Human Anatomy and Physiology Laboratory Booklet

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A Member of The Pennsylvania Alliance for Design of Open Textbooks

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About the Author

Dr. Martilias Farrell is a Visiting Professor of Biology at Cheyney University of Pennsylvania. His research spans the application of emerging technologies—including those at the intersection of biology, medicine, and computation—to deepen our understanding of the natural world and improve the human experience. Equally committed to teaching, Dr. Farrell designs scientific learning experiences that are accessible, resource-conscious, and grounded in the principles of rigor and reproducibility. He believes that good science doesn’t require expensive equipment—just sharp thinking, disciplined execution, and a deep curiosity about how the world works. Through his lab manuals and instruction, he encourages students to question boldly and investigate purposefully, regardless of where they begin.

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Note to the Reader

Dear Reader,

Thank you for checking out my lab manual. This booklet is designed to be used by the instructor – the students should not receive a raw copy of this booklet. Instead, you should be able to print out the pages (either on paper or to a new PDF that the student can download) that are specific to the student laboratory activity. Each laboratory activity should be an even number of pages, so you can maximize double sided printing. Most of the laboratory activities include "Notes for the instructor", which the students should not receive. In addition, there is some appendix content that will be helpful.

As a scientist that has performed research in laboratories that have ranged in funding support, I feel it's important to demonstrate that good science can be performed without lavish budgets. Indeed, the pivotal facet of science is reproducibility, and modern biomedical science has painted itself into a corner through published work that is inherently incapable of being reproduced due to the costs involved. Therefore, you should be able to perform these activities in this booklet with minimal resources. My institution's teaching labs contain microscopes, prepared microscope slides, and anatomical models. Hopefully your institution considers these things the "basics" of undergraduate teaching labs and has provided this equipment. Some of the labs described require more equipment or consumables, but I have provided links to Amazon items that can be considered.

In addition to wherever you have found this manual, I will also maintain versions on GitHub: General Biology Laboratory Booklet, and Human Anatomy and Physiology Laboratory Booklet. I welcome pull requests or any other forms of collaboration.

While these labs are relatively simple, they do seem to challenge the students and intrigue them. I feel it is important to emphasize to the students that science does not need to be fancy. Instead, it needs to be rigorous and reproducible, and scientists need to be disciplined in their work.

In the future, I hope to establish a virtual mega lab, where some of the data collected from the investigatory labs can be combined and ultimately published.

I wish you the best in your teaching.

Sincerely,
Martilias Farrell, PhD

Axial Code Lab

Materials

- Mounting putty
- Colored tape or markers
- Toothpicks or skewers
- Fine-tip markers (pens will be OK)
- Axial skeletons (at least 1 skeleton per 2 groups)

Learning Objective

To become familiar with axial bone anatomy by using bone terminology to encode and decode messages collaboratively.

Lab Overview

In today’s lab, you will work in teams to:

1. **Create a coded message** using a coding system based on axial bone names.
2. **Decode another team’s message** using the same system.

You will use a **code dictionary** provided in this packet. The dictionary lists axial bones in rows and words associated with each bone in columns. Your message will be encoded using flags that specify:

1. The position of the word in the message.
2. The column in the dictionary to reference.
3. Any suffix to add to the word.

Figure 1: A flag mounted on the zygomatic bone with the data blob “1.A-S.” Image by Author.

Example of a Flag

- A flag labeled "**1.A-S**" would mean:
  - **1:** The word appears first in the message.
  - **A:** Look in column A of the dictionary.
  - **-S:** Add the suffix "-s" to the word.

For Instance

- If the flag is placed on the **zygomatic bone**, look up "zygomatic" in the dictionary.

- In column A, the word is "nerve." Adding the suffix "-s" makes the word "nerves."

If additional flags read "**2.E**" on the parietal bone (word: "also") and "**3.A**" on the maxilla (word: "fun"), the complete message is: "**Nerves also fun.**"

GET A GROUP LETTER FROM THE INSTRUCTOR.

Grading

- Each word in your **encoded message** is worth **10 points** (out of 100).
- Messages shorter than 10 words will result in a reduced maximum score:
  - **Example**: A 7-word message limits your score to a maximum of 70%.
- For decoding errors:
  - **-10 points per incorrect word** in the decoded message.
  - The score for both teams in the pair is averaged, and all members of a group receive the same score.

Example Scenarios:

- A 12-word message with 2 errors in decoding earns 100%:
  120 points (encoded)−20 points (errors)=100 points.
- A 7-word message decoded perfectly earns 70%.

Coding Instructions

1. Message Creation

- Write a message with **at least 7 words** that is grammatically sensible.
- Do not use any bone more than once.

2. Flag Preparation

- Create flags using toothpicks, tape (choose one color for your group), and markers.
- Write the necessary code on each flag (e.g., "1.A-S").
- Mount the flags on the corresponding bones using the mounting putty.

3. Submit Your Message

- Once your flags are in place, inform the partner group that your message is ready.
- Submit your message to your instructor.

Decoding Instructions

1. Message Decoding

- Look for the flags placed by the partner group.
- For each flag:
  - Identify the bone it is mounted on.
  - Use the code to look up the correct word in the dictionary.
  - Apply any suffix provided.
- Continue until you decode the full message.

2. Submit Decoded Message

- Once you finalize the decoded message, submit it to your instructor.

Important Notes

- Plan your message carefully to ensure clarity and grammar.
- Double-check flag placement and coding for accuracy.
- Collaborate effectively to decode your partner's message.

Skull-Based Code Dictionary

BONE	A	B	C	D	E
Condylar process	food	troubled	protect	*the*	*know*
Coronal (frontal) suture	puncture	general	eminent	*be*	*take*
Coronoid process	infamous	wry	giants	*to*	*people*
Cribriform plate	coalition	amused	shower	*of*	*into*
Crista galli	rough	purring	share	*and*	*year*
Ethmoid bone	unruly	bucket	soda	*a*	*your*
External auditory meatus	breezy	swanky	argument	*in*	*good*
Foramen magnum	activity	driving	defective	*that*	*some*
Frontal bone	refuse	offer	safe	*have*	*could*

BONE	A	B	C	D	E
Hyoid bone	ambitious	ink	halting	*I*	*them*
Incisive foramen	value	gaudy	lame	*it*	*see*
Lacrimal bone	offbeat	sassy	easy	*for*	*other*
Lambdoid suture	helpful	questionable	proud	*not*	*than*
Mandible	confused	abstracted	friction	*on*	*then*
Mastoid process	annoy	the	explain	*with*	*now*
Maxillae	fun	repeat	signal	*he*	*look*
Mental foramen	mere	windy	bucket	*as*	*only*
Nasal bone	beneficial	sable	stranger	*you*	*come*
Nasal conchae (superior/middle/	rain	include	minute	*do*	*its*
Palatine bone	houses	gigantic	low	*at*	*over*
Occipital bone	yellow	party	adjoining	*this*	*think*
Parietal bone	drab	spade	broad	*but*	*also*
Occipital condyle	overt	division	bawdy	*his*	*back*
Olfactory foramina	cub	absent	alike	*by*	*after*
Perpendicular plate	defeated	road	annoy	*from*	*use*
Sagittal suture	obtainable	agonizing	insidious	*they*	*two*
Sella turcica	sugar	sigh	babies	*we*	*how*
Sphenoid bone	last	instruct	messy	*say*	*our*
Squamous suture	rampant	jealous	string	*her*	*work*

BONE	A	B	C	D	E
Styloid process	inject	foot	mute	*she*	*first*
Supraorbital foramen	fierce	pathetic	hysterical	*or*	*well*
Temporal bone	lyrical	scarf	bolt	*an*	*way*
Vomer bone	toothpaste	hulking	attract	*will*	*even*
Zygomatic bone	nerve	school	pet	*my*	*new*
Zygomatic process	nice	flock	official	*one*	*want*
Atlas	morning	sugar	knock	*all*	*because*
Axis	squeak	dead	ants	*would*	*any*
Body	outrageous	crib	fold	*there*	*these*
Cervical vertebrae	marble	army	enchanting	*their*	*give*
Coccyx	seed	flawless	melodic	*what*	*day*
Intervertebral discs	faulty	able	fax	*so*	*most*
Lamina	magnificent	amount	rain	*up*	*us*
Lumbar vertebrae	school	hollow	pipe	*out*	*the*
Manubrium (body)	main	present	cough	*if*	*be*
Pedicle	credit	divide	the	*about*	*to*
Sacrum	fireman	glacier	miracle	*who*	*of*
Spinous process	the	presentation	rampant	*get*	*and*
Vertebral column	parsimonious	scarce	confess	*which*	*a*
Suprasternal notch	unpack	launch	enjoy	*go*	*in*

BONE	A	B	C	D	E
Sternum	berserk	embarrass	greet	*me*	*that*
Thoracic vertebrae	lying	poised	agreeable	*when*	*have*
Transverse process	the	wake	tempt	*make*	*I*
Vertebral ribs (floating)	feeling	unhealthy	grate	*can*	*it*
Vertebrochondral ribs (false)	past	salty	bee	*like*	*for*
Transverse foramina	ahead	button	ban	*time*	*not*
Vertebral foramen	draconian	tin	premium	*no*	*on*
Vertebrosternal ribs (true)	madly	scrape	fool	*just*	*with*
Xiphoid process	sort	victorious	waiting	*him*	*he*

Read “Axial Code Lab (Instructor Notes)”

Dance Move Lab

Materials Needed

- Paper
- Pens or pencils
- Anatomical terminology reference

Learning Objective

To apply anatomical terminology by describing the movements involved in a popular dance sequence. This exercise reinforces understanding of joint actions and body positioning in a collaborative and creative context.

Lab Overview

In today’s lab, you will work in groups (minimum 3 people, depending on attendance) to:

1. Write a sequence of anatomical movement descriptions for a well-known dance.
2. Exchange your descriptions with another group and attempt to identify the dance they have described.

Example

For the “YMCA” dance:

- The first move, forming a "Y" with your arms, could be described as: **“Extension of both elbow joints and abduction of both shoulder joints.”**
- Similarly, you would describe the "M," "C," and "A" movements in anatomical terms.

For dances with many steps (e.g., the “Macarena”), you can limit the description to 5–6 key moves as long as it is enough for another group to recognize the dance.

Instructions

1. Group Formation

- Form groups of at least 3 members.

- Write the names of your group members and today's date at the top of a sheet of paper under the heading **"Dance Move Lab."**

2. Dance Description

- Select a popular dance but **do not write its name** on the paper.
- Write a step-by-step description of the dance's movements using anatomical terminology (e.g., "flexion of the right hip and left knee" or "pronation of both forearms").

3. Exchange Papers

- Pass your paper to another group.
- The receiving group will write their names on the back of the paper and attempt to identify the dance based on your descriptions.

4. Dance Identification

- The receiving group will determine the dance and write its name on the back of the paper.
- If they cannot identify the dance or need clarification from your group, both groups may lose points.

5. Submission

- Once finished, submit the paper to the instructor with the following information:
  - Descriptions of the movements (front of the paper).
  - Guessed dance name and the receiving group's names (back of the paper).

Grading

- Both groups will receive the same score.
- Grading is based on:
  - The clarity and accuracy of the anatomical terminology used in the dance description.
  - The receiving group's ability to correctly identify the dance.

Point Deductions:

- If the receiving group cannot identify the dance, both groups will lose points.
- Groups that confer with each other to clarify the descriptions will also lose points.

Tips for Success

- Be detailed but concise in your descriptions.
- Avoid common dance-related terms (e.g., “twirl,” “step forward”)—stick to anatomical terminology.
- Focus on recognizable moves that make the dance unique.

Read “Dance Move Lab (Instructor Notes)”

Bone Measurement Lab

Learning Objectives

- Identify and measure specific bones in the human body.
- Collect, organize, and analyze data to explore potential relationships between bone dimensions and other physical characteristics.
- Present findings in a clear and concise manner.

Lab Overview

Understanding bone measurements can reveal insights into human anatomy and individual variations based on genetics and environment. In this lab, you will gather and analyze data about your own skeletons, identifying relationships between bone measurements, height, and other physical attributes.

Instructions

1. Group Formation

- Form a group with a minimum of 4 people.

2. Bone Selection

- Choose at least 5 bones to measure across all group members. Refer to the textbook and skeleton models for bone identification.
- Ensure the bones selected are measurable and easily identifiable. Examples include:
  - Length of the humerus.
  - Length of the femur.
  - Circumference of the wrist (radius and ulna combined).
  - Length of the clavicle.

3. Additional Measurements

- Measure the height of each group member.
- Select at least 2 additional measurements that can be easily reproduced, such as:
  - Distance from the fingertips to the kneecap when standing tall.
  - Span from the left shoulder to the right elbow.
  - Length of the foot.

4. Data Collection

- Record all measurements in a clear and organized data table. Ensure consistent measurement techniques across all group members for accuracy and reproducibility.

Example Data Table Format

Name	Height (cm)	Humerus (cm)	Femur (cm)	Wrist Circum. (cm)	Additional 1 (cm)	Additional 2 (cm)
Group Member 1	...	...	...	...	...	...
Group Member 2	...	...	...	...	...	...

5. Analysis

- As a group, analyze the data to identify potential relationships or patterns.
- Consider questions such as:
  - Is there a correlation between height and femur length?
  - Are arm measurements proportional to leg measurements?
  - Do individuals with similar heights have similar bone lengths?

6. Presentation

- Create a **PowerPoint presentation** to share your findings with the class next week.
- Include the following sections:
  - **Introduction:** Purpose of the lab and the significance of bone measurements.
  - **Methods:** Description of how you conducted the measurements and ensured consistency.
  - **Results:** Data table and visualizations (e.g., graphs, charts).
  - **Discussion:** Analysis of patterns, correlations, or anomalies in the data.
  - **Conclusion:** Summary of findings and their potential implications.

7. Submission

- Email or upload your PowerPoint to the instructor by the deadline. Be prepared to present during the next lab session.

Grading Criteria

Your group's grade will be based on the following:

1. Data Collection (30%)

- Accuracy and completeness of the measurements.
- Clear and organized data table.

2. Analysis (30%)

- Identification and explanation of patterns or relationships.
- Logical reasoning and depth of analysis.

3. Presentation (30%)

- Clarity, organization, and professionalism of the PowerPoint.
- Effective delivery and explanation of findings.

4. Collaboration (10%)

- Equal participation from all group members.

Tips for Success

- Double-check measurements for accuracy.
- Use graphs and charts in your presentation to make data easier to interpret.
- Practice your presentation to ensure smooth delivery.

Binaural Beats Perception Lab

Objective

To explore the phenomenon of binaural beats and investigate how the brain integrates auditory information from two ears to create the perception of a beat at a frequency corresponding to the difference between the tones played in each ear.

Materials

- Binaural Beats Research Tool web page: Your instructor will provide the link.
- Headphones (Bluetooth only!!)
- Computer or mobile device with internet access
- Timer (just use a watch)
- Record your observations in a word document and upload to D2L dropbox

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Procedure

1. Hardware Test

1. Begin by testing your headphones to ensure that the left and right channels are functioning correctly.
2. On the "Binaural Beats Research Tool" web page, locate the "Hardware Test" section.
3. Click the "Test Left" button and listen for a tone in your left ear. Adjust the volume slider to a comfortable level. Pay particular attention to your other (right) ear. If you hear a tone in your right ear, the hardware is flawed and can't be used for binaural beat generation (There is “bleed-through” to the other channel).
4. Repeat the process for the right ear using the "Test Right" button and volume slider.

2. Binaural Beat Perception

1. In the "Binaural Beats Generator" section, set the left channel frequency to 400 Hz and the right channel frequency to 410 Hz. Adjust volumes to comfortable levels.
2. Click the "Toggle Left" button to start the tone on the left, confirming that you only hear the tone in the left ear.
3. Click the "Toggle Right" button to start the tone on the right.

4. Listen carefully and note your perception of the binaural beat. You should perceive a beat that pulsates at a frequency equal to the difference between the two tones (in this case, 10 Hz).
5. Experiment with different frequency combinations, keeping the difference between the two frequencies within the range of 1-30 Hz. Record your observations in your lab notebook.

3. Frequency and Volume Variation

1. Select a binaural beat combination that you can clearly perceive.
2. Slowly adjust the volume slider for one ear while keeping the other constant. Observe how the perception of the binaural beat changes as the volume difference increases. Record your observations.
3. Reset the volume levels and repeat the experiment, this time slowly adjusting the frequency of one ear while keeping the other constant. Observe how the perception of the binaural beat changes as the frequency difference increases. Record your observations.

4. Extended Binaural Beat Exposure

1. Choose a binaural beat frequency combination that you find pleasant or interesting. To attempt to "entrain" the brain to a certain frequency, you can use the information below. But remember, you need to have the difference of the 2 frequencies equal to the brain wave frequency.
2. Brain Wave Frequencies:
    - Delta waves (0.5-4 Hz): Deep sleep and relaxation (so set left to 300 and right to 304, for example).
    - Theta waves (4-8 Hz): Light sleep, meditation, and creativity.
    - Alpha waves (8-14 Hz): Calm and relaxed but alert states.
    - Beta waves (14-30 Hz): Active thinking, problem-solving, and focus.
    - Gamma waves (30+ Hz): Higher-level cognitive functioning and information processing. Relate these brain waves to the frequency differences of binaural beats explored in the lab.
3. Set the volume to a comfortable level and listen to the binaural beat continuously for 20 minutes. You can do whatever during this time — scroll through your phone, even!
4. During this time, pay attention to your mental and physical state. Note any changes in your mood, focus, relaxation levels, or other sensations. Record your observations in your lab notebook.

5. Individual Differences:

1. Compare your observations with those of your classmates. Are there any noticeable differences in the perception of binaural beats among individuals?

2. Discuss possible factors that might contribute to these individual differences.

Analysis and Discussion

1. Explain the concept of binaural beats and how they are produced.
2. Describe your experience in perceiving binaural beats. How did the perception change with variations in frequency and volume?
3. Share your observations from the extended binaural beat exposure. Did you notice any changes in your mental or physical state?
4. Reflect on the lab experience and discuss any challenges or unexpected observations you encountered.

Safety Precautions

- Use headphones at a moderate volume to avoid potential hearing damage.
- If you experience any discomfort or dizziness during the lab, stop immediately and inform your instructor.

Lab Activity: Exploring Synaptic Summation

Learning Objectives

1. Construct and analyze circuits that demonstrate synaptic summation.
2. Explore the effects of excitatory and inhibitory inputs on postsynaptic neuron activity.
3. Develop critical thinking skills by solving challenges related to neural communication.

By the end of this lab, you will have hands-on experience with synaptic summation and a deeper understanding of how neurons integrate information.

Lab Overview

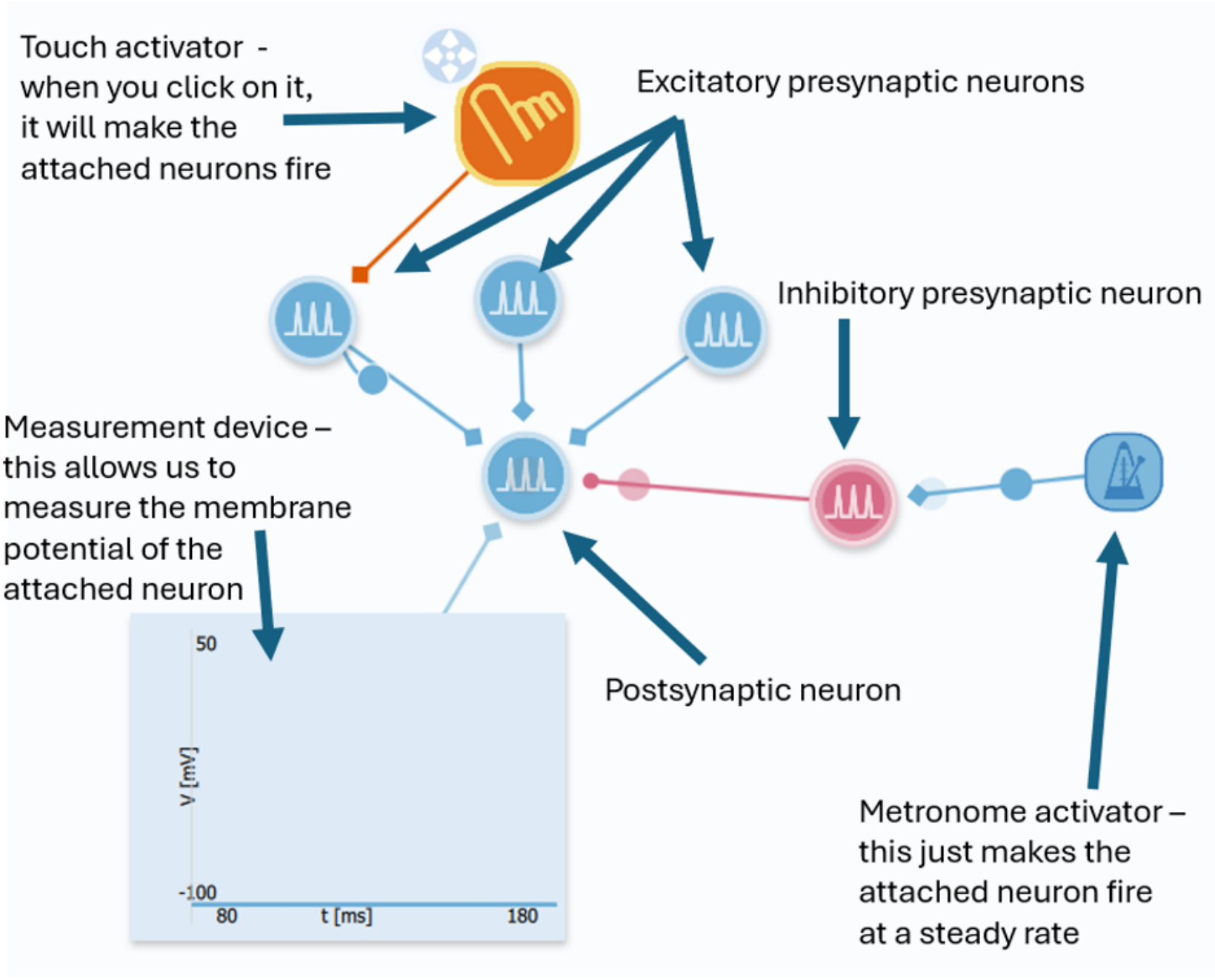
Understanding how neurons communicate is key to grasping the complexities of the nervous system. Synaptic summation, a fundamental process in neuronal communication and information processing, occurs when multiple signals from presynaptic neurons combine to influence the activity of a postsynaptic neuron. This integration determines whether a neuron fires an action potential and enables communication within neural networks.

In this lab, you will use Neuronify, an interactive simulation tool, to explore synaptic summation. Through building and experimenting with various neural circuits, you will investigate concepts like temporal summation and the impact of excitatory and inhibitory inputs on neuronal behavior.

Getting Started

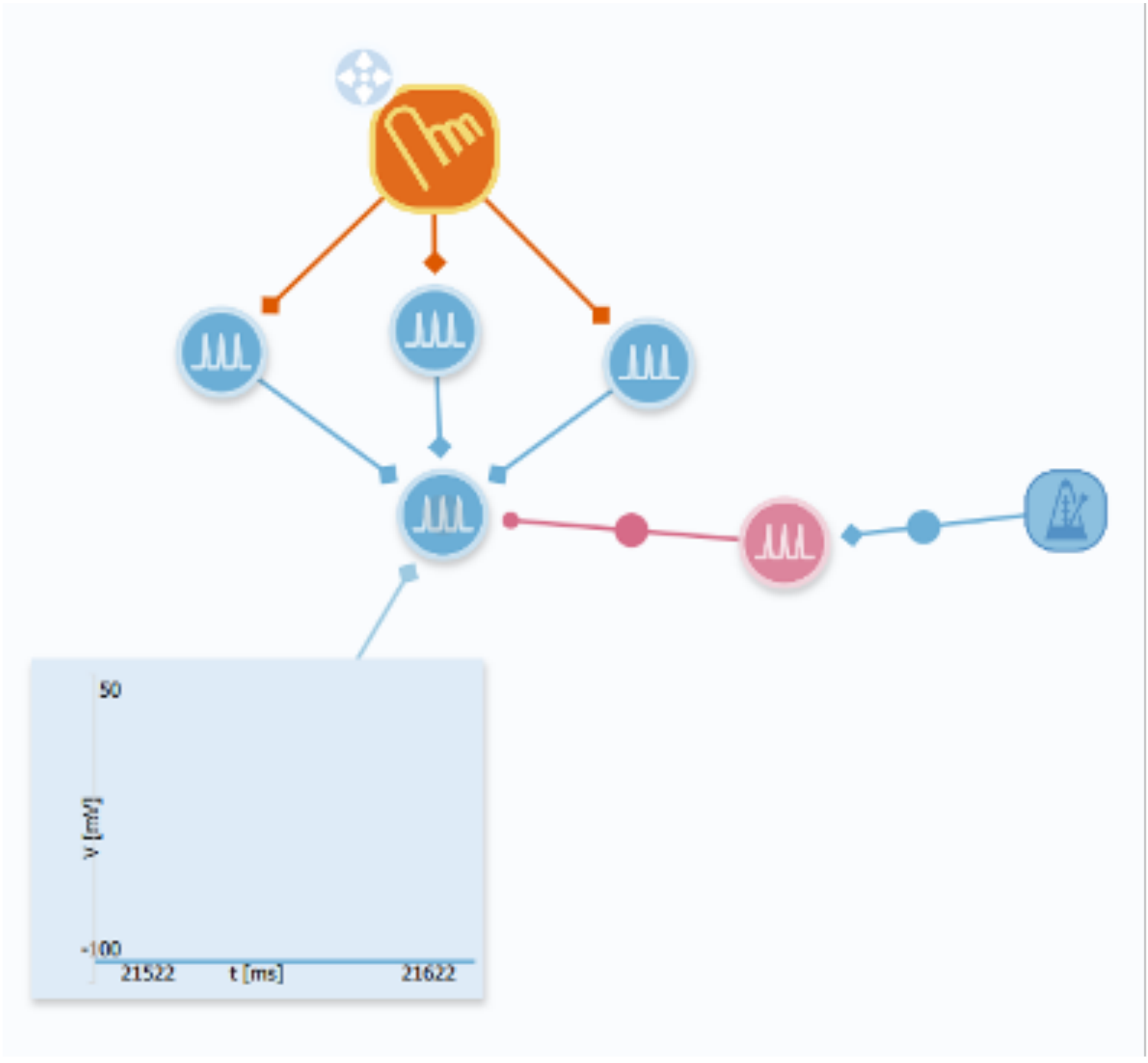
1. **Install Neuronify:** Follow the provided "How to install Neuronify" instructions to download and install the Neuronify simulation program.

Step 1: Build Your First Circuit



Example Circuit A: the breakdown

- **Build a Simple Circuit:** Build the circuit as shown in the figure above. Construct a circuit where a postsynaptic neuron is connected to three excitatory neurons and one inhibitory neuron is attached to a rate-firing device (metronome). This will make the inhibitory neuron fire automatically at a steady rate. Attach a measurement device to the postsynaptic neuron to monitor its activity.
- Press the **trigger button**. Notice that the postsynaptic neuron does not fire. This occurs because the inhibitory neuron is hyperpolarizing the postsynaptic neuron.
- Gradually attach the **touch activator** to one of the other neurons and press the trigger button. With two neurons firing, does the postsynaptic neuron fire? Try attaching the third neuron, so your final circuit should look like the image below. *Note: the figure above and below are the same circuit. Example Circuit A contains detailed explanation, while B does not.*



Example Circuit B: A sample neural circuit created in Neuronify.

Observe

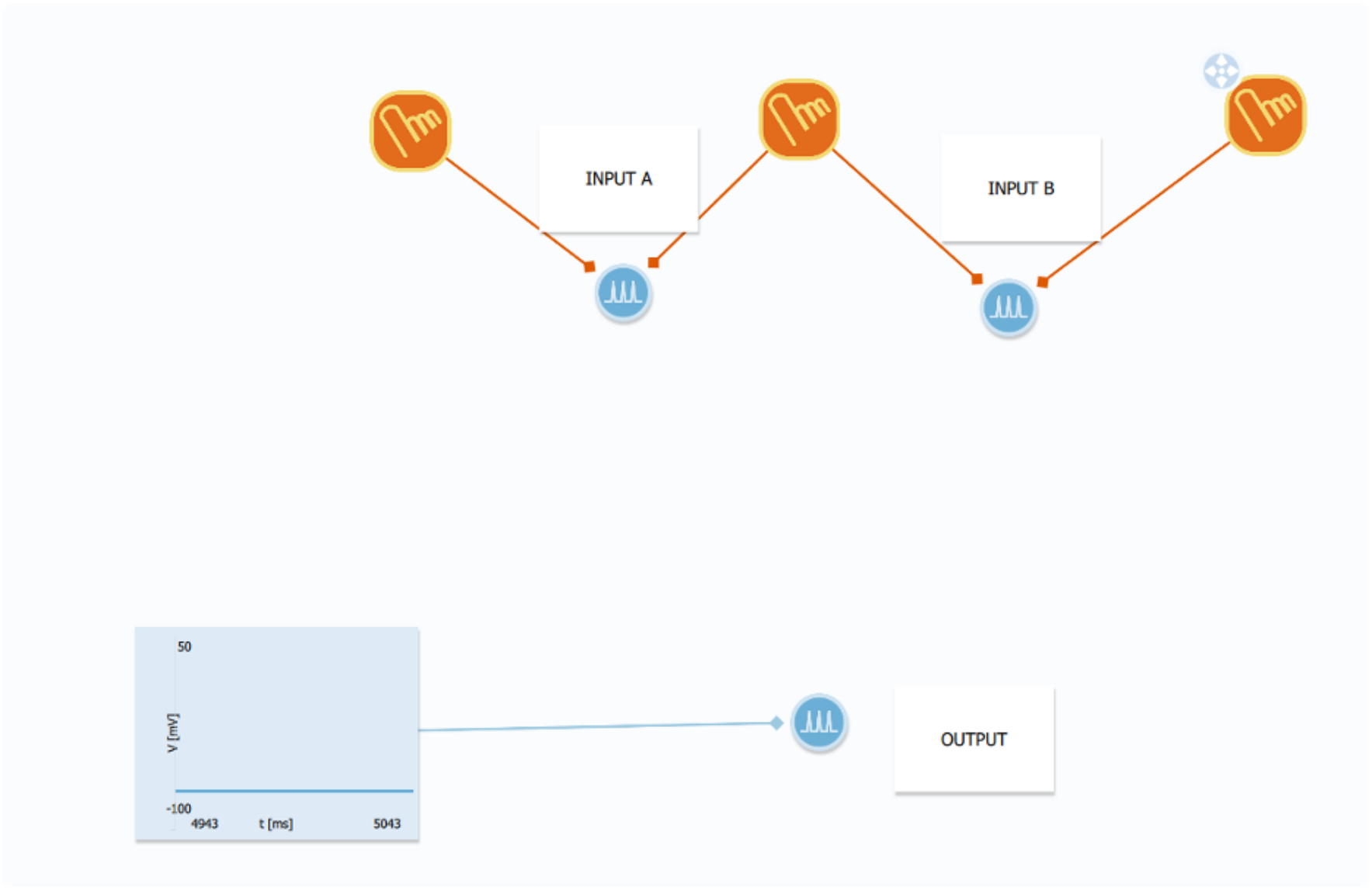
- When you activate the touch activator, does the postsynaptic neuron fire?
- Pay close attention to the voltage measurements as you add connections.

Step 2: Build New Circuits

You can expand your experiments by moving to a new canvas area:

- **Move the canvas** by clicking and dragging empty space.
- **Zoom in or out** using your mouse scroll wheel or touchpad.

To start the next set of challenges, use this basic "skeleton" circuit:



Logic Circuit Basics

- **Inputs:** The leftmost button activates Input A, the rightmost button activates Input B, and the middle button activates both.
- **Goal:** Create a circuit that controls whether the output neuron fires based on specific input combinations.

Challenges

The challenges listed below also introduce you to logic tables. These tables show 0s and 1s, which are binary. “1” means yes and “0” means no. In relation to the circuit, for an input, 1 would mean the input is activated. In terms of an output, 1 would mean that the output is activated.

1. Build an AND circuit. This circuit will have a final neuron that only fires when there are stimuli from input A and B. If there is only a stimulus from 1 input, the final neuron will not fire.

Truth Table for AND Circuit

Input A	Input B	Output
0	0	0
0	1	0
1	0	0
1	1	1

2. Build an OR circuit. The final neuron will fire if either input is active.

Truth Table for OR Circuit

Input A	Input B	Output
0	0	0
0	1	1
1	0	1
1	1	1

3. Build an XOR circuit (exclusive or). The final neuron will fire if only 1 of the stimuli are active, but not both

Truth Table for XOR Circuit

Input A	Input B	Output
0	0	0
0	1	1
1	0	1
1	1	0

4. Build a circuit of your own design! Leave a description of what the circuit does in a note on your canvas.

5. Save your file and then upload to D2L in the dropbox for the lab.

Laboratory Exercise: Visualizing Surfactant Action and Lung Function

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Learning Objective

To visually observe the effect of a common surfactant (liquid dish soap) on the surface tension of water and relate this observation to the function of pulmonary surfactant in the lungs.

Introduction

Breathing relies on the inflation and deflation of millions of tiny air sacs in the lungs called alveoli. These alveoli have a moist lining, primarily water, which is essential for gas exchange. However, water molecules strongly attract each other, creating a force called surface tension at the air-water interface. This surface tension acts like stretched skin, resisting expansion and promoting collapse, especially in the small alveoli.

The Law of Laplace ($P \propto T/r$) tells us that the pressure (P) needed to keep a sphere open against surface tension (T) is higher for smaller radii (r). This means smaller alveoli face a greater collapsing force.

To overcome this, specialized lung cells (Type II pneumocytes) produce pulmonary surfactant, a mix of lipids and proteins. This surfactant dramatically lowers surface tension at the alveolar air-liquid interface. This prevents alveolar collapse (especially at end-exhalation), reduces the effort needed to breathe, and helps stabilize alveoli of different sizes.

Household dish soap contains synthetic surfactant molecules. Like pulmonary surfactants, these molecules have water-loving (hydrophilic) and water-hating (hydrophobic) parts. At the water’s surface, they disrupt the water's cohesive forces, lowering surface tension. This experiment uses dish soap as a simple *analogy* to demonstrate this fundamental principle.

Materials

- Shallow, light-colored plate or bowl
- Tap water
- Liquid dish soap
- Finely ground black pepper
- Toothpick or cotton swab (Q-tip)
- Paper towels

Procedure: the Pepper Scatter Experiment

1. **Setup:** Pour water onto the plate (approx. 1 cm deep).
2. **Add Indicator:** Gently sprinkle pepper evenly across the water's surface. Observe that it floats.
3. **Control:** Dip a clean, dry toothpick/Q-tip (or finger) into the center. Observe the effect (should be minimal).
4. **Apply Surfactant:** Put a tiny drop of dish soap on the tip of a different clean toothpick/Q-tip (or finger).
5. **Observe Effect:** Gently touch the soap-coated tip to the center of the water's surface. Immediately observe the pepper's reaction.
6. **Cleanup/Repeat:** Discard the soapy water, rinse the plate thoroughly, dry, and repeat with fresh water/pepper if desired. Residual soap will interfere.

Observations & Data

Record your observations in a table like the one below.

Observation and Data Table Example

Step	Condition	Observation (Pepper Behavior)	Inferred Surface Tension	Lung Analogy Connection
2	Pure Water			
3	Pure Water			
5	Water + Soap			

Interpretation & Discussion Questions

1. Why did the pepper float on the undisturbed water's surface?

2. Explain why the pepper scattered rapidly when the soap was introduced. What caused the movement?

3. How does the initial state (pepper on water) relate to the condition inside lung alveoli without sufficient surfactant (e.g., in Neonatal Respiratory Distress Syndrome)?

4. How does the effect of adding soap relate to the function of pulmonary surfactant in healthy lungs? What are the key benefits surfactant provides?

5. This experiment is an analogy. What are some key differences between household dish soap and the complex pulmonary surfactant system in terms of composition and function under dynamic breathing conditions?

Respiratory Rate Dynamics

Introduction

Your respiratory system is essential for life, as its responsible for gas exchange – bringing oxygen (O2) into your body and removing carbon dioxide (CO2). This process is tightly linked to your body's metabolic activity. When your cells work harder, like during exercise, they need more O2 and produce more CO2. Your respiratory system responds by adjusting how fast and how deeply you breathe to meet these changing demands and maintain stable levels of gases in your blood (homeostasis). Today, you will investigate how your respiratory rate changes between rest, exercise, and recovery, using simple observation and measurement techniques.

Learning Objectives

Upon completion of this lab, you should be able to do the following:

- Conceptually trace the pathway of air through the respiratory system.
- Observe and accurately measure your resting respiratory rate.
- Describe the visual difference between quiet breathing and the increased breathing effort after exercise.
- Measure your respiratory rate immediately following a period of light exercise.
- Observe and measure your respiratory rate during a recovery period post-exercise.
- Explain *why* respiratory rate increases during exercise and decreases during recovery based on metabolic needs.
- (Optional) Relate voluntary breath-holding duration to the body's drive to breathe.

Materials

- Timer (Stopwatch, phone timer app, or clock with a second hand)
- Pen or pencil
- This handout and paper for notes/calculations

Safety First!

Exercise

- Only participate in the exercise portion if you feel well and have no medical conditions that prevent light activity (check with your instructor if unsure).
- Make sure you have a clear space to move safely. Wear appropriate footwear.
- **Stop exercising immediately** if you feel any pain, dizziness, lightheadedness, or become excessively short of breath. Inform your instructor if you experience any of these symptoms.

Breath Holding (if Performed)

- Always perform this activity **while seated**.
- **Stop immediately** if you feel dizzy or uncomfortable. Do not push yourself to extreme limits.

Procedure

1. Background & Breathing Observation (Approx. 10 Min)

1. **Air Pathway:** Take a moment to think about the path air takes when you inhale through your nose or mouth. Where does it travel on its way to your lungs? What happens during this process? How does it get back out when you exhale?
2. **Observing Breathing Types:**
   - Sit quietly and breathe normally (Eupnea). Notice the rhythm and apparent ease of breathing.
   - Now, take a few deeper, faster breaths, as if you just finished running up a flight of stairs (Hyperpnea). Observe the increased movement of your chest and shoulders and the faster pace at which they move. Note the visible difference in effort compared to quiet breathing.

2. Measuring Your Resting Respiratory Rate (RR) (Approx. 10 Min)

1. **Rest:** Sit quietly and relax for 2-3 minutes. Avoid talking or moving around.
2. **Measure:** Count the number of times you breathe in one full minute (one breath = 1 inhale + 1 exhale).
   - *Timing Options:* You can count for the full 60 seconds, or count for 30 seconds and multiply by 2, or count for 15 seconds and multiply by 4. Be consistent!

3. **Repeat:** Perform this measurement 2-3 times, resting for about 30 seconds between counts.
4. **Calculate & Record:** Calculate the average of your measurements. Record this average in the Data Table under "Resting RR".

3. Exercise and Recovery Rates (Approx. 15 Min)

1. **Safety & Preparation:** Read the exercise safety guidelines again. Decide if you will participate. Stand up and ensure you have a clear space.
2. **Exercise:** Perform **2 minute**s of continuous light exercise. Choose ONE of these:
   - Walk briskly in place.
   - Moderately paced jumping jacks.
   - Step up and down on a low (safe) step.
   - Walk briskly around the designated area.

   Aim for an effort level that makes your breathing noticeably faster and deeper but not overwhelming.

3. **Measure Immediate Post-Exercise RR:** As soon as the 2 minutes are up, sit down immediately and start counting your breaths for one minute (or 30 sec x 2/15 sec x 4). Record this value in the Data Table under "Immediate Post-Exercise RR." Note any observations about how your breathing feels or looks. Describe breathing effort visually (e.g., deeper, faster).
4. **Measure Recovery RR:** Remain seated and rest quietly. Wait 3 minutes after you stop exercising. Then, measure your respiratory rate again for one minute (or 30 sec x 2/ 15 sec x 4). Record this in the Data Table under "Recovery RR (3 min post-exercise)." Is it closer to your Resting or Post-Exercise RR?
5. **You don’t need to do this part 3 times**

4. Optional - Baseline Breath Holding (Approx. 10 Min)

(Perform this ONLY if instructed and remember the safety rules: Stay seated!)

1. **Rest:** Sit quietly for a minute or two (ensure you are fully recovered from exercise, if done).
2. **Hold Breath:** Breathe normally for a few cycles. After exhaling normally and quietly, gently pinch your nose closed and hold your breath. Time how long you can hold it comfortably. Do not strain.
3. **Record:** Record the time in seconds in the Data Table under "Baseline Breath-Hold."
4. **Reflect:** Pay attention to the feeling or urge that makes you need to breathe again.

5. Data Collection

Record all your measurements and observations in the table below.

Data Table

Respiratory Data Table Example-1

Parameter	Trial 1	Trial 2	Trial 3	Average/ Value	Observations/Notes
Resting RR (breaths/ min)					
Immediate Post-Exercise RR		X	X	(Use 1st count)	
Recovery RR (3 min post-exercise)		X	X	(Use 1st count)	
Baseline Breath-Hold (sec) (Optional)					

Discussion Questions

Answer the following questions based on your data and your understanding of the respiratory system.

1. Compare your Resting RR to your Immediate Post-Exercise RR. Describe the difference you measured.

2. Explain the physiological reasons why your respiratory rate increased during exercise. Connect this to the concepts of cellular respiration, oxygen demand, and carbon dioxide production.

3. Compare your Immediate Post-Exercise RR to your Recovery RR (at 3 minutes post-exercise). Did your breathing rate completely return to your resting level? Explain why it changed during recovery.

4. (If breath-holding was performed) What physiological factor is the primary stimulus for breathing? How does breath-holding demonstrate this control mechanism? How might this relate to why you breathe faster during exercise?

5. Overall, how do these changes in your respiratory rate help your body maintain homeostasis (a stable internal environment) during different levels of activity?

Appendix A: Notes for the Instructor

Axial Code Lab (Instructor Notes)

This lab can be a bit confusing, but once the students understand the assignment, they enjoy it. Instructors can modify or add to the dictionary to enhance the lab. The instructor needs to make sure that each group submits the message to the instructor. Then, when the groups begin to decode, the instructor needs to make sure that each group submits the decoded message to the instructor. The instructor can create a printout for this function, but students can just write their messages on pieces of paper. The instructor can then compare the 2 messages for grading.

The instructor must assign and record group identifiers to track which group is decoding whose messages. The group identifiers (and member names) should be on the papers the students hand in, as well as information about which group they decoded.

Return to Axial Code Lab

Dance Move Lab (Instructor Notes)

A printed anatomical terminology reference is suggested. Students can request AI bots to describe dances using anatomical terminology very easily.

Return to Dance Move Lab

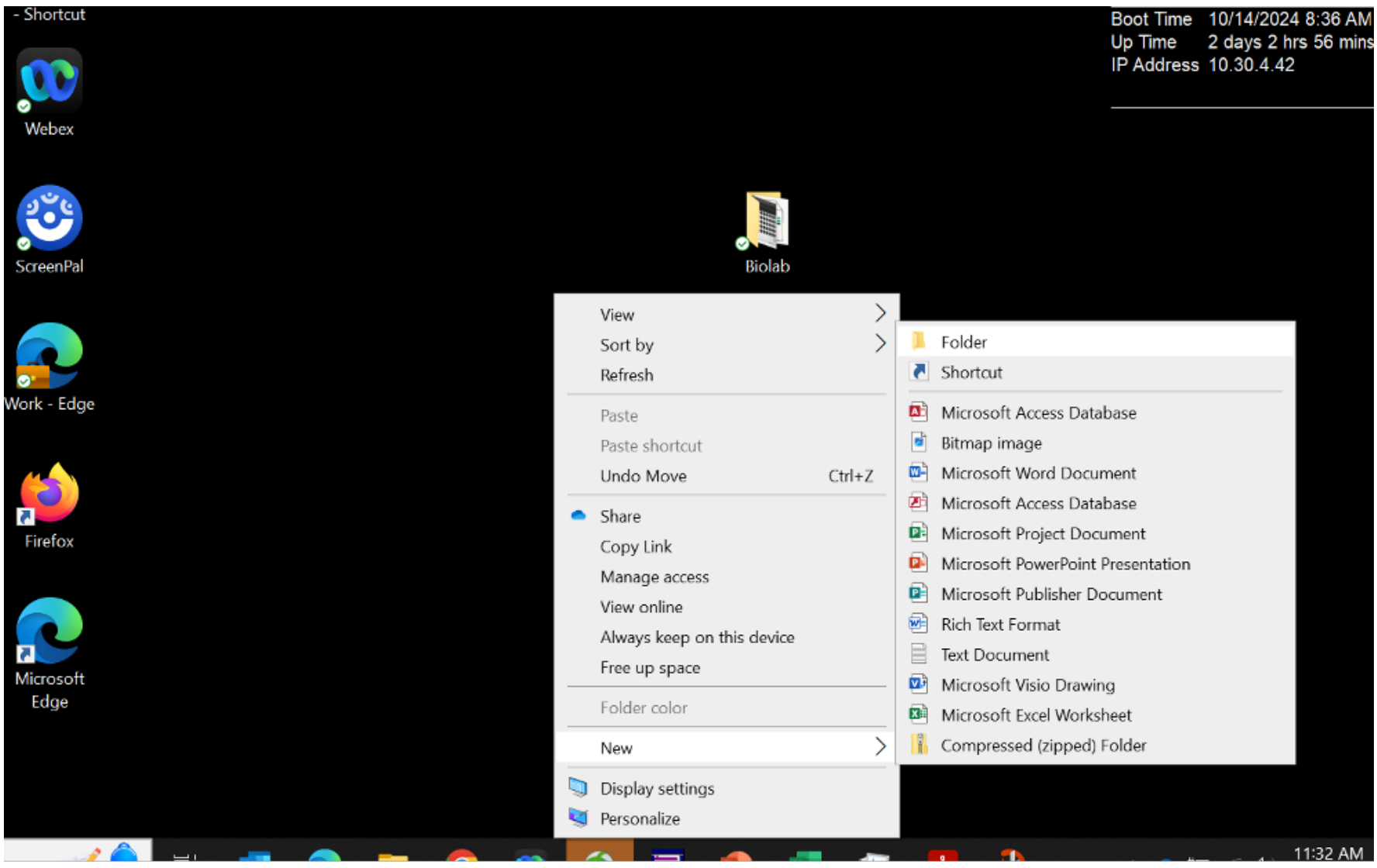
Appendix B: How To Install Neuronify

Install Options

- The following pages in this appendix are for installing Neuronify on Windows without admin privileges using a zip file that can be hosted by the instructor
- You may be able to install using other methods, or just use the web app, as can be found here: Ovilab Neuronify Network App Webpage.
- The source code is here: CINPLA/neuronify GitHub Webpage.

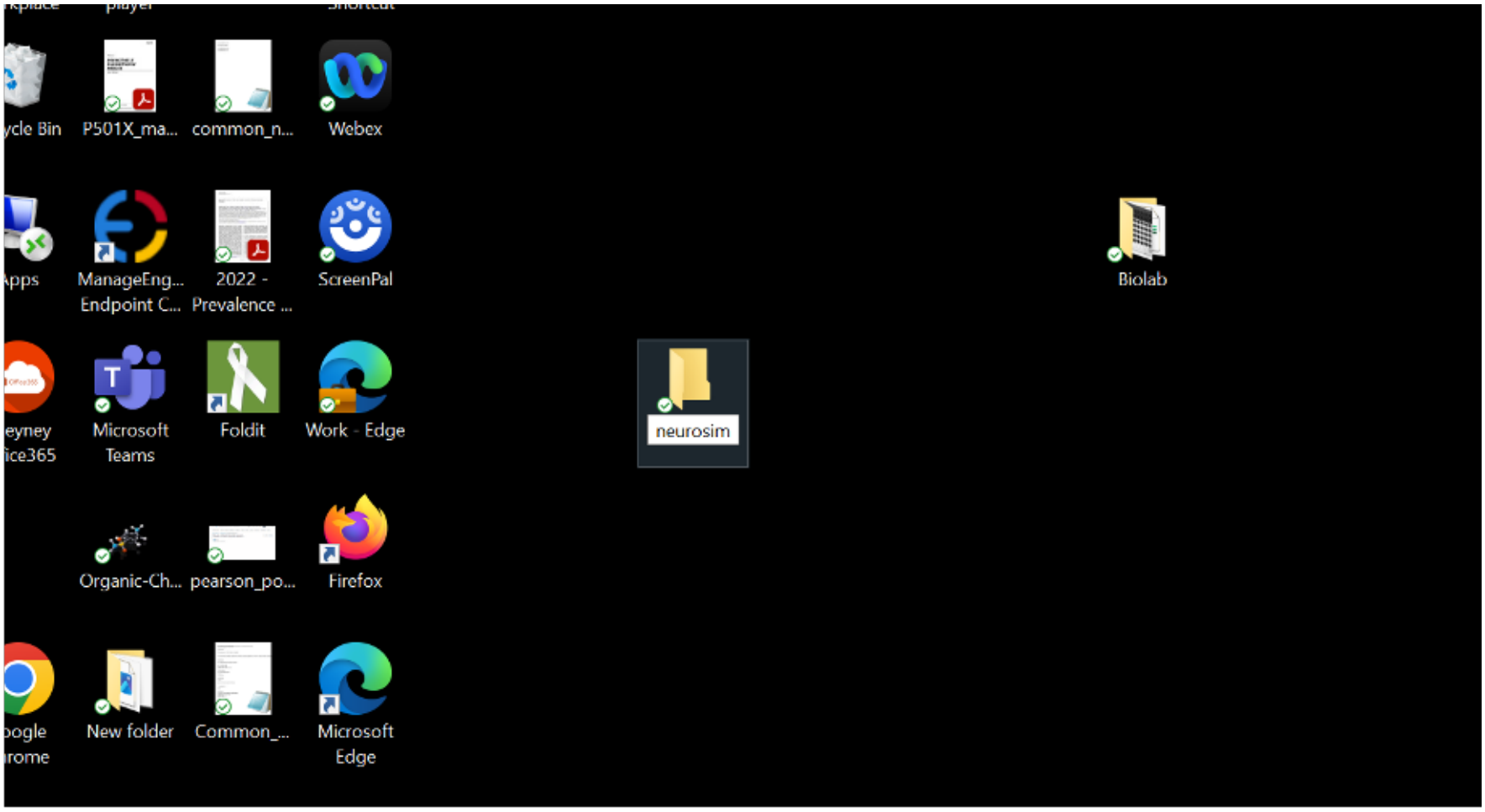
Install Directions

1. First, we need to create a new folder. Right click on empty space on your desktop, go to New, then go to Folder, and click on it.



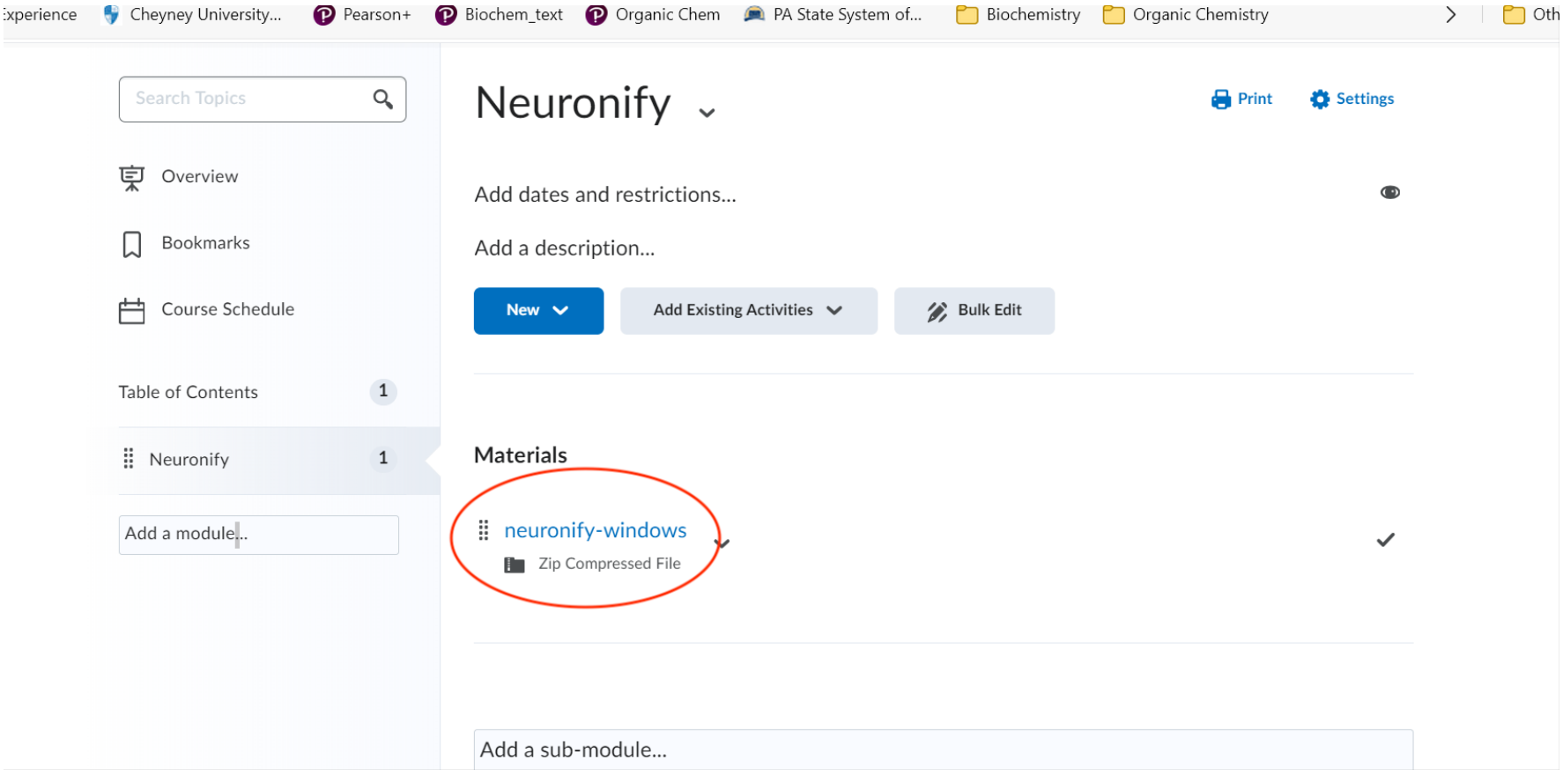
Step 1: Creating a new folder

2. After you click, a new folder will be created. Enter a name for the folder… like “neurosim”.



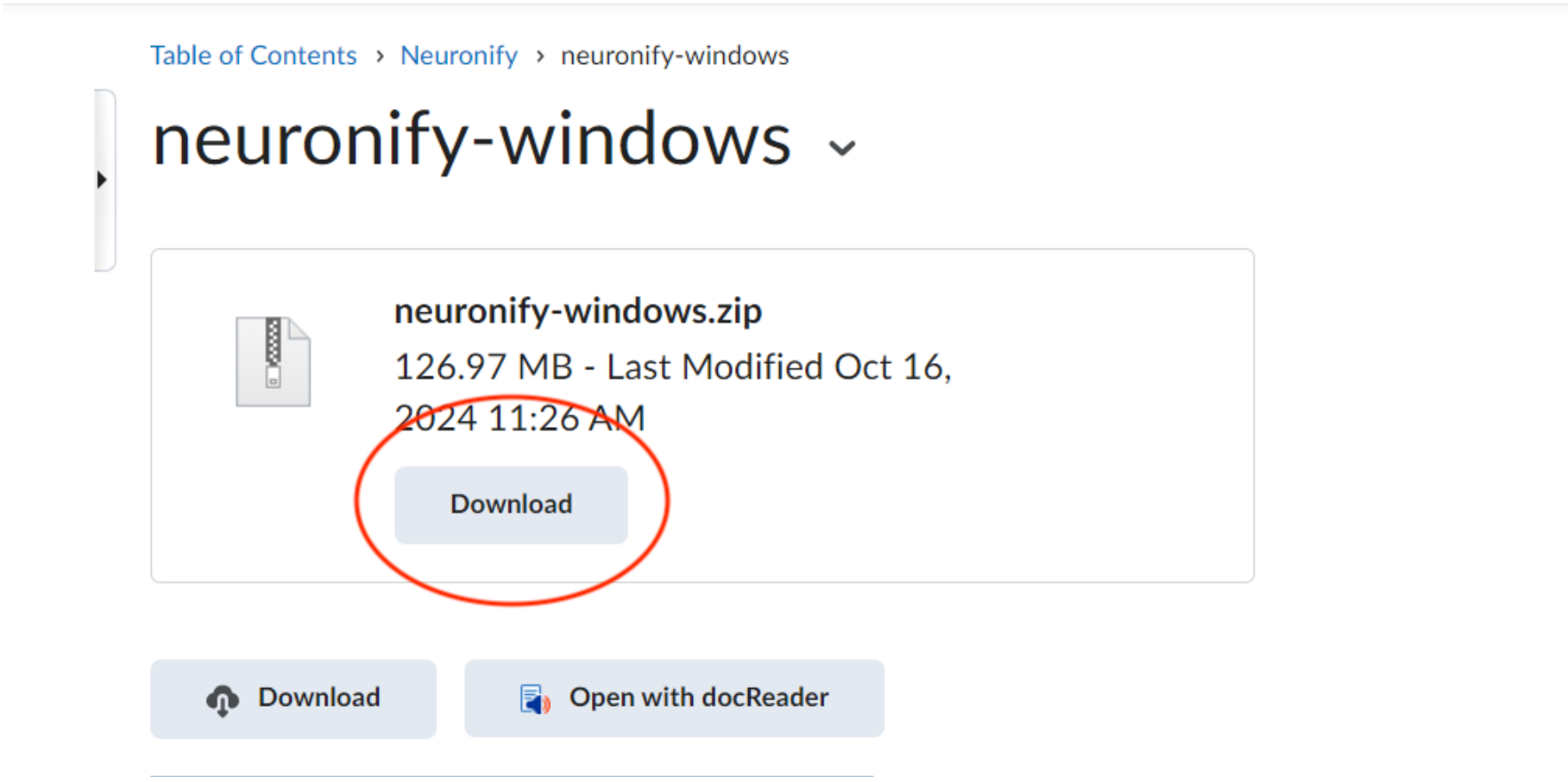
Step 2: Naming the new folder

3. Go to D2L, go to the Neuronify module and click on the circled link “neuronify-windows” above



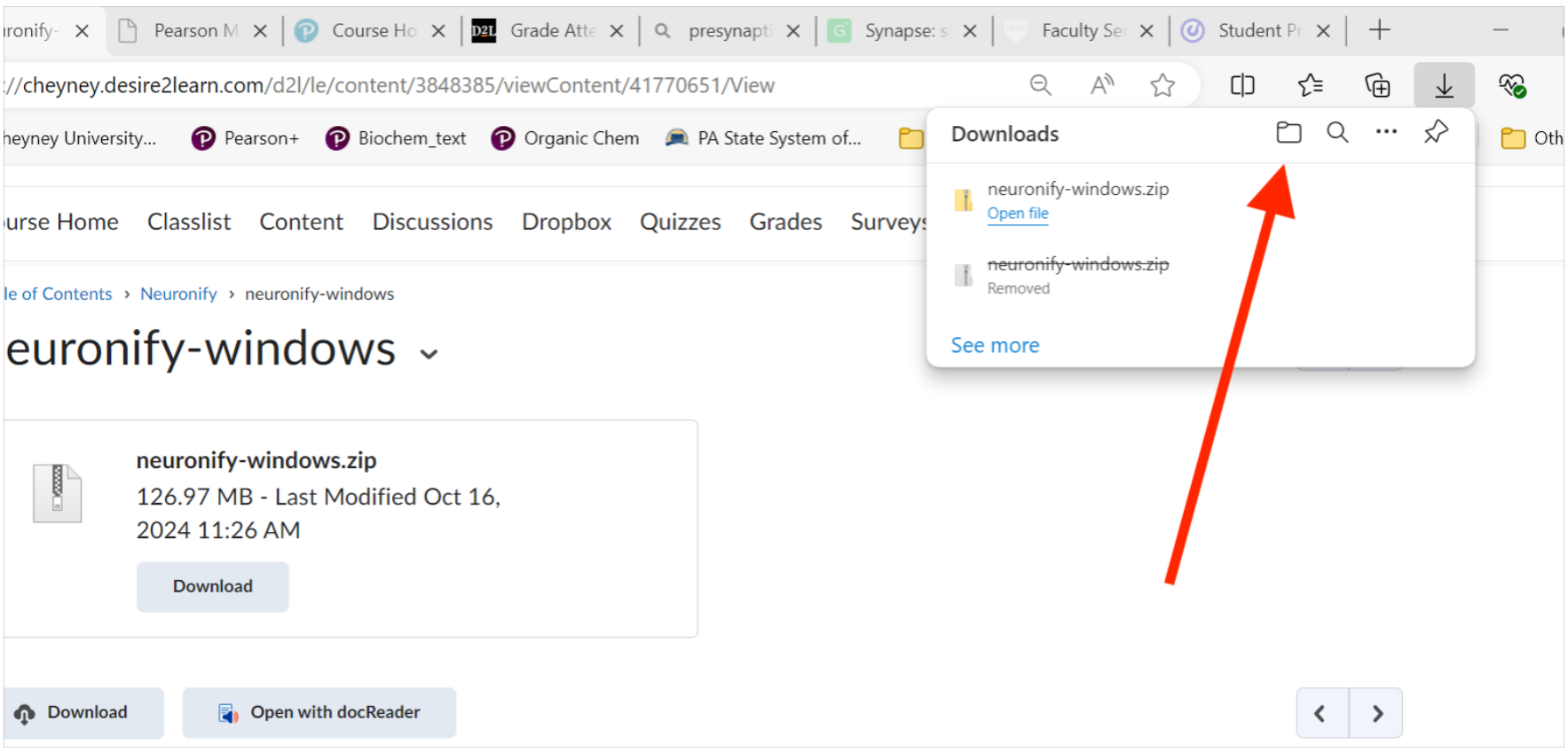
Step 3: D2L Neuronify Module

4. Click “Download” on the zip file (the file is also available via GitHub, refer to the “Note to the Reader” section for more information).



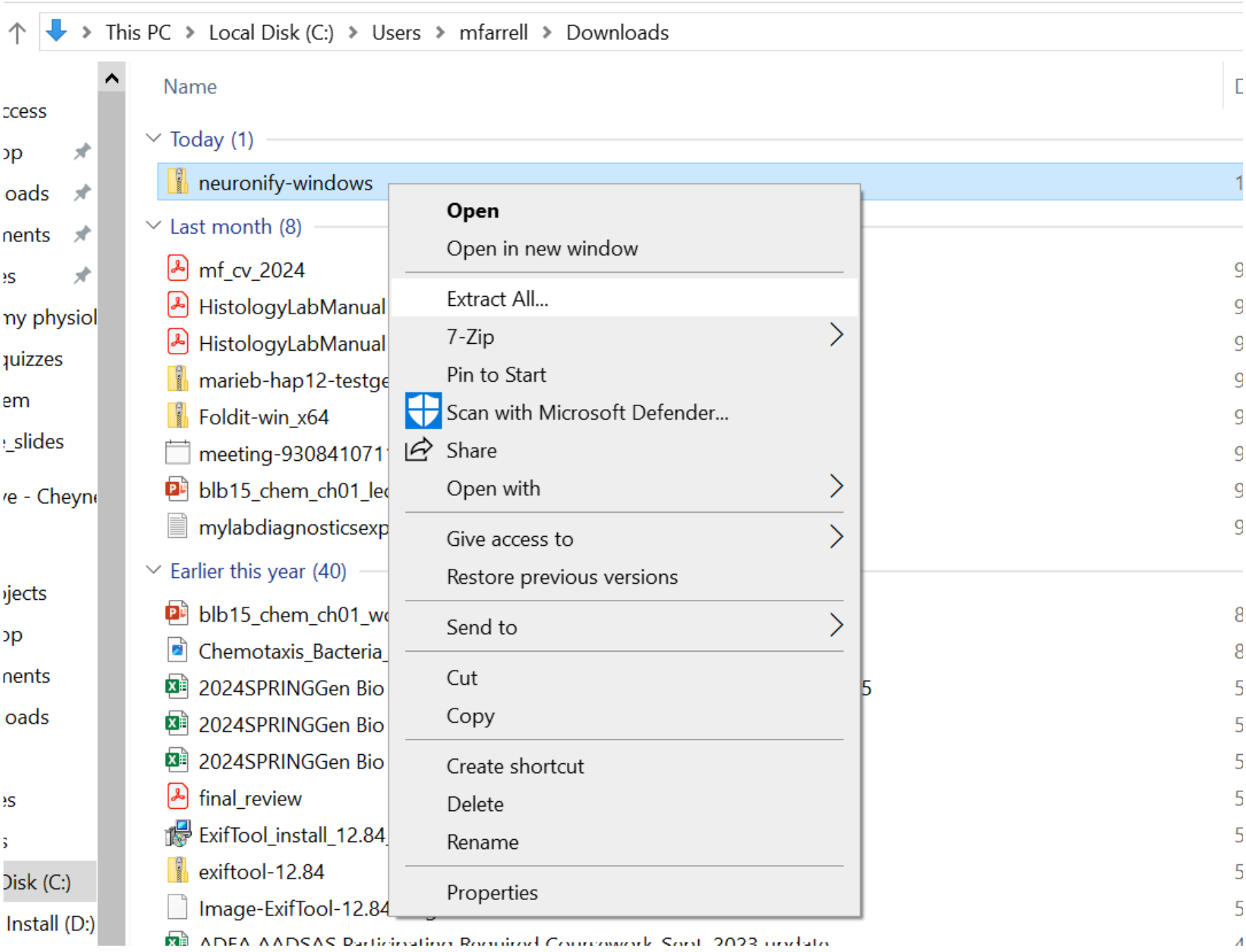
Step 4: Downloading “neuronify-windows”

5. Click on the little folder icon; this will open the location of the file.



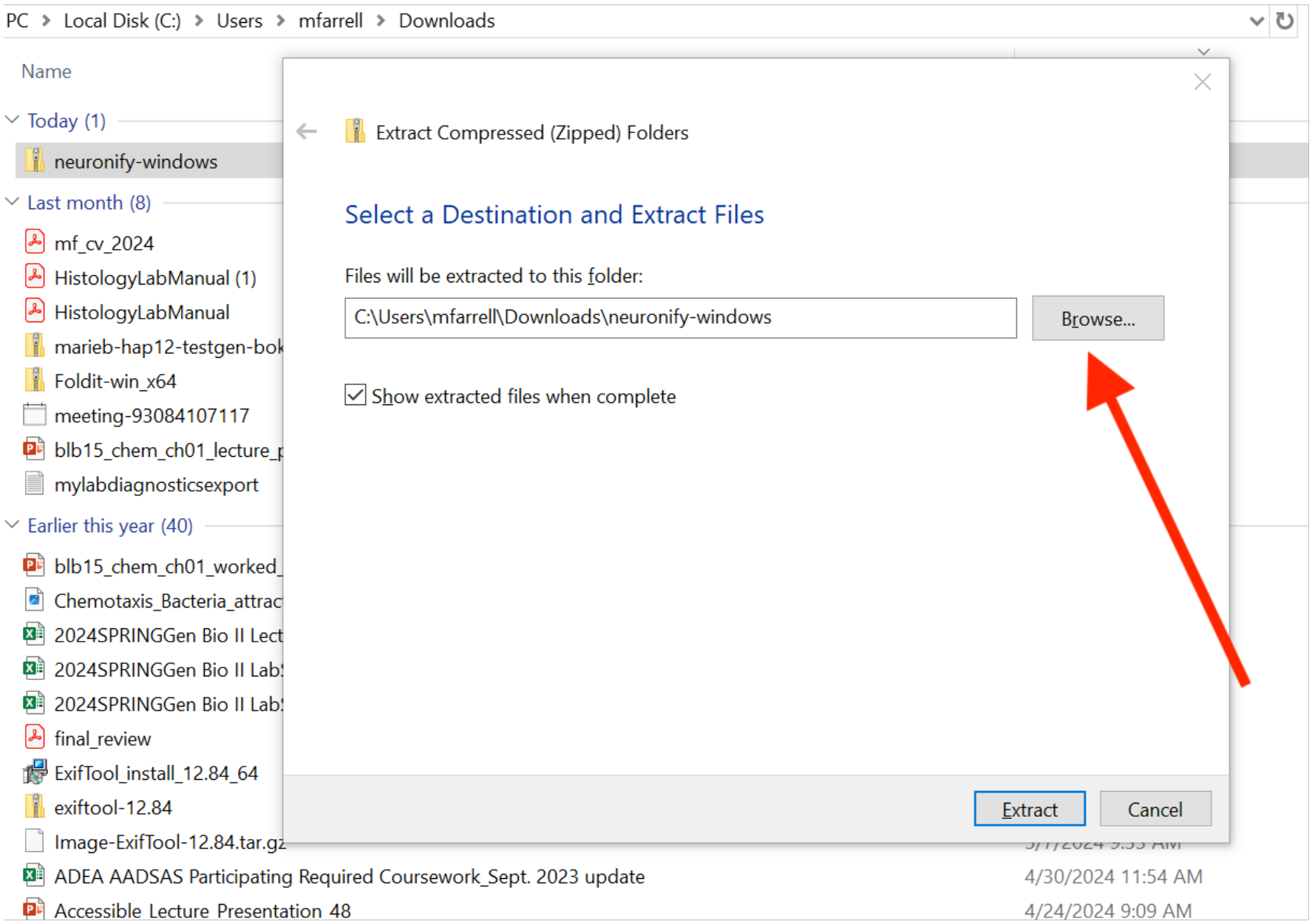
Step 5: Opening to the file location

6. Right click on the file and then select “Extract All…”



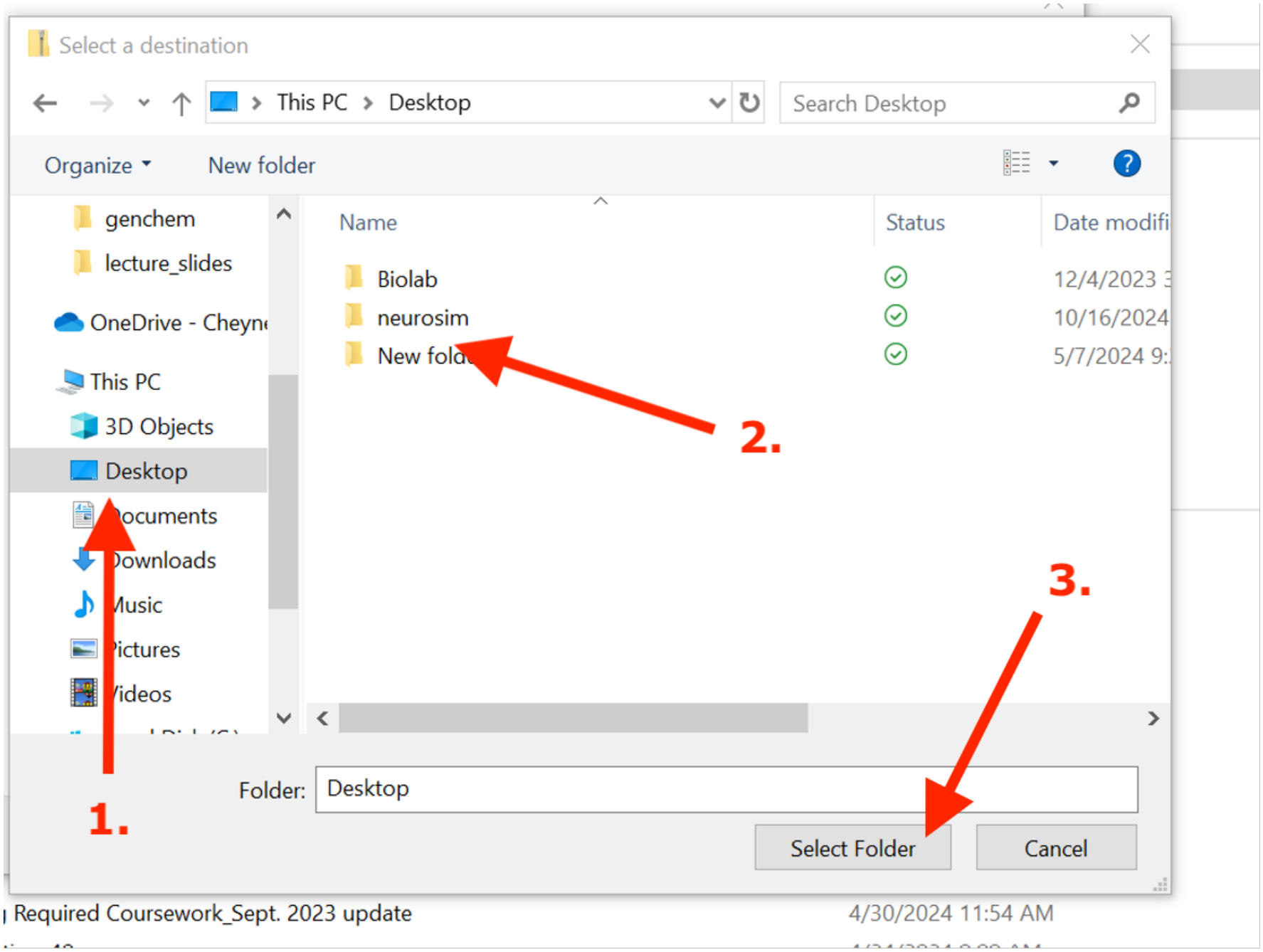
Step 6: “Extract All…” from the Zip file

7. Hit “Browse” to select the destination for the extraction.



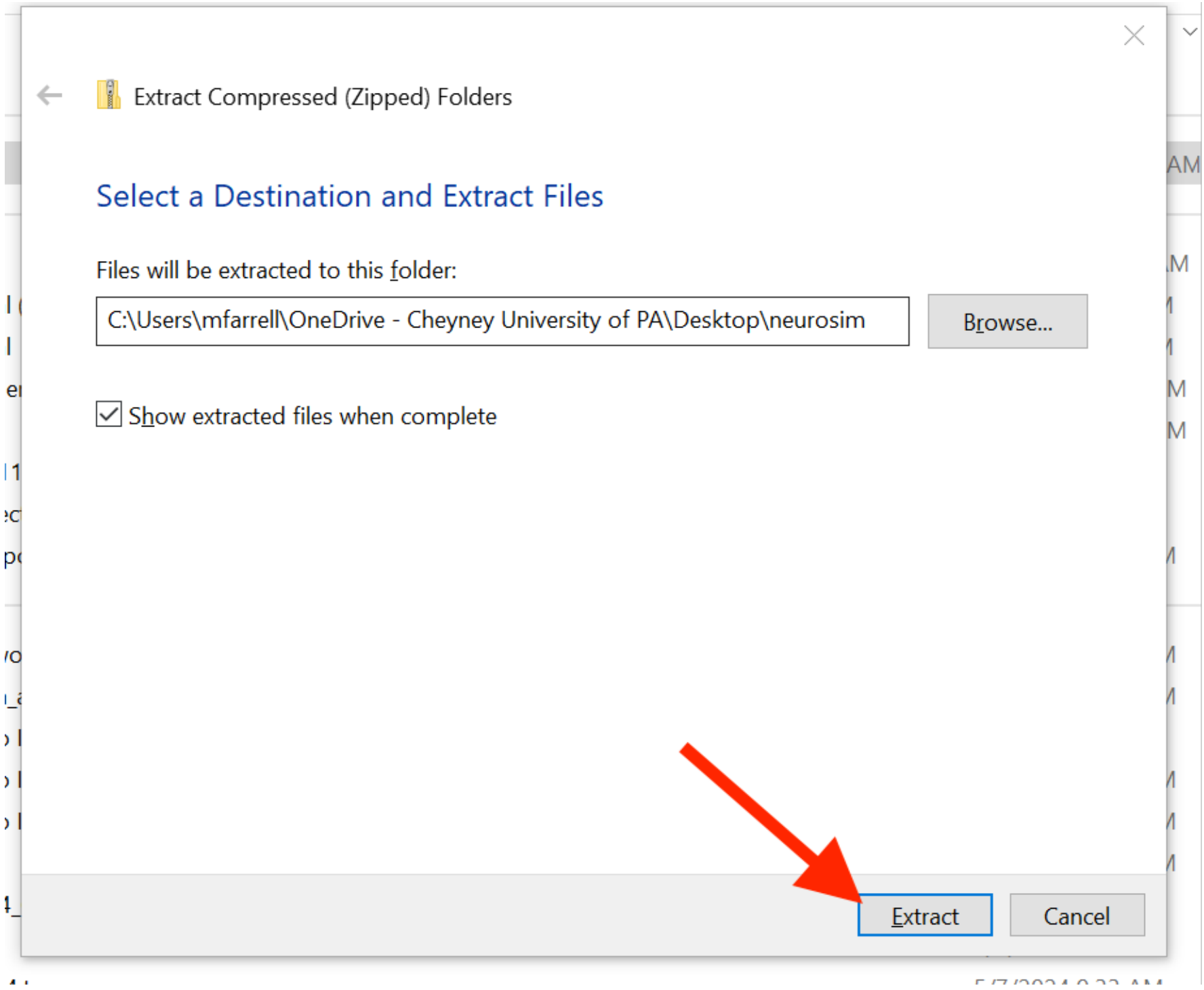
Step 7” Selecting the file destination

8. On the left, select desktop (1), then select the neurosim folder (2) on the right, then hit select folder at the bottom (3).



Step 8: Choosing the “neurosim” folder

9. Click on extract

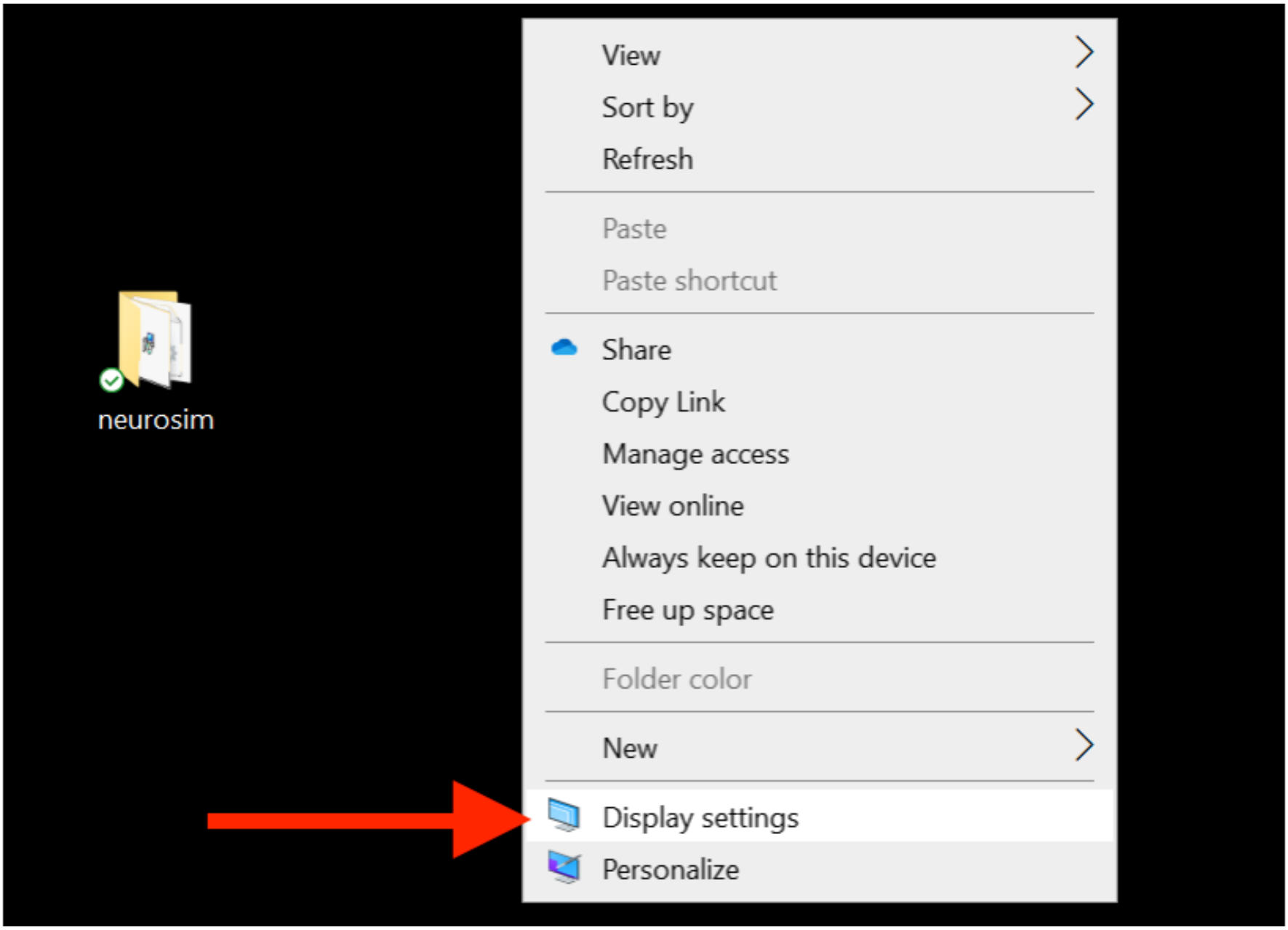


Step 9: Extract

Magnification

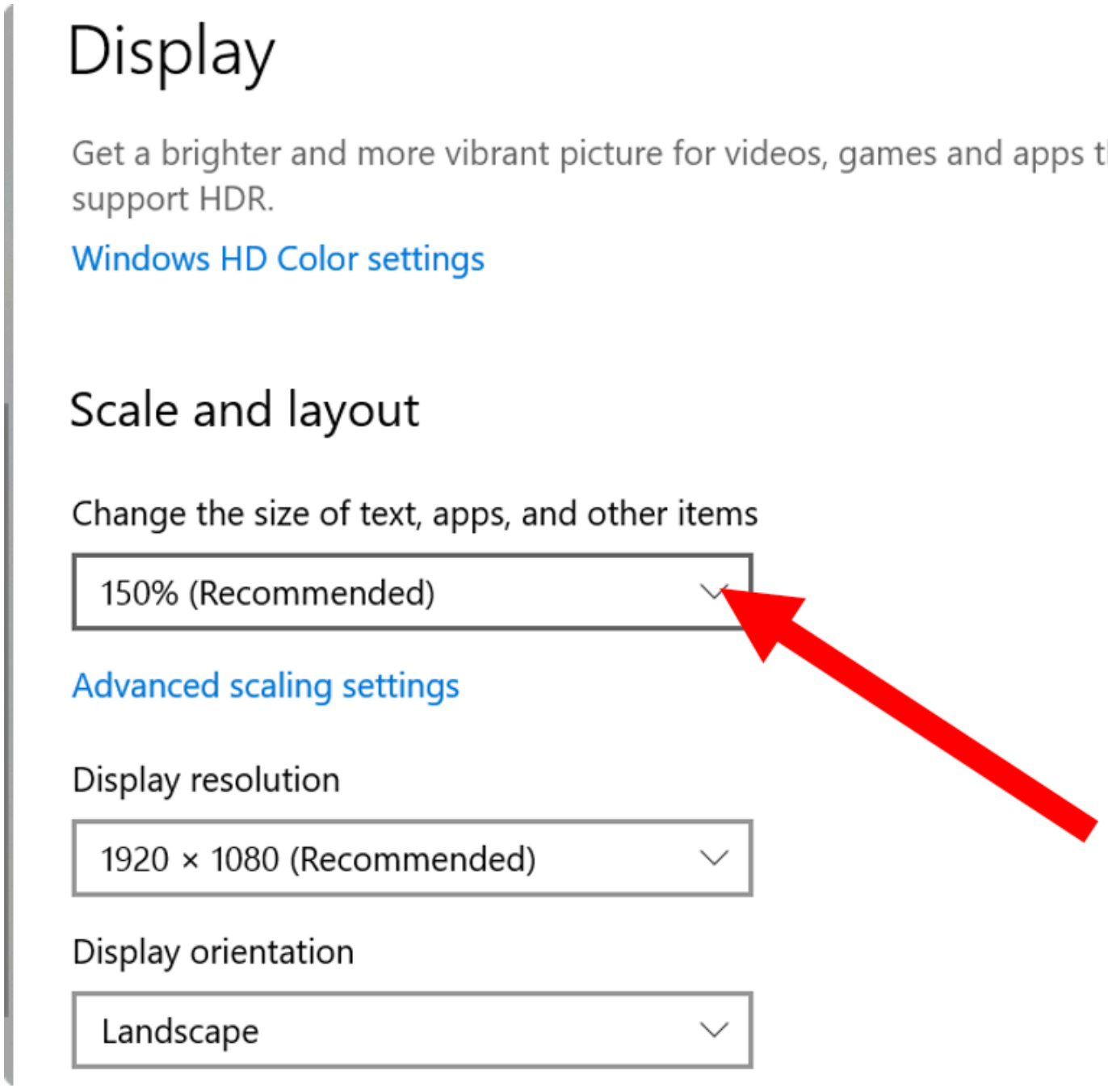
- The Neuronify software was made in 2017 and for various reasons has difficulty working with modern screen resolutions.
- In order to work easily in Neuronify, you can modify your computer's text magnification using the following steps detailed in the next 2 images and accompanying text.

Magnification Step 1: Right click on empty desktop space and select "Display Settings".



Magnification Step 1: Opening Display settings

Magnification Step 2: Scroll Down to “Scale and Layout”

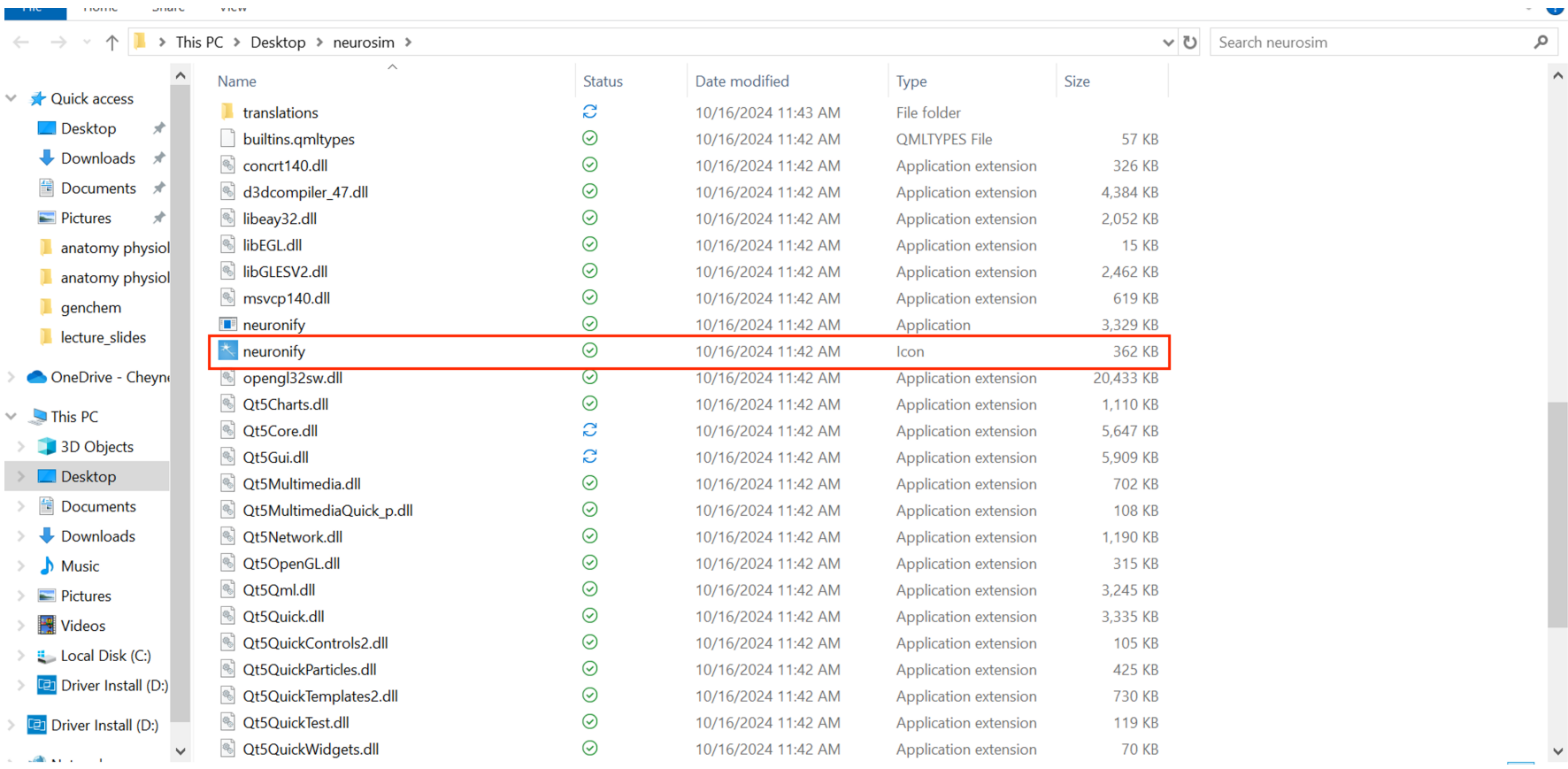


Magnification Step 2: Selecting the size of text, apps, and other items dropdown

Magnification Step 3: In the dropdown, select 100%. Note: All the text on your screen will become really small. You can change this back after you are done working with the software.

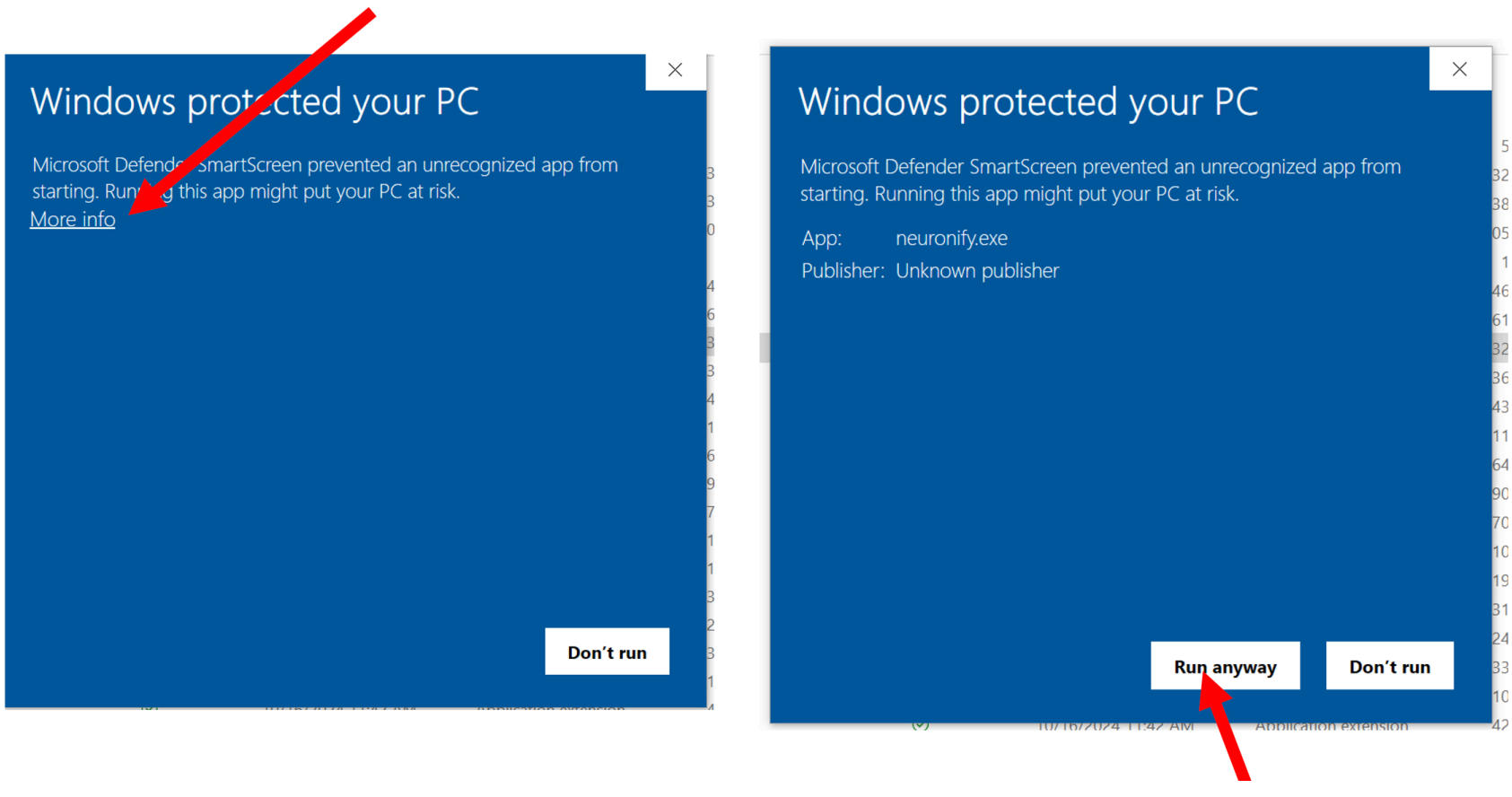
Magnification Step 3: Selecting “100%” in the dropdown

10.Double-click on the application file, Neuronify in the neurosim folder



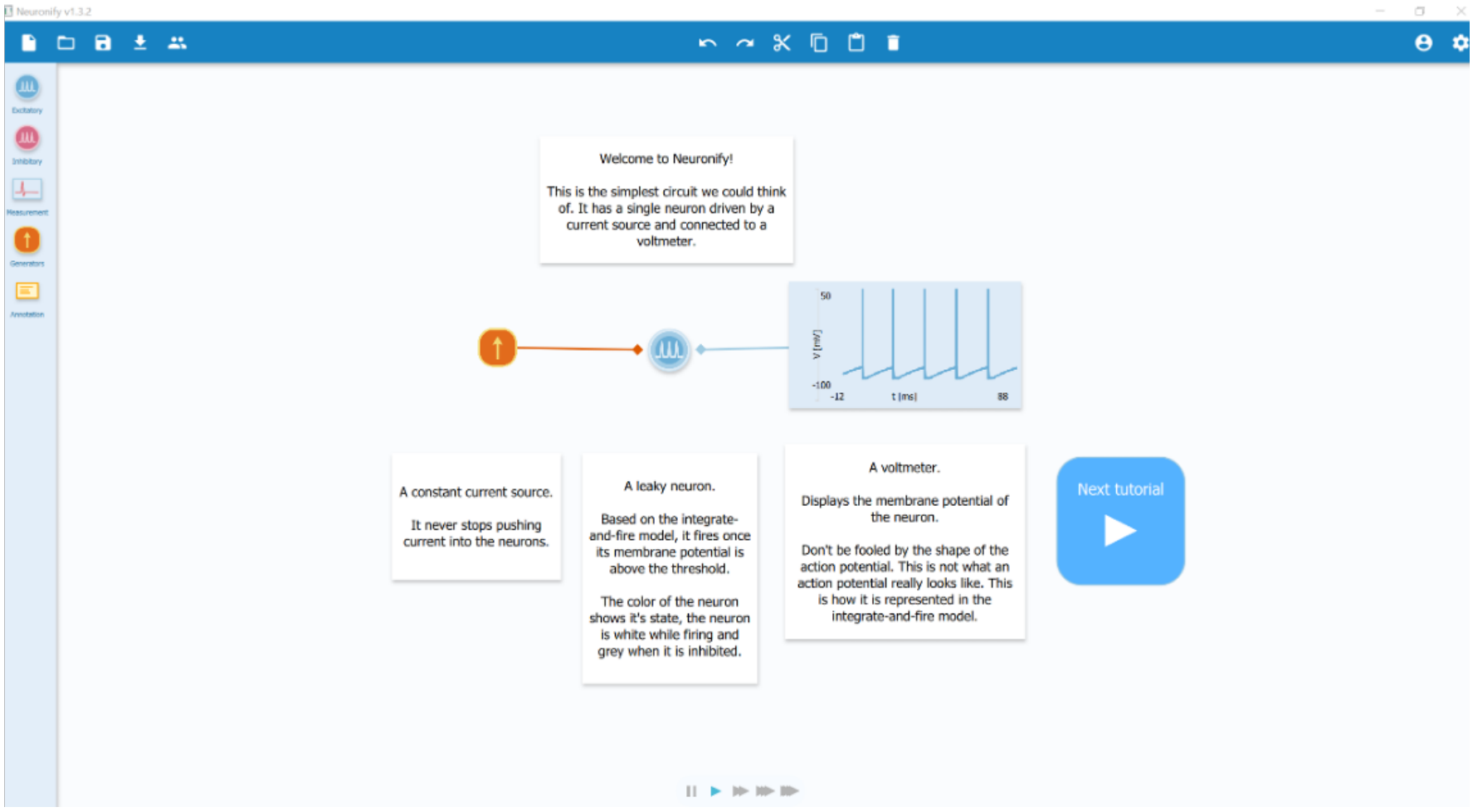
Step 10” Opening the “Neuronify Application file

11. Windows will show a warning because we didn’t get the application from their walled garden. Hit “More info”, then hit “Run anyway”.



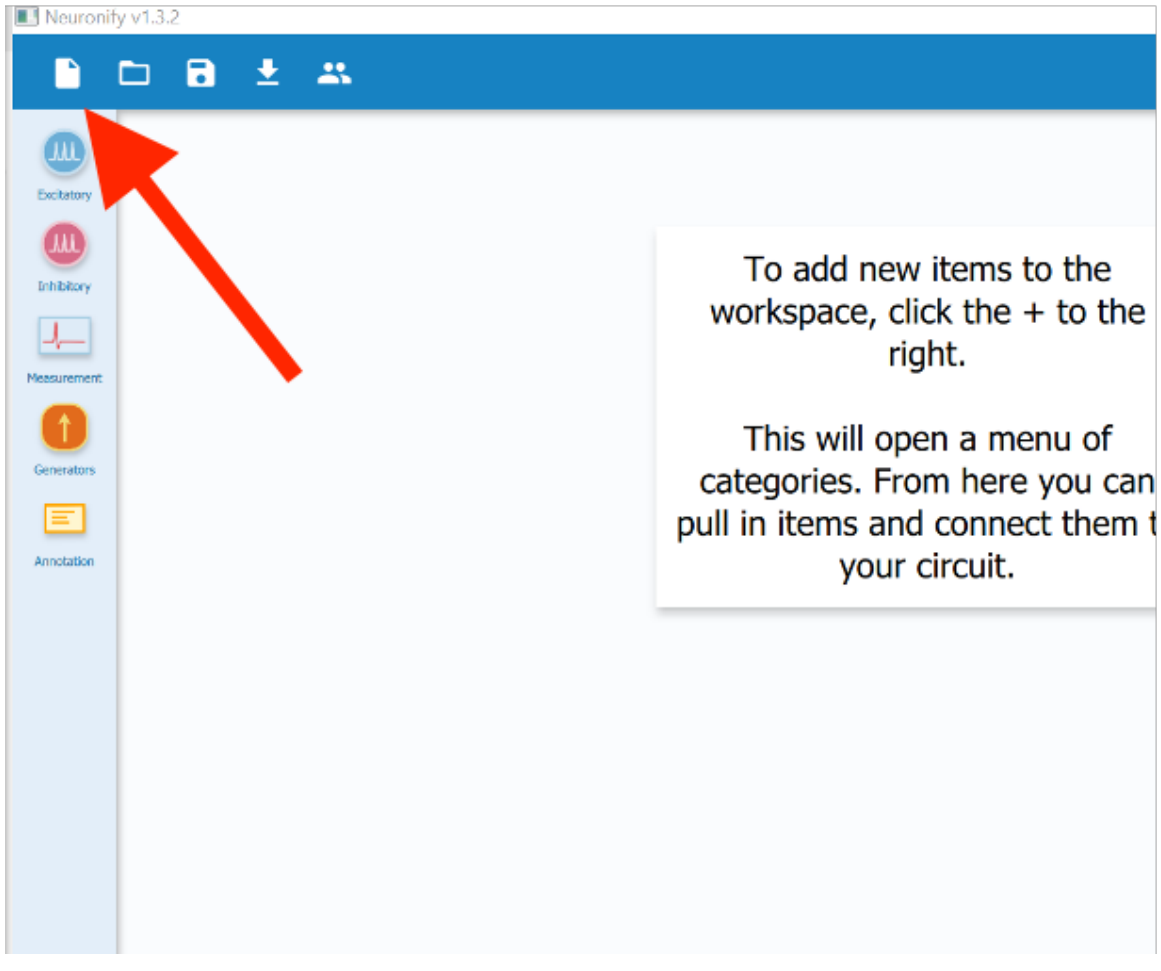
Step 11: “Run anyway”

12. The program loads into a tutorial. Go through the tutorial and learn how the simulation works.



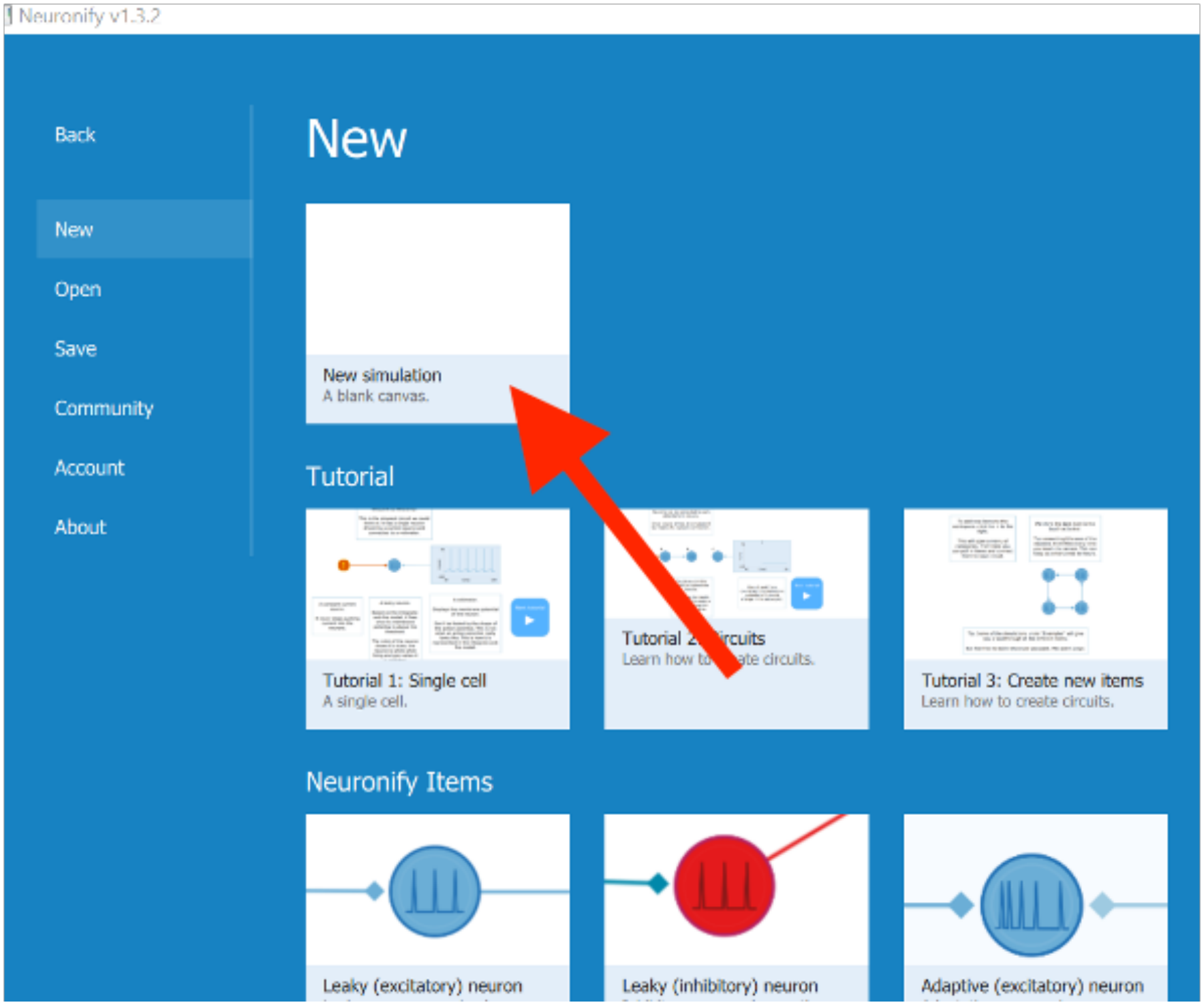
Step 12: Program application tutorial

13. When you are done with the tutorial, hit the “new file” button on the top left.



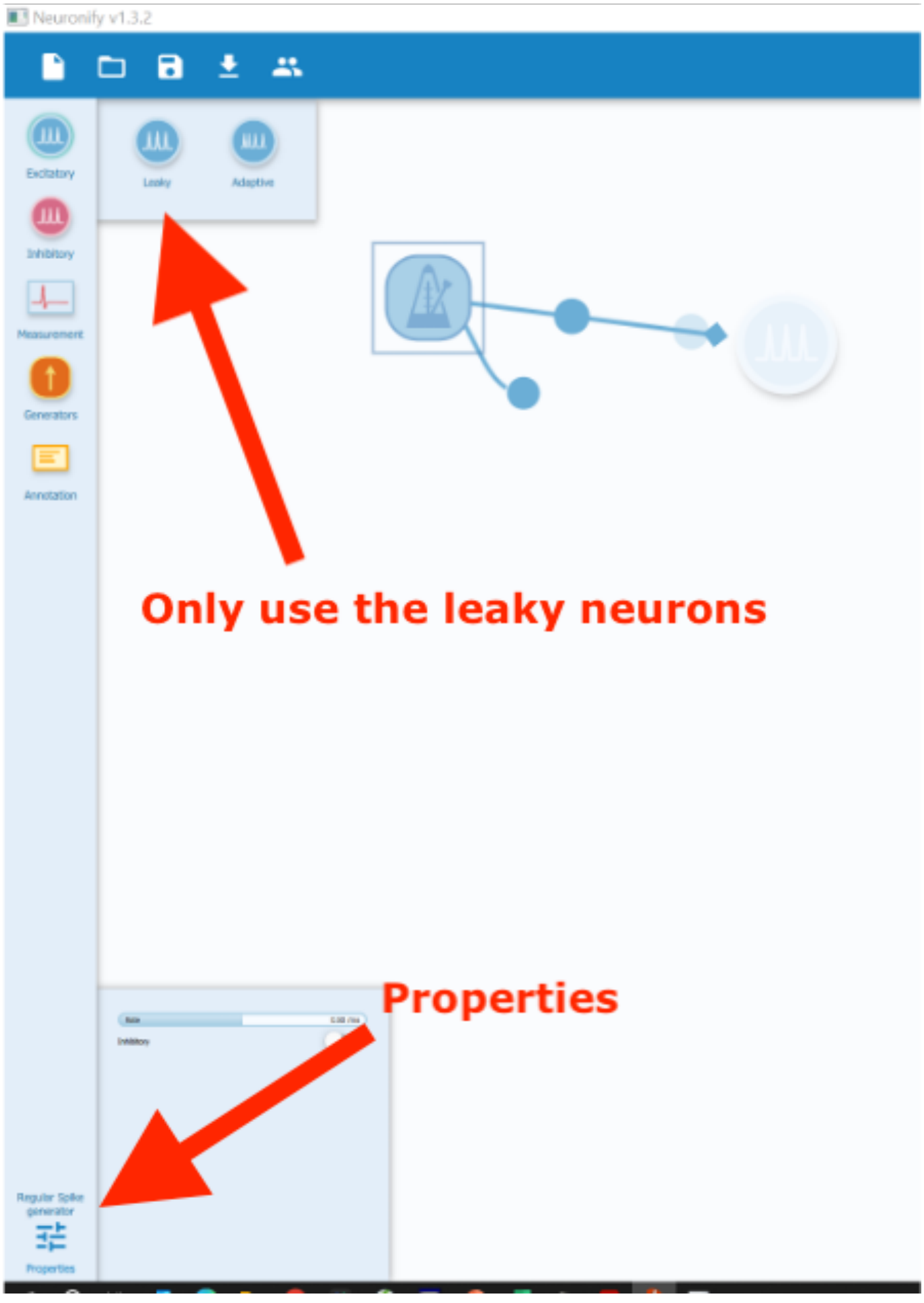
Step 13: Creating a new file

14.Select “New Simulation”. Don’t save changes.



Step 14: New simulation

15. Start building a neuronal circuit! Remember that to place something, you drag it into the space. Once it is in the space, you can click on it to get a connector. Also, keep in mind that once you click on it, there is a properties button on the bottom left. Note: Don’t fiddle with the properties too much. We want to build our circuits with the default behavior of these neurons.

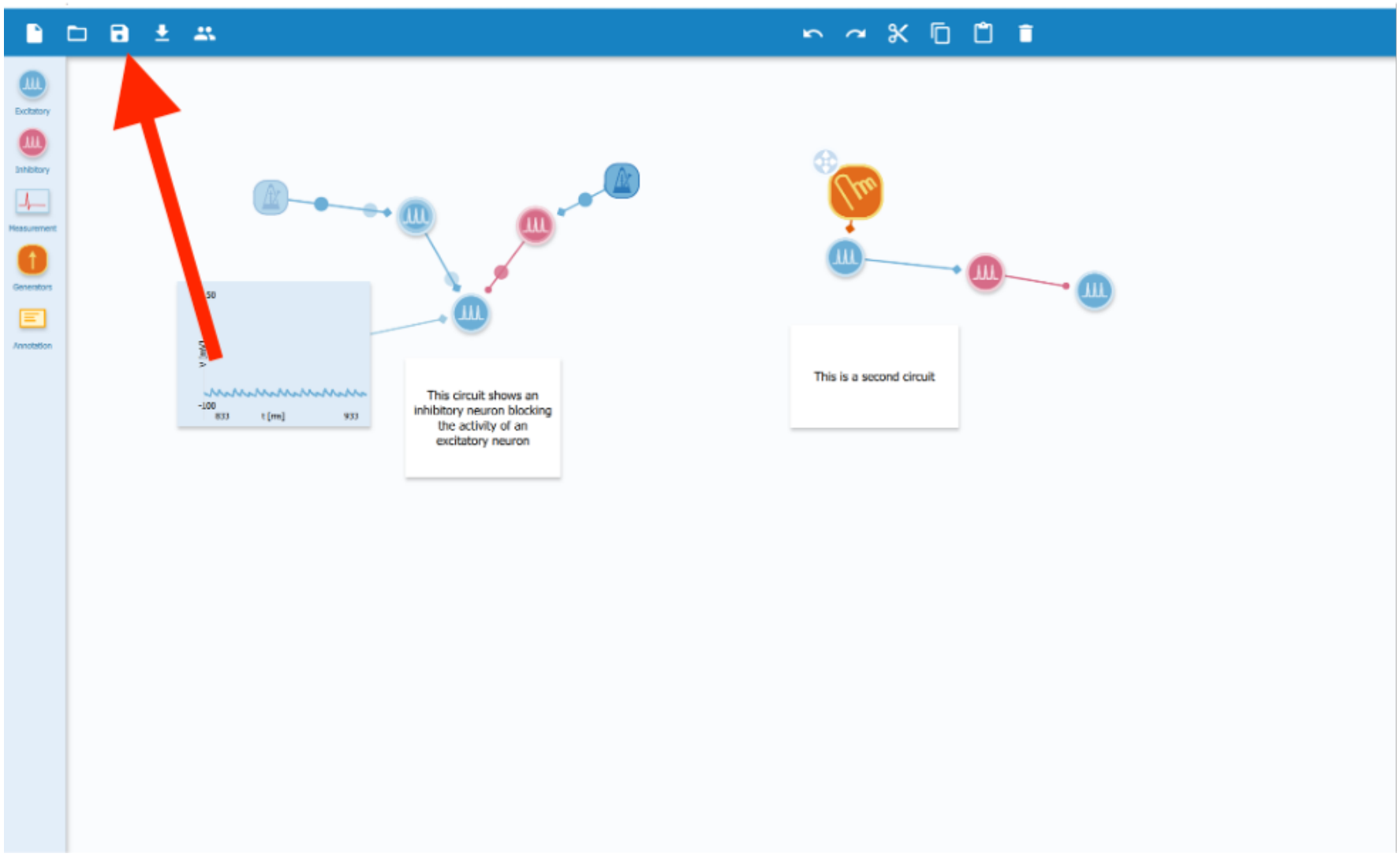


Step 15: Building your circuit

Saving a File

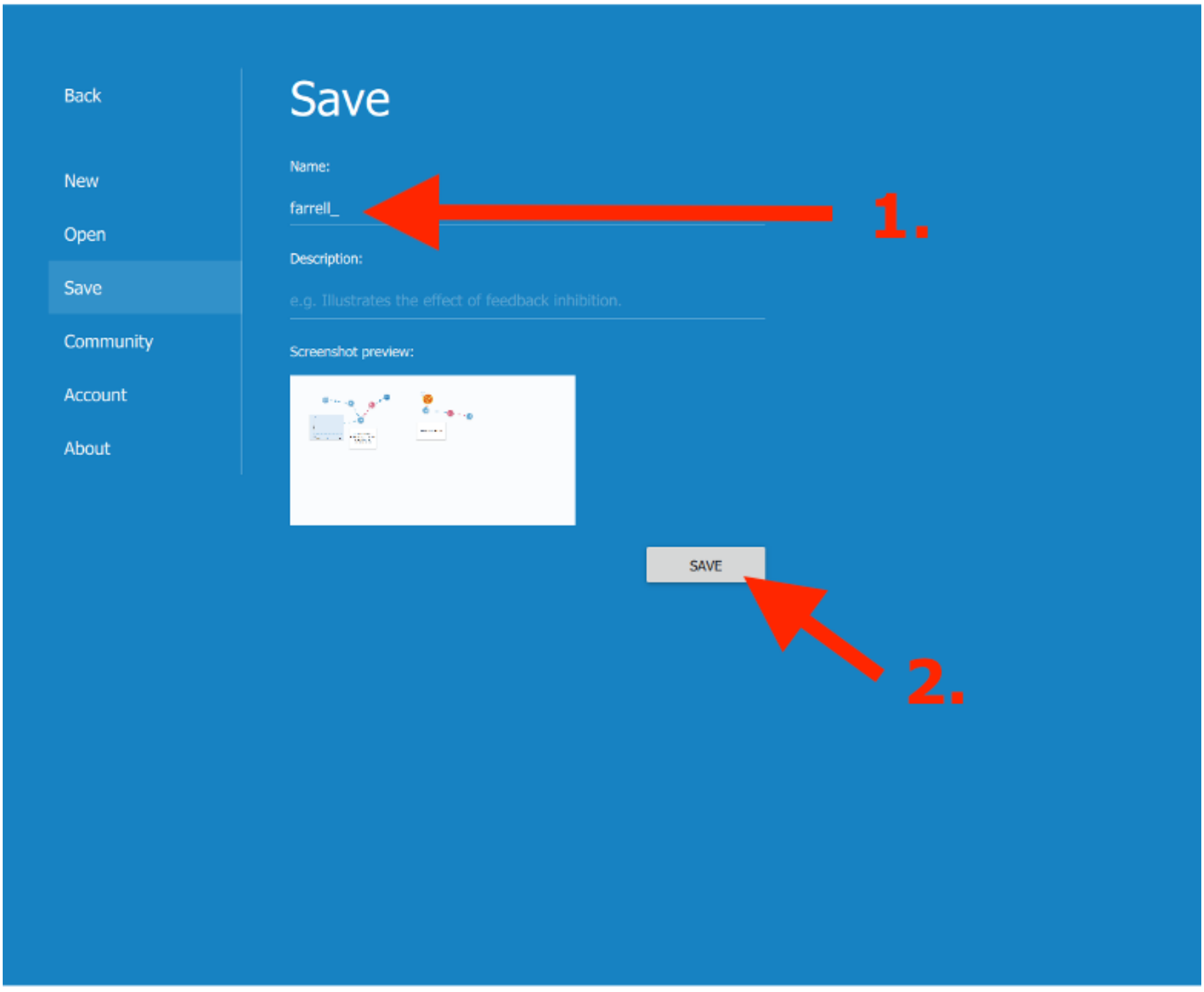
The steps demonstrate how to save a file with your circuits on them.

Saving Step 1: When you have built all of your circuits, hit the “Save As” icon.



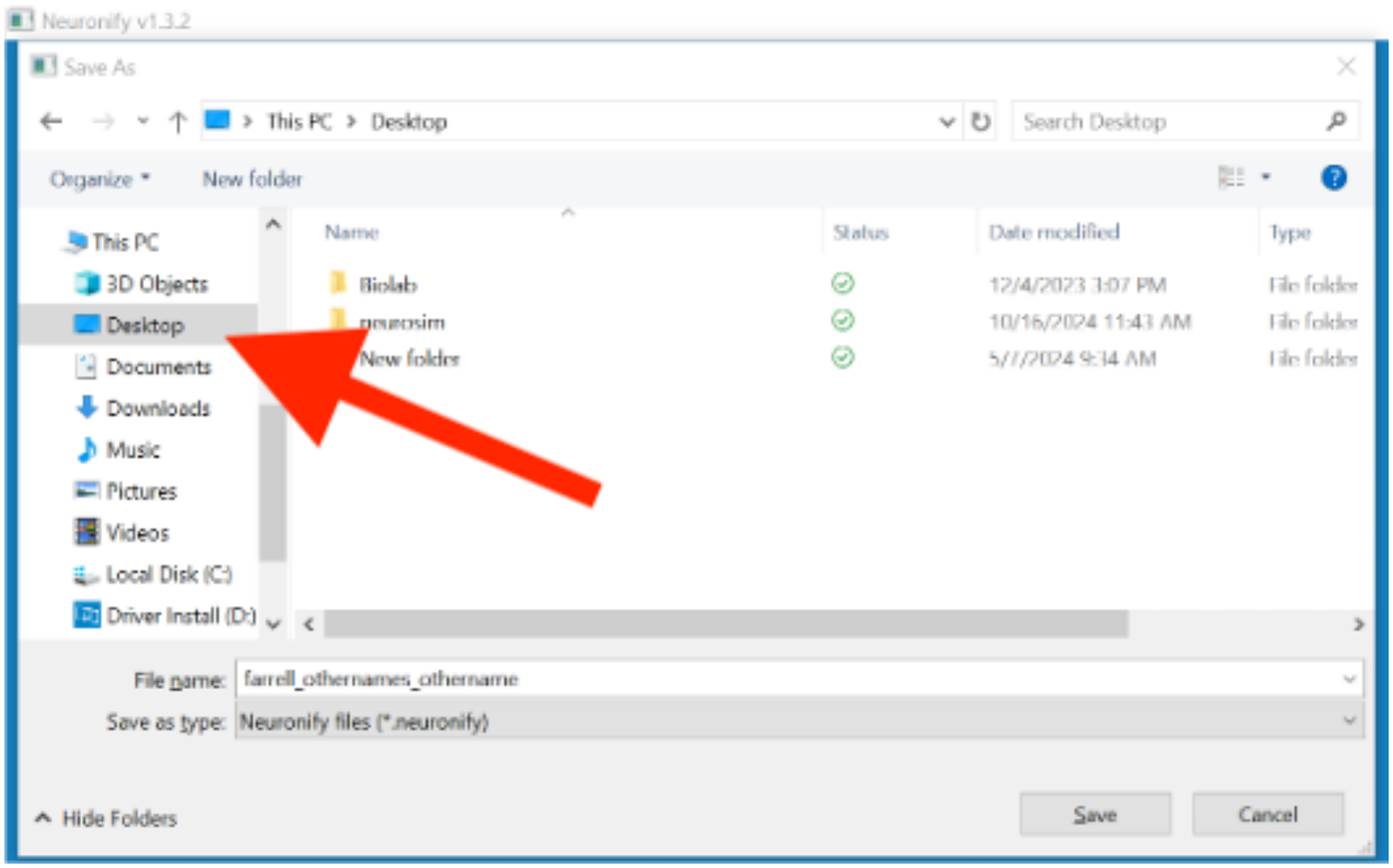
Saving Step 1: Selecting the “Save As” icon

Saving Step 2: Enter the last names of all members of your group and then hit "Save".



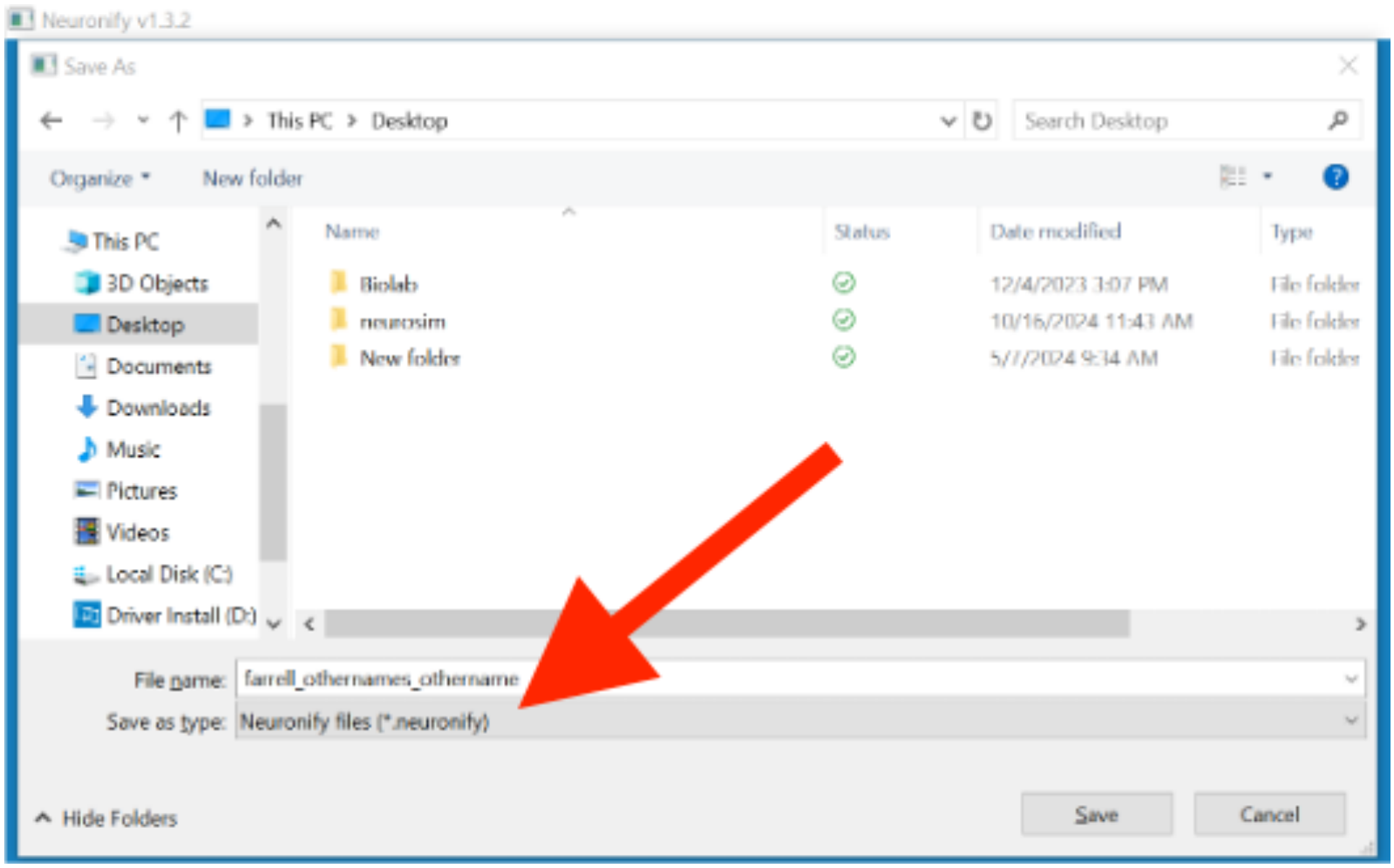
Saving Step 2: Naming your file

Saving Step 3: Go to the desktop so you can find the file.



Saving Step 3: Where to save your file

Saving Step 4: Enter the last names of all members of your group again and then hit “Save”. Then upload the file to D2L Dropbox in the Neuronify module



Saving Step 4: Group member names

Appendix C: Binaural Beats Web Page Code

Below you will find code to create a binaural beats research tool webpage. Each file that is needed starts with the name in this format:

```
===style.css ===

Copy the code below the name into a new file with that name. You should be
able to host this page on any free hosting service, such as github. You can
also run from a linux computer. The runserver.sh script is for this purpose.
Once you have an address for the webpage, you can include it in the document
for the lab.

===style.css ===

body {
    font-family: Arial, sans-serif;
    text-align: center;
    background-color: #f4f4f4;
    margin: 0;
    padding: 10px;
    max-width: 100%;
    box-sizing: border-box;
}

h1 {
    background-color: #6200ea;
    color: white;
    margin: -10px -10px 15px -10px;
    padding: 15px;
    font-size: clamp(1.5rem, 5vw, 2rem);
}

h2 {
    color: #6200ea;
    margin-bottom: 15px;
    font-size: clamp(1.2rem, 4vw, 1.5rem);
}

h3 {
    font-size: clamp(1rem, 3.5vw, 1.2rem);
}

.section {
    background: white;
    border-radius: 8px;
```

```
    padding: 15px;
    margin-bottom: 15px;
    box-shadow: 0 2px 4px rgba(0,0,0,0.1);
    width: 100%;
    max-width: 800px;
    margin-left: auto;
    margin-right: auto;
}

.channel-control {
    display: flex;
    flex-direction: column;
    align-items: center;
    gap: 20px;
    margin-bottom: 20px;
}

@media (min-width: 768px) {
    .channel-control {
        flex-direction: row;
        justify-content: center;
        gap: 40px;
    }

    body {
        padding: 20px;
    }

    h1 {
        margin: -20px -20px 20px -20px;
    }
}

.channel {
    text-align: left;
    width: 100%;
    max-width: 300px;
    padding: 15px;
    background-color: #f8f8f8;
    border-radius: 8px;
}

.channel h3 {
    color: #333;
    margin-bottom: 15px;
```

```
}

label {
    display: block;
    margin: 10px 0 5px;
    color: #666;
    font-size: 0.9rem;
}

input[type="number"] {
    width: 120px;
    padding: 10px;
    margin-bottom: 10px;
    border: 1px solid #ddd;
    border-radius: 4px;
    font-size: 1rem;
}

input[type="range"] {
    width: 100%;
    margin: 10px 0;
    height: 30px; /* Larger touch target */
}
```

```
button {
    padding: 12px 20px;
    color: white;
    background-color: #6200ea;
    border: none;
    border-radius: 5px;
    cursor: pointer;
    margin: 5px;
    font-size: 1rem;
    min-width: 120px;
    touch-action: manipulation;
    -webkit-tap-highlight-color: transparent;
}

button:hover {
    background-color: #3700b3;
}

button:active {
    background-color: #3700b3;
    transform: translateY(1px);
```

```
}

.global-controls {
    margin-top: 20px;
    padding-top: 20px;
    border-top: 1px solid #eee;
}

/* Prevent text selection on double tap */
* {
    -webkit-touch-callout: none;
    -webkit-user-select: none;
    user-select: none;
}

/* Allow text selection in inputs */
input[type="number"] {
    -webkit-user-select: auto;
    user-select: auto;
}

===index.html ===
<!DOCTYPE html>
<html lang="en">
<head>
    <meta charset="UTF-8">
    <meta name="viewport" content="width=device-width, initial-scale=1.0">
    <title>Binaural Beats Research Tool</title>
    <link rel="stylesheet" href="style.css">
    <link rel="manifest" href="manifest.json">
</head>
<body>
    <h1>Binaural Beats Research Tool</h1>

    <div id="hardware-test" class="section">
        <h2>Hardware Test</h2>
        <div class="channel-control">
            <div class="channel">
                <h3>Left Channel</h3>
                <button id="test-left-button">Test Left</button>
                <input type="range" id="test-left-volume" min="0" max="1"
step="0.1" value="0.5">
                <label for="test-left-volume">Volume</label>
            </div>
```

```
            <div class="channel">
                <h3>Right Channel</h3>
                <button id="test-right-button">Test Right</button>
                <input type="range" id="test-right-volume" min="0" max="1"
step="0.1" value="0.5">
                <label for="test-right-volume">Volume</label>
            </div>
        </div>
    </div>

    <div id="binaural-controls" class="section">
        <h2>Binaural Beats Generator</h2>

        <div class="channel-control">
            <div class="channel">
                <h3>Left Channel</h3>
                <label for="left-frequency">Frequency (Hz):</label>
                <input type="number" id="left-frequency" value="300" min="20"
max="1000">
                <input type="range" id="left-volume" min="0" max="1"
step="0.1" value="0.5">
                <label for="left-volume">Volume</label>
                <button id="left-toggle">Toggle Left</button>
            </div>

            <div class="channel">
                <h3>Right Channel</h3>
                <label for="right-frequency">Frequency (Hz):</label>
                <input type="number" id="right-frequency" value="310"
min="20" max="1000">
                <input type="range" id="right-volume" min="0" max="1"
step="0.1" value="0.5">
                <label for="right-volume">Volume</label>
                <button id="right-toggle">Toggle Right</button>
            </div>
        </div>

        <div class="global-controls">
            <button id="start-button">Start All</button>
            <button id="stop-button">Stop All</button>
        </div>
    </div>

    <script src="app.js"></script>
</body>
```

```
</html>

=== runserver.sh ===
python3 -m http.server

=== app.js ===
const audioContext = new (window.AudioContext || window.webkitAudioContext)();

class ToneGenerator {
    constructor() {
        this.oscillator = null;
        this.gainNode = null;
        this.isPlaying = false;
    }

    start(frequency, volume = 0.5) {
        if (this.isPlaying) this.stop();

        this.oscillator = audioContext.createOscillator();
        this.gainNode = audioContext.createGain();

        this.oscillator.type = 'sine';
        this.oscillator.frequency.setValueAtTime(frequency,
audioContext.currentTime);

        this.gainNode.gain.setValueAtTime(volume, audioContext.currentTime);

        this.oscillator.connect(this.gainNode);
        this.isPlaying = true;
        this.oscillator.start();
    }

    stop() {
        if (this.oscillator) {
            this.oscillator.stop();
            this.oscillator.disconnect();
            this.gainNode.disconnect();
            this.oscillator = null;
            this.gainNode = null;
            this.isPlaying = false;
        }
    }

    setFrequency(frequency) {
        if (this.oscillator) {
```

```
            this.oscillator.frequency.setValueAtTime(frequency,
audioContext.currentTime);
        }
    }

    setVolume(volume) {
        if (this.gainNode) {
            this.gainNode.gain.setValueAtTime(volume,
audioContext.currentTime);
        }
    }
}

// Hardware test components
const testLeft = new ToneGenerator();
const testRight = new ToneGenerator();

// Binaural beat components
const binauralLeft = new ToneGenerator();
const binauralRight = new ToneGenerator();

// Hardware test controls
const testLeftButton = document.getElementById('test-left-button');
const testRightButton = document.getElementById('test-right-button');
const testLeftVolume = document.getElementById('test-left-volume');
const testRightVolume = document.getElementById('test-right-volume');

// Binaural controls
const leftFrequency = document.getElementById('left-frequency');
const rightFrequency = document.getElementById('right-frequency');
const leftVolume = document.getElementById('left-volume');
const rightVolume = document.getElementById('right-volume');
const leftToggle = document.getElementById('left-toggle');
const rightToggle = document.getElementById('right-toggle');
const startButton = document.getElementById('start-button');
const stopButton = document.getElementById('stop-button');

// Setup audio routing for hardware test
const setupChannelRouting = (generator, channel) => {
    if (generator.gainNode) {
        const merger = audioContext.createChannelMerger(2);
        generator.gainNode.disconnect();
        generator.gainNode.connect(merger, 0, channel);
        merger.connect(audioContext.destination);
    }
```

```
};

// Hardware test event listeners
testLeftButton.addEventListener('click', () => {
    if (!testLeft.isPlaying) {
        testLeft.start(440, testLeftVolume.value);
        setupChannelRouting(testLeft, 0);
        testLeftButton.textContent = 'Stop Left Test';
    } else {
        testLeft.stop();
        testLeftButton.textContent = 'Test Left';
    }
});

testRightButton.addEventListener('click', () => {
    if (!testRight.isPlaying) {
        testRight.start(440, testRightVolume.value);
        setupChannelRouting(testRight, 1);
        testRightButton.textContent = 'Stop Right Test';
    } else {
        testRight.stop();
        testRightButton.textContent = 'Test Right';
    }
});

testLeftVolume.addEventListener('input', (e) => {
    testLeft.setVolume(e.target.value);
});

testRightVolume.addEventListener('input', (e) => {
    testRight.setVolume(e.target.value);
});

// Binaural beat event listeners
const updateBinauralBeats = () => {
    if (binauralLeft.isPlaying) {
        binauralLeft.setFrequency(parseFloat(leftFrequency.value));
        binauralLeft.setVolume(leftVolume.value);
    }
    if (binauralRight.isPlaying) {
        binauralRight.setFrequency(parseFloat(rightFrequency.value));
        binauralRight.setVolume(rightVolume.value);
    }
};
```

```
leftToggle.addEventListener('click', () => {
    if (!binauralLeft.isPlaying) {
        binauralLeft.start(parseFloat(leftFrequency.value), leftVolume.value);
        setupChannelRouting(binauralLeft, 0);
        leftToggle.textContent = 'Stop Left';
    } else {
        binauralLeft.stop();
        leftToggle.textContent = 'Start Left';
    }
});

rightToggle.addEventListener('click', () => {
    if (!binauralRight.isPlaying) {
        binauralRight.start(parseFloat(rightFrequency.value),
rightVolume.value);
        setupChannelRouting(binauralRight, 1);
        rightToggle.textContent = 'Stop Right';
    } else {
        binauralRight.stop();
        rightToggle.textContent = 'Start Right';
    }
});
```

```
startButton.addEventListener('click', () => {
    if (!binauralLeft.isPlaying) {
        binauralLeft.start(parseFloat(leftFrequency.value), leftVolume.value);
        setupChannelRouting(binauralLeft, 0);
        leftToggle.textContent = 'Stop Left';
    }
    if (!binauralRight.isPlaying) {
        binauralRight.start(parseFloat(rightFrequency.value),
rightVolume.value);
        setupChannelRouting(binauralRight, 1);
        rightToggle.textContent = 'Stop Right';
    }
});

stopButton.addEventListener('click', () => {
    binauralLeft.stop();
    binauralRight.stop();
    leftToggle.textContent = 'Start Left';
    rightToggle.textContent = 'Start Right';
});

// Frequency and volume control listeners
```

```
leftFrequency.addEventListener('input', updateBinauralBeats);
rightFrequency.addEventListener('input', updateBinauralBeats);
leftVolume.addEventListener('input', updateBinauralBeats);
rightVolume.addEventListener('input', updateBinauralBeats);

=== manifest.json ===
{
    "name": "Binaural Beats Research Tool",
    "short_name": "Binaural Beats",
    "start_url": "./",
    "display": "standalone",
    "background_color": "#ffffff",
    "theme_color": "#6200ea",
    "icons": [
        {
            "src": "icon.png",
            "sizes": "192x192",
            "type": "image/png"
        },
        {
            "src": "icon-512.png",
            "sizes": "512x512",
            "type": "image/png"
        }
    ]
}

=== service-worker.js ===
self.addEventListener('install', event => {
    console.log('Service Worker installed');
});

self.addEventListener('activate', event => {
    console.log('Service Worker activated');
});

self.addEventListener('fetch', event => {
    console.log('Fetching:', event.request.url);
});
```