Recipes of the Brain: a CBS Cookbook

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Table of Contents

01 **Action Potential**
Na/K ion flow, All-or-none law, Absolute & Relative Refractory Period

02 **Anatomy of a Neuron**
Dendrites, Soma, Nucleus, Axon, Myelin, Axon terminal

03 **Huron's Theory**
Evolutionary vs. Ancient

04 **Brain Imaging**
fMRI, MRI, DTI, EEG

05 **Eye to Cortex**
Anatomy of the eye & the retinotopic map

06 **Circuitry of External Drives**
Fear and appetite behavior

01 Action Potential

Ingredients for Action Potential

- Marshmallow (Ion gate)
- Skittles (Cell membrane)
- Oatmeal (Cell membrane)
- Swedish fish (Na ions)
- Mini Haribo gummy bears (K ions)
- Airheads (arrows to indicate movement of the ions)

Action Potential

1. Start at resting potential, which is when the neuron is not transmitting information. This means pumping Na+ out and K+ into the cell in a 3:2 ratio.
2. Resting potential is changed by an excitatory or inhibitory input, which happens via synapses on dendrites or the cell body.
3. Add an excitatory input. This makes the membrane potential more positive and thus depolarizes the cell.
4. If the membrane potential reaches a certain threshold from your stimulus, the nerve or muscle fiber will give a complete response/firing; otherwise, there is no response at all. Make sure to apply enough stimulus to reach that threshold.
5. Once you do, you will generate an action potential. This means pumping Na into and K out of the cell. Here, you can savor your dish!
6. Immediately following the action potential is the absolute refractory period, in which you will not be able to induce a second action potential no matter how hard you try. Just be patient!
7. Afterwards is the relative refractory period, in which the nerve or muscle fiber will only respond/fire to a stronger impulse than normal. You can choose to add that necessary stimulus to induce a second action potential and savor this dish again, or you can clean up by pumping out K ions and returning to resting potential.
8. If you choose to add an inhibitory input at step 3, your dish will not come out right; this error makes the membrane potential more negative and thus hyperpolarizes the cell. In other words, you will lose the opportunity to create an action potential.

02 Anatomy of a Neuron

Ingredients for Anatomy of a Neuron

- Trolli Sour Worms, Airheads (Dendrites & Axon terminal)
- Trolli Sour Worms (Axon)
- Orange peel (Cell body/soma)
- Marshmallow (Nucleus)
- Cheerios (Myelin)

Anatomy of a Neuron

1. Create branches that are no longer than 3 mm in length and taper towards the ends. These are known as dendrites, and they collect signals from another nerve cell, convert signals into electrical impulses, and send them to the cell body (soma).
2. Keep in mind that depending on whether the neuron is a part of the central or peripheral nervous system, the shape and structure of dendrites will differ.
3. Next, create the soma and make it 10-25 microns in size. The soma's main purpose is to integrate signals delivered from the dendrites and to maintain cell processes.
4. Connect the base of the dendrites to the soma so that they serve as extensions.
5. Build organelles inside of the soma, such as the nucleus; make the nucleus produce RNA for the synthesis of proteins
6. On the other side of the soma, attach a single, long strand of fiber known as the axon. The axon conducts signals from the soma to the axon terminals.
7. The diameter should be less than 1 micron, and you can choose anywhere from 0.1 mm to 3 ft for length!
8. Combine some phospholipids and proteins to create the myelin.
9. Wrap this substance around the axon; it serves to protect the axon and speed up the transmission of a signal.
10. Lastly, make the axon extend into branches in a similar manner to dendrites.
11. Make each of the branches swell to 5 microns in size at the tips in the synapse region. These button-like ends are known as the axon terminals.
12. Put chemicals inside the axon terminals so that the neuron can use them to communicate signals.

03 Huron's Theory

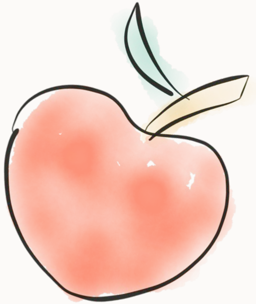
Auditory input enters thalamus

Auditory input travels to amygdala and cerebral cortex & is processed

Cerebral cortex response inhibits amygdala's fear response; now you can enjoy music without being scared!

Ingredients for Huron's Theory

- Peanut M&M (amygdala)
- Oatmeal (gray matter)
- Rice pudding (white matter)
- Apple (thalamus)
- Oreo cream (part of cerebral cortex involved in interpretation)
- Cheerios (auditory input)
- Strawberry jam (slow inhibitory response)
- Grape jelly (fast response)

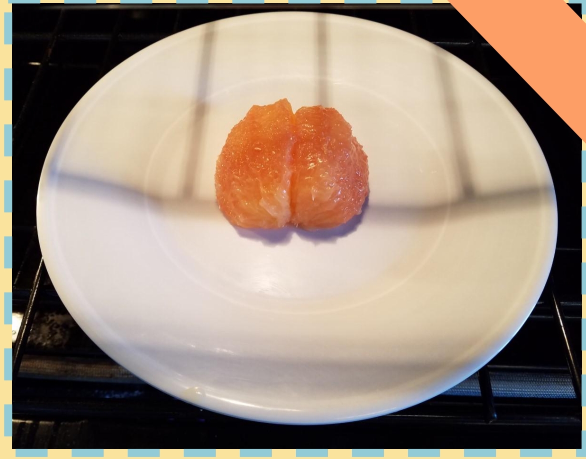


Huron's Theory

A Symphony of Flavors:

1. First, we prepare the brain according to the contrastive affect theory, created by David Huron.
2. Add auditory input which will first be absorbed by the thalamus. You can improvise here depending on how strong you like your music or its effect on your body. I recommend increasing the volume, lowering the pitch, quick tempo changes, and even scream-like sounds. Don't be afraid to try new harmonies either!
3. Once the auditory input has been absorbed by the thalamus, it will then start to move towards two different directions. Some of the auditory input will be absorbed by the amygdala, a traditional, ancient brain ingredient usually involved in the interpretation of emotions and best known for invoking fear.
4. The amygdala will then produce musical chills or shivers. This response is automatic and is actually a result of the amygdala reacting with the auditory stimulus in order to cook up the best fear response to a possible threat.
5. This dish is not done yet! Huron's theory is well-known to have two distinct flavors. The amygdala's response is known as the fast track flavor while this next step, that of the cerebral cortex's, is known as the slow track flavor. This slow track actually came after the fast track as a result of evolution, more specifically from the addition of music.
6. The rest of the auditory input that hasn't been mixed with the amygdala actually was absorbed by the cerebral cortex. This step takes more time to allow for the cerebral cortex to interpret the stimulus as not poisonous or dangerous (completely edible).
7. Dopamine is released and an inhibitory response is produced by the cerebral cortex after the auditory stimulus has been properly mixed. This inhibitory response is then mixed with the amygdala and results in a whole different flavor, where one can now enjoy the music without fearing that it's possibly dangerous (it's definitely safe to eat).

04 Functional Magnetic Resonance Imaging (fMRI)



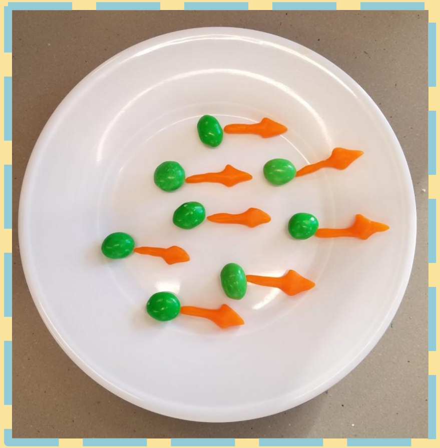
Ingredients for fMRI

- Grapefruit (Brain)
- Oven (MRI machine)
- Oven heat (BOLD signal)

Brain Imaging: fMRI

1. Enter the brain into the MRI machine, which is used both in fMRI and MRI brain imaging. Watch out as the machine is extremely loud and make sure the brain stays still in order to obtain a clear image. In addition, the MRI machine includes a tube with copper wires or coils that have electricity flow through them which forms a magnetic field. And do not forget to mix in the helium in order to cool the coils!
2. Add the BOLD, or Blood Oxygen Level Dependent, signal to the mix. The BOLD signal is what is measured in the fMRI. Therefore this ingredient is especially important! Because active neurons need oxygen as fuel, brain regions with increased oxyhemoglobin appear brighter and have heightened BOLD signal.
3. Next, carefully watch as the MRI machine takes cross-sectional images to create a 4D video of the brain. Do not remove the brain from the machine as a scan is taken every 2-3 seconds at a temporal resolution of 500-3000ms and spatial resolution of 2-3mm^3.
4. Lastly, once the scan is complete, which usually takes under an hour, remove the brain from the MRI machine and enjoy!

04 Magnetic Resonance Imaging (MRI)



Ingredients for MRI

- Grapefruit (Brain)
- Oven (MRI machine)
- Peanut M&Ms (Protons)
- Noodles (Radio waves)
- Airheads (Direction markers)

Brain Imaging: MRI

1. Place the brain in the MRI machine.
2. Add the protons and closely observe as they align to the direction of the magnetic field. Because humans have a lot of water molecules in our bodies, the protons line up in the magnetic field.
3. Mix in a radiofrequency pulse in order to send the protons into a temporarily excited state off their alignment. Watch as the protons flip their direction.
4. End the pulse and allow the protons to relax and sit in order for them to emit energy in the form of radio waves. The MRI machine coils will detect these waves.
5. Make sure to note that MRI signals differ depending on the tissue. For example, the more or less dense gray matter is, it will have increased or decreased brightness in the MRI image.
6. Remove the brain from the machine and remember to wipe down all surfaces.

04 Diffusion Tensor Imaging (DTI)

Ingredients for DTI

- Peanut M&Ms (Isotropic and anisotropic ellipsoids)
- Grapefruit (Brain)
- Oven (MRI machine)
- Airheads (Direction markers)
- Ketchup, Mustard, Yogurt, Nutella, Peanut butter, Ranch dressing, jelly (DTI white matter tracts)

Brain Imaging: DTI

1. Enter the brain into the MRI machine.
2. Measure the tissue water diffusion rate, which is what direction the water molecules are moving within a certain tissue.
3. Because you will be making DTI, you should immediately add the water molecules so they can diffuse differently depending on the arch, integrity, type, and presence of barriers
4. Look for isotropic and anisotropic ellipsoids, or tensors, as they are what models the diffusion process. Isotropic ellipsoids are usually equal in direction whereas anisotropic ellipsoids are unequal in direction.
5. Remove the brain from the machine.
6. Observe and analyze the final product: a connectome illustrating color-coded white matter fiber tracts to show the location of water motion.

04 Electroencephalogram (EEG)

Ingredients for EEG

- Grapefruit (Brain)
- Orange (Scalp)
- Orange peel and Airheads (EEG cap with wires)

Brain Imaging: EEG

1. Prepare the scalp by washing it and marking electrode locations with a utensil.
2. Place the EEG cap on the scalp and ensure that the wires are attached to each electrode.
3. Make sure the electrodes are reading the brain's neurons' ionic current fluctuations. You should see electrical activity as brain cells communicate.
4. Please use EEG to measure epilepsy, sleep disorders, coma, brain death, brain damage, stroke, encephalitis, and encephalopathy. EEG can also be used in scientific experiments. It is both cheaper and less invasive than MRI imaging.
5. Remove the EEG cap.

05 Eye to Cortex

Anatomy of the eye

Can you guess the secret ingredients of the fovea?

01
02
03
04
05
06

Ingredients for Eye to Cortex

Anatomy of the Eye

- Pupil (cheerios)
- Cornea (rice pudding)
- Iris (blueberry yogurt)
- Lens(peach ring)
- Sclera (rice pudding)
- Retina (crushed up oreos)
- Fovea (red sour patch)
- Optic nerve (twizzler)

Secret Ingredients within Fovea: Photoreceptors!

- Fovea (peach ring)
- Ganglion cells (orange airheads)
- Bipolar cells (red sour patch)
- Rods (blue sour patch)
- Cones (green sour patch)

Eye to Cortex

A Recipe for Those Who Eat With Their Eyes:

1. First, we prepare all the brain ingredients involved in receiving and processing visual stimuli.
2. Sprinkle visual input (in the form of photons) through the eyes which will be absorbed by the photoreceptors. The visual input has to go through many layers of the eye before it can be processed in the fovea. It has to pass through the cornea, pupil, iris, lens, and finally the retina, where the fovea and photoreceptors are located.
3. Add a pinch of the left visual field to the right side of each retina for it to ferment for a bit
4. Add a pinch of the right visual field to the left side of each retina for it to ferment for a bit
5. We have two different varieties of photoreceptors: cones and rods. It's important to note that when preparing these photoreceptors, rods should not be kept out in the light as much as cones as they are better stored in more dim lighting (so they don't go bad). Make sure to have the perfect ratio of rods to cones (20:1) so the flavor shines through properly.
6. When the visual input and photoreceptors have properly been combined, sift out the visual input which has now changed from light energy to bioelectric signals.
7. Coat the axons of ganglion cells in myelin to shape them into the optic nerve. Now combine these bioelectric signals with the ganglion cells (also located in the retina), traveling as action potentials to the visual cortex through the optic nerve.

05 Retinotopic Map

Ingredients for Retinotopic Map

- White matter (rice pudding)
- Gray matter (oatmeal)
- Pupils (green gumdrops)
- Temporal hemiretina (peach rings)
- Fovea (cheerios)
- Nasal hemiretina (orange peel)
- Optic nerve (twizzler)
- Optic chiasm (where twizzlers cross)
- Lateral geniculate nucleus (yellow M&Ms)
- Optic radiation (from left visual field: blue sour patch, from right visual field (green sour patch)
- Primary visual cortex (left:strawberry jam, right: blueberry yogurt)

Eye to Cortex pt. 2

Preparation of the Retinotopic Map:

1. After the left and right visual fields have gone through fermentation, where each of the optic nerves contain both visual field spices, harvest the left visual field spice from the left optic nerve and add it to the right optic nerve. Then harvest the right visual field spice from the right optic nerve and add it to the left optic nerve. Prepare the optic chiasm beforehand because harvesting needs to take place alongside the optic chiasm as it cools.
2. These signals will then be processed in two different techniques to form a harmonious dish with lots of visual impact and it'll even make your body move.
3. The following steps will now require two people, as they must be performed at the same time since they require ingredients from the other at specific times, as if they are interacting with one another
4. The first technique is the ventral system, which consists of shaping visual recognition and allows for the flavor of perception to come through. This step is crucial for the ability to connect internal models to visual stimuli. Without this step, the individual will be unable to recognize and properly interpret the object.
5. The second technique — performed alongside the ventral system — consists of accessing the location of the object. The key step to this technique is spatial vision, which allows action that relates to touching or moving the object to shine through. Otherwise, the individual will not be able to complete actions that are related to these objects.
6. Make sure that these techniques are being performed with one another with communication and interaction by the two individuals performing them. If they were to become separated from the other with someone stopping in between, the dish would completely lack an essential component that would've allowed it to be properly savored.

06 Circuitry of External Drives

Ingredients for Circuitry of External Drives

- Airheads (Direction markers)
- Hello Panda cookie (Stimuli)
- Gummy worm (High road)
- Gummy worm (Low road)
- Peeps (Sensory cortex)
- Oreos (Amygdala)
- Marshmallow (Lateral nucleus)
- Sour Patch watermelon (Central nucleus)
- Peanut butter M&Ms (Emotional behavior, Autonomic responses, Hormonal responses)

Circuitry of External Drives

1. Prepare the ingredients and understand that this mainly involves fear and appetitive behavior.
2. Once you receive a stimulus, double check it enters the thalamus, the sensory relay station where all information converges before it goes off to specific cortical areas.
3. Next, prepare the "high road" or "low road".
4. The high road is the processing of balanced, well coordinated types of information. For this road, you will need to mix in the sensory cortex like the hippocampus before information can travel into the amygdala's lateral nucleus and then the central nucleus.
5. The low road is the shortcut processing that is unconscious and can go to the amygdala before humans are aware. For example, images can be shown less than 50ms, which is less time than it takes for the information to reach the sensory cortex. But, this information through the low road can immediately activate the amygdala.
6. After the sensory information is processed, transfer it out of the central nucleus, so it can cause hormonal responses, emotional behaviors, and autonomic responses.