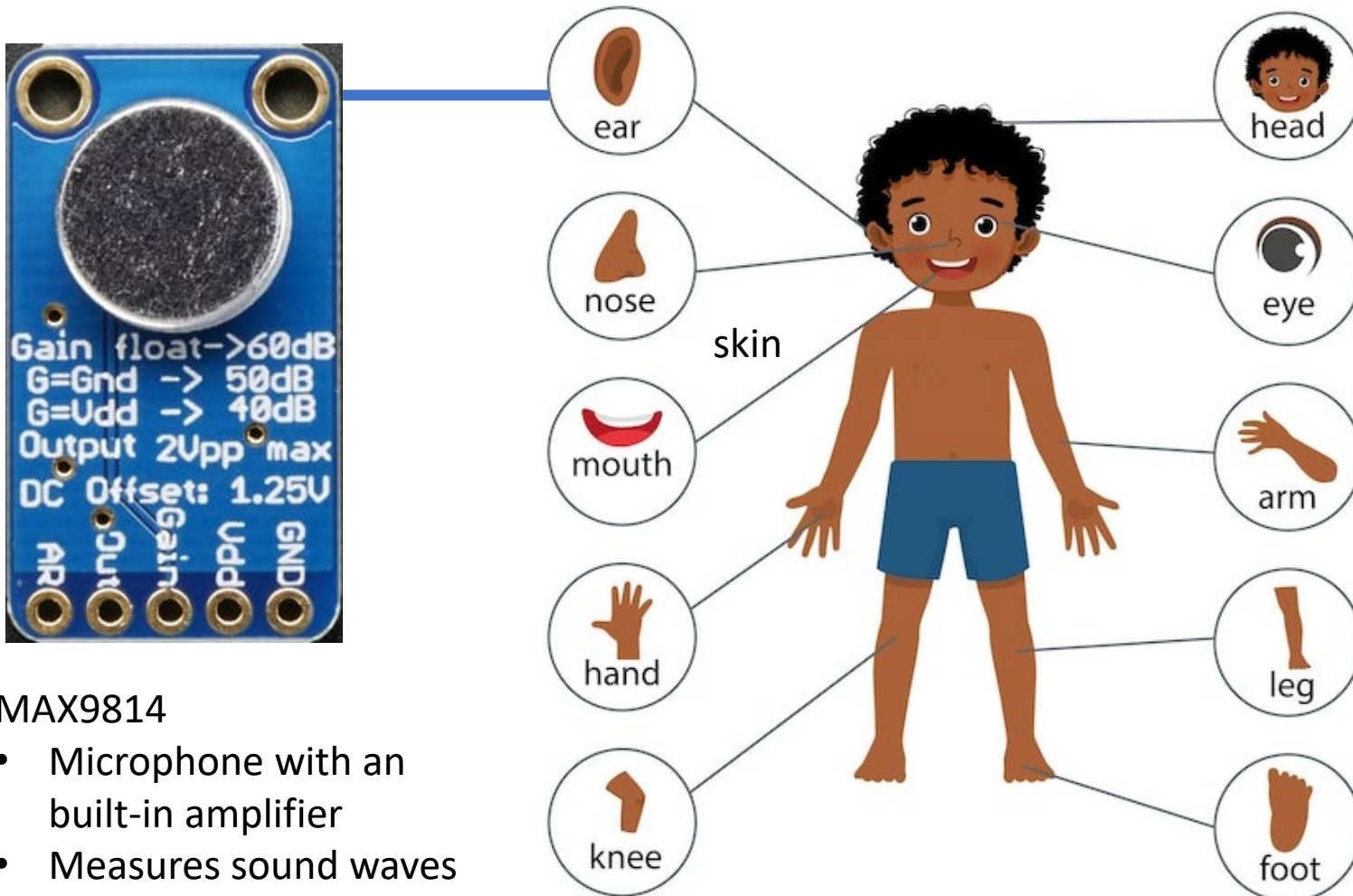# To sense the environment, we will add various sensors

BME680 measures
- Pressure
- Humidity
- Temperature
- Gas

To sense the environment, we will add various sensors
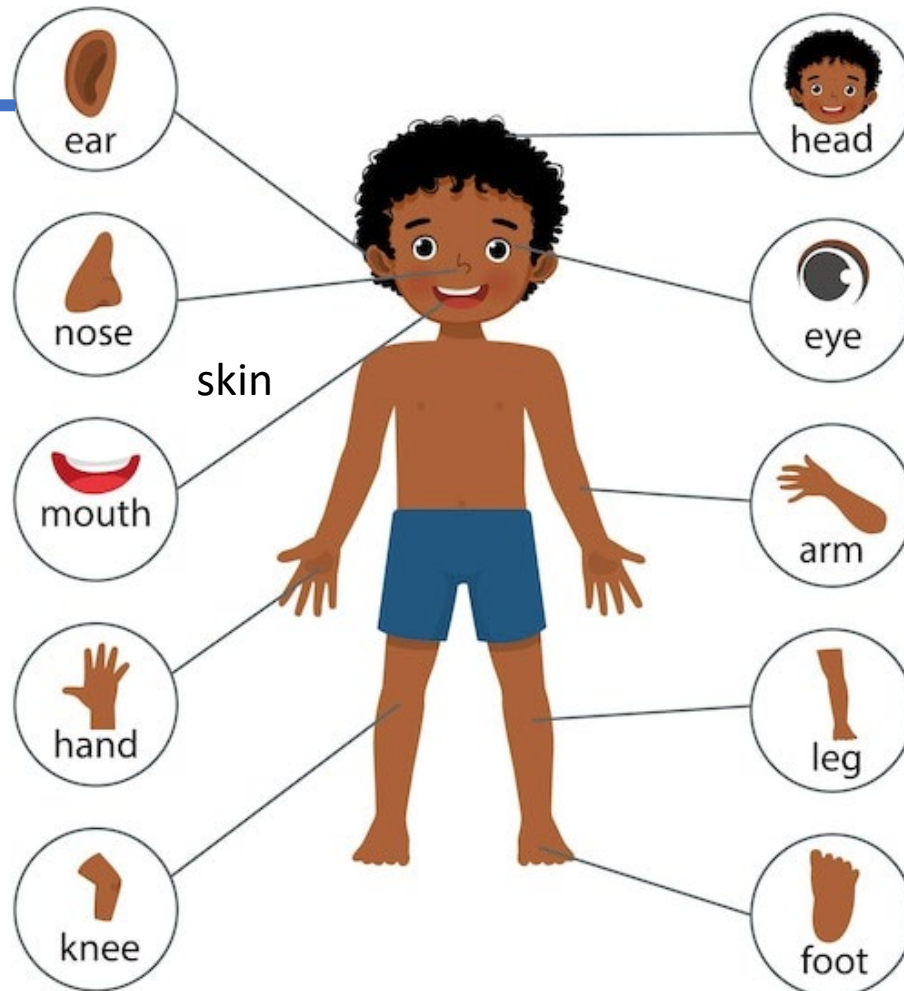
MAX9814
- Microphone with an built-in amplifier
- Measures sound waves

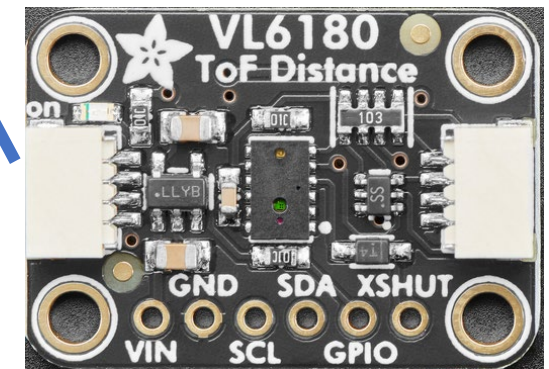# To sense the environment, we will add various sensors

ear

nose

skin

mouth

hand

knee

head

eye

arm

leg

foot

TSL2591
- Light sensor (LUX)
- Infrared & full-spectrum

VL6180: Time-of-flight distance sensor

MAX4466
- Microphone with a built-in amplifier
- Measures sound waves

To sense the environment, we will add various sensors

LSM9DS1 (9-DOF)
- Accelerometer
- Gyro
- Magnetometer
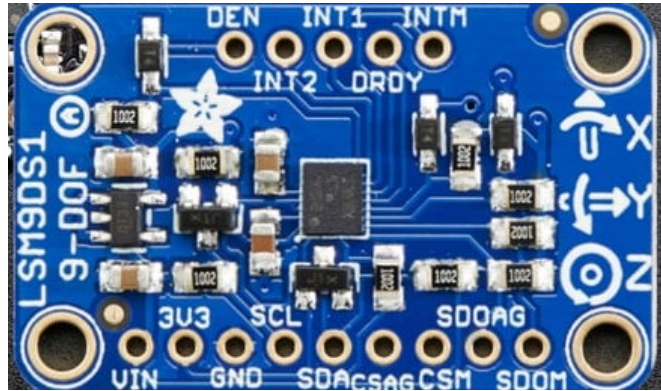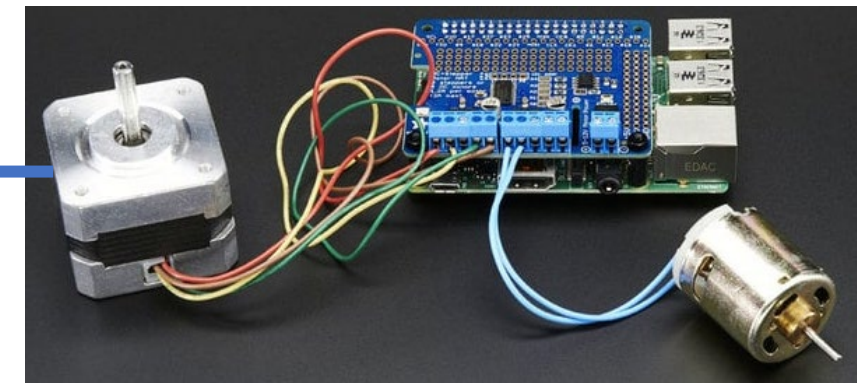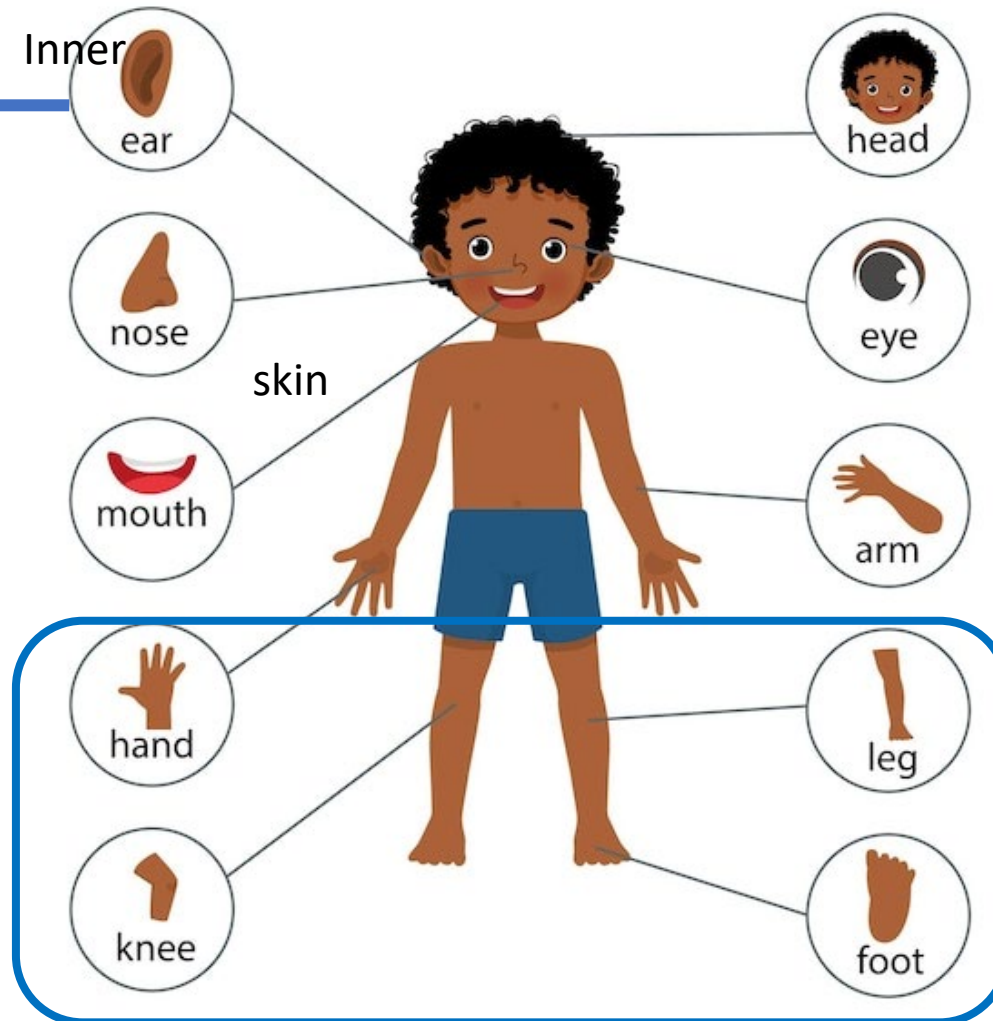
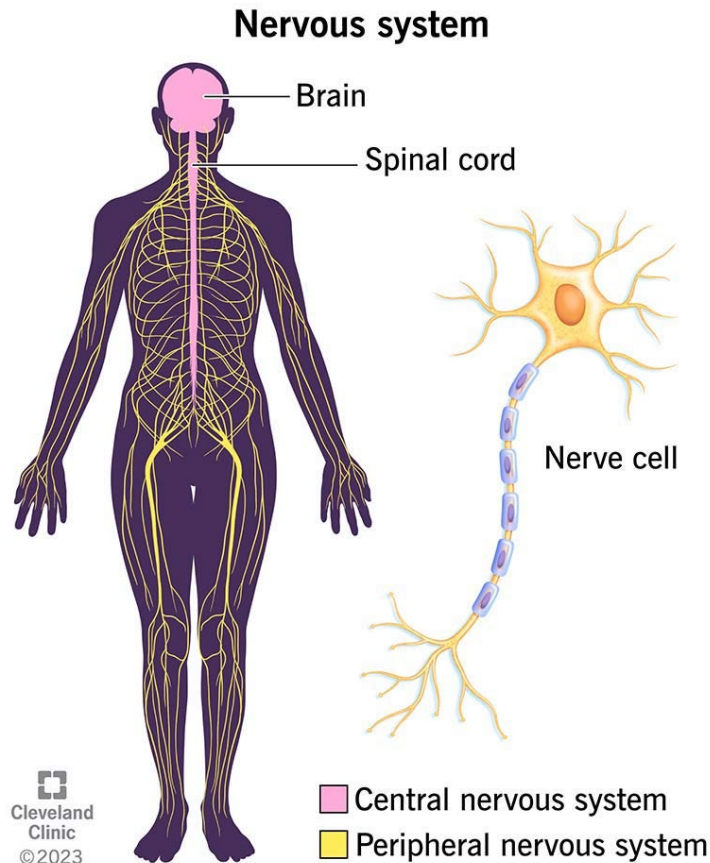# To sense the environment, we will add various sensors

LSM9DS1 (9-DOF)
- Accelerometer
- Gyro
- Magnetometer

Inner ear

skin

ear
nose
mouth
hand
knee

head
eye
arm
leg
foot
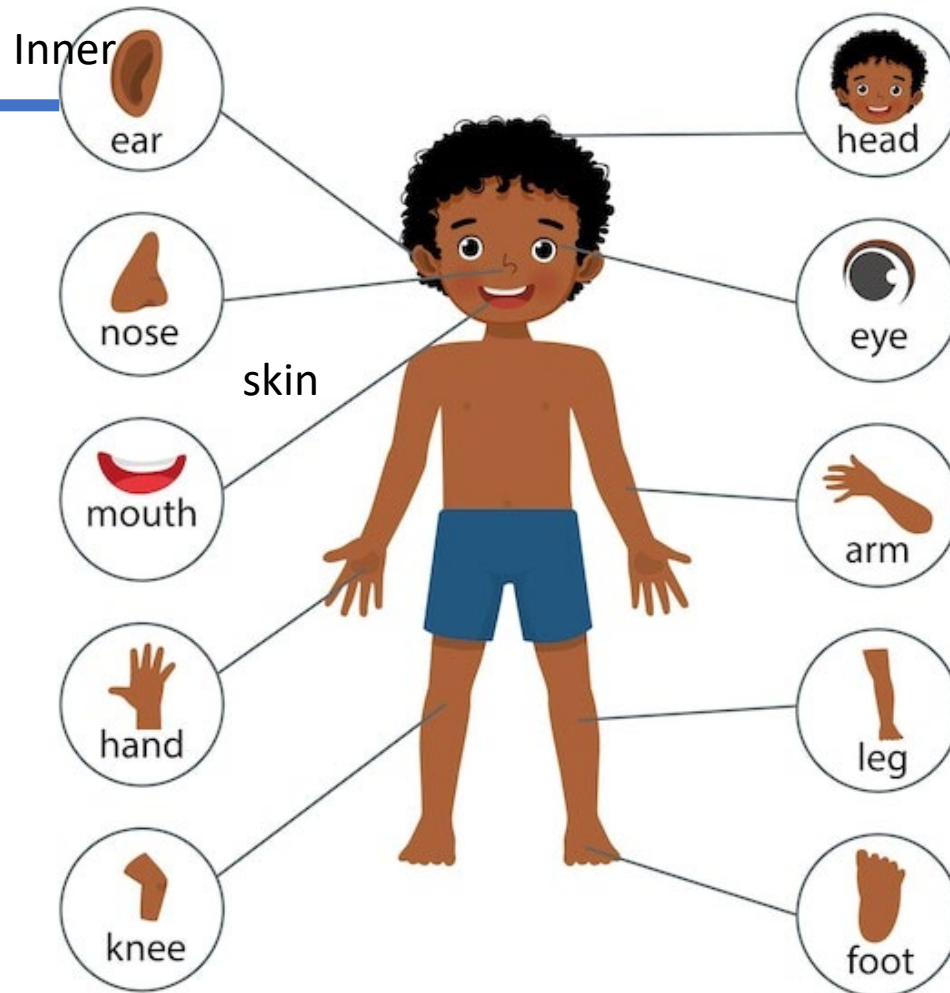
Stepper Motors and Control Board

The sensor signals will need to be sent to the processor via communication buses

Nervous system

Brain

Spinal cord

Nerve cell

Cleveland
Clinic
©2023

Central nervous system
Peripheral nervous system

Within the boards, we have communication bus & protocol
- Serial communication (UART, Universal Asynchronous Receiver/Transmitter)
- I2C (Inter-integrated Circuit)
- SPI (Serial Peripheral Interface)

There are also wireless communication available:

TECHNOLOGY	APPLICATION	SUCCESS METRICS	DATA RATE	RANGE
Wi-Fi	LAN, Internet	Speed, Flexibility	.1-7 Gbps	100m
Li-Fi	LAN, Internet	Security, Speed, Cost	1-3.5 Gbps	10m
Bluetooth	PAN, Mobile Credentials	Cost, Convenience	48 Mbps	<300m
ZigBee	Sensor Networks	Reliability, Power, Scalability, Cost	.250 Mbps	70-300m

Finally, you need to "program" how the brain process the signals

- You will write programs and download to the microprocessor:
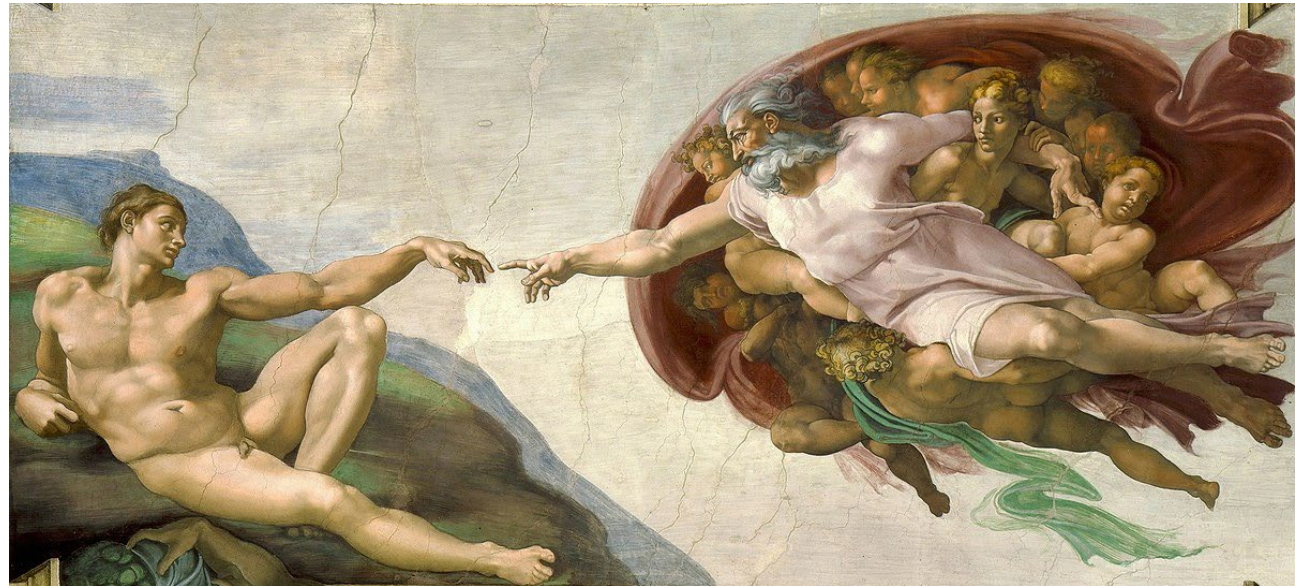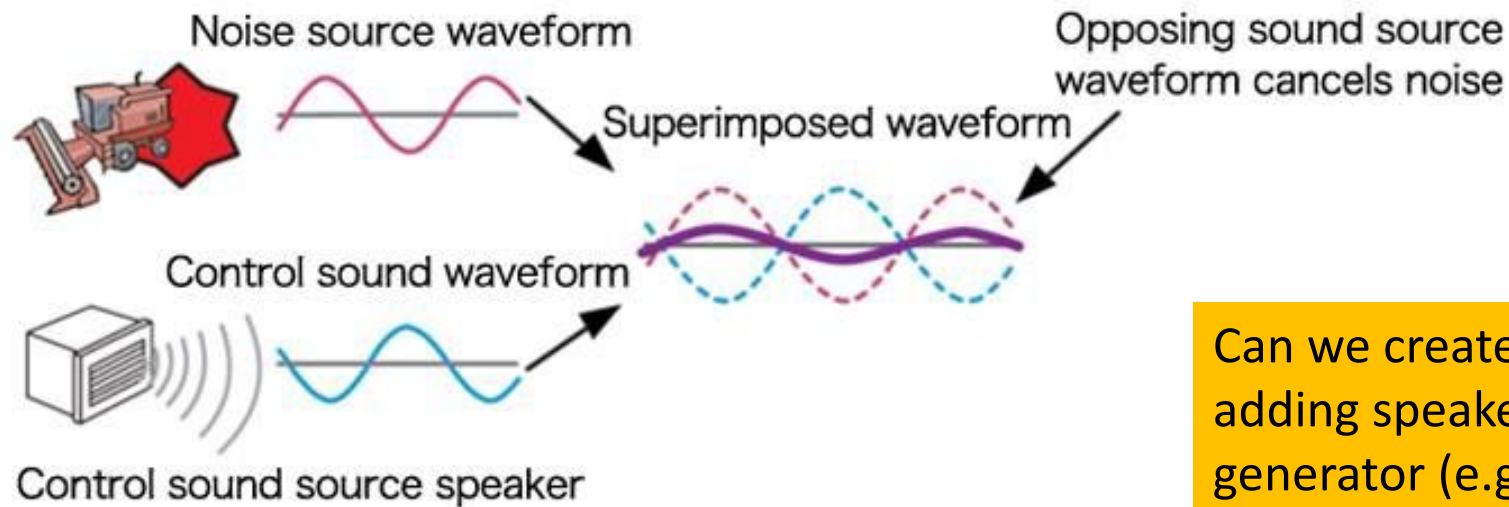

- Arduino: C++ (in Arduino IDE), or python (circuit python)
- Python: to process the recorded data (on your PC) to make sense of the data

PHYS523: Projects

Project Idea: Noise cancellation of noisy pumps

In 1989, Bose Corporation introduced its "**Series I Aviation Headset**" which became the first commercially available ANR headset. It included a noise-cancelling function and was powered either by NiCad batteries (with a claimed battery life of 8 hours) or by power from the aircraft.

Noise source waveform

Opposing sound source waveform cancels noise

Superimposed waveform

Control sound waveform

Control sound source speaker

Can we create a device to cancel the noise by adding speakers in the vicinity of the noise generator (e.g., a noisy pump or air-handler)?

Project Idea: An Arduino-based radiation detector to identify radio-isotopes, including radon gas

Gamma ray spectroscopy with Arduino UNO
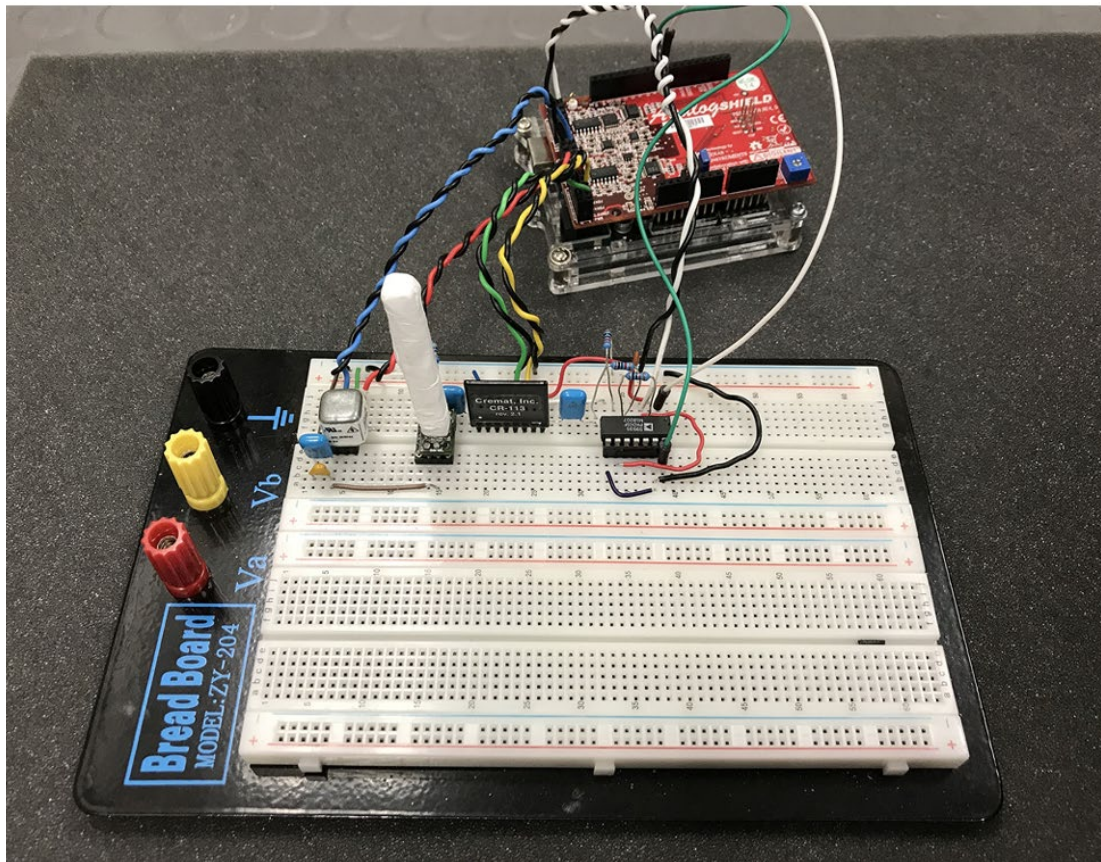
- https://pubs.aip.org/aapt/ajp/article/86/5/384/1041617/Gamma-ray-spectroscopy-with Arduino-UNO

- Goal: add the capability to detect radon gas

Project Idea: A music tuner for beginning violin players