


Physiology : Neuronal circuits notes part 1 :

1. What are neuronal circuits?

 A neuronal circuit = a group of interconnected neurons working together to perform a function.

Think of it like:

- Input → Processing → Output



Example:

- Touch something hot → signal enters → processed → muscles withdraw

2. Frequency vs excitatory state (your graph)


- X-axis = how strong the input is (excitation)
- Y-axis = how fast the neuron fires

Key idea:

- Each neuron has a threshold
- Below threshold →  no firing
- Above threshold →  firing increases


Why curves differ:

- Some neurons:
- Fire early (low threshold) → very sensitive
- Fire late (high threshold) → need strong stimulus
- Have different maximum firing rates

 This allows the nervous system to:

- Detect weak AND strong stimuli
- Encode intensity

3. Receptive (Stimulated) field


 “The neuronal area stimulated by each incoming nerve fiber”

What it means:


- One sensory neuron activates many neurons around it

Discharge zone vs Facilitated zone

Discharge zone (center)

- Strong stimulation
- Neurons reach threshold
-  They FIRE


Facilitated zone (surrounding)

- Weak stimulation
- Neurons do NOT reach threshold alone
-  They are “ready” but not firing

Why this is important:

- Improves precision of sensation
- Helps brain localize stimuli

4. Inhibitory zone

 Opposite of excitation

- Center = strong inhibition
- Surroundings = weaker inhibition

Function:

- Sharpens signals
- Prevents spread of unnecessary activity

5. Reciprocal inhibition (VERY IMPORTANT)

Definition:

When one pathway is activated → another is inhibited

Example (knee reflex):

- Quadriceps contracts → knee extends
- Hamstrings must relax


How?

- Sensory neuron → excites motor neuron (quadriceps)
- At same time → activates inhibitory interneuron
- This inhibits motor neuron to hamstrings

Why important:

- Prevents muscles from fighting each other
- Ensures smooth movement

6. Divergence

 One neuron → many neurons

Types:

A. Divergence in same tract

- Signal spreads but stays in same pathway

B. Divergence into multiple tracts

- One signal goes to:
- Spinal cord
- Brainstem
- Cortex

Function:

- Amplification
- One input → large response

7. Amplifying divergence

 Signal becomes stronger as it spreads

Example:

- One neuron → activates 10 → activates 100

Clinical meaning:

- Small stimulus → big motor response

8. Convergence

 Many neurons → one neuron

Types:

A. From same source

- Multiple fibers from same region

B. From different sources

- Different inputs combine

Function:

- Summation

Two types:

- Spatial summation → many neurons at once
- Temporal summation → same neuron repeatedly

9. Convergence in rods (vision)

- Many rods → one bipolar cell → one ganglion cell

 Result:

- High sensitivity (good in dark)
- Low precision (blurry vision)

Big picture (VERY IMPORTANT)

The nervous system uses:

- Divergence → spread & amplify signals
- Convergence → integrate information
- Inhibition → refine & control signals

Final summary (exam gold)

- Threshold → determines firing
- Discharge zone → fires
- Facilitated zone → almost fires
- Inhibitory zone → suppresses activity
- Divergence → 1 → many (amplification)
- Convergence → many → 1 (summation)
- Reciprocal inhibition → coordination of movement

Further explanations :

🎯 1. Receptive (Stimulated) Field — the BIG idea

🔑 Definition (but understand it properly):

👉 A receptive field = the area (or group of neurons) influenced by ONE sensory input

🧠 Think of it like this:

Imagine:

- One sensory neuron = a stone
- It hits the water → creates ripples

👉 The ripples = neurons that get affected

👉 It's:

- One input → affects a region
- That region has different strengths of activation

🔥 2. Discharge zone vs Facilitated zone

This is the MOST IMPORTANT concept here

🔴 Discharge zone (CENTER)

👉 Strong stimulation

- Neurons reach threshold
- Generate action potentials
- 👉 They FIRE

🟡 Facilitated zone (SURROUNDINGS)

👉 Weak stimulation

- Neurons get partial depolarization
- But NOT enough to reach threshold
- 👉 They are “on standby”

🧠 Think of it clinically:

Example: Touch your skin with a pen

- Center (where you press):
 - 👉 strong signal → neurons FIRE
- Surrounding skin:
 - 👉 weak signal → neurons are “ready”

💡 Why is this genius?

Because if:

- Another stimulus comes nearby
 - 👉 those “ready” neurons will fire faster

→ This is summation

🧠 **KEY CONCEPT:** Summation (hidden inside facilitated zone)


👉 Facilitated neurons can fire if:


- Another stimulus comes (spatial summation)
- Same stimulus repeats (temporal summation)

🚫 3. Inhibitory zone

Now the opposite system.

 Center = strongest inhibition

 Surroundings = weaker inhibition

 What does inhibition do?

 It suppresses neurons.

 Why is this important?

Example: Sharp sensory localization

If you touch your finger:

- Center neurons → activated
- Surrounding neurons → inhibited

 Result:

- You feel the stimulus precisely
- Not “spread everywhere”

 This is called:

 Lateral inhibition

 4. Divergence (1 → MANY)

 Definition:

One neuron sends signals to multiple neurons

 Why?

 To spread information

Types:

A. Same tract

- Signal spreads but stays in same pathway

B. Multiple tracts

- Signal goes to:
- Spinal cord (reflex)
- Brainstem (basic control)
- Cortex (conscious awareness)

Example:

Touch something hot:

- Signal goes to:
- Spinal cord → withdraw hand (FAST)
- Brain → feel pain (SLOWER)

5. Amplifying divergence

 Special type of divergence

- 1 neuron → 10 → 100 → 1000

Why?

 To increase strength of response

Clinical example:

Small stimulus → big response

- Tap patellar tendon → whole quadriceps contracts

6. Convergence (MANY → 1)

Definition:

Multiple neurons → ONE neuron

Why?

 To integrate information

Example:

A motor neuron receives:

- Input from brain
- Input from spinal cord
- Input from sensory neurons

 Then decides: fire or not

This leads to: **SUMMATION**

1. Spatial summation

- Many neurons → same time

2. Temporal summation

- Same neuron → repeated signals

7. Convergence in rods (VERY IMPORTANT)

What happens:

- MANY rods → 1 bipolar → 1 ganglion

Result:

Advantage:

- Very sensitive → can detect dim light. (low threshold)

👉 So they have a **low threshold for activation (firing)**

Disadvantage:

- Poor precision → Low spatial resolution : poor / blurred vision

💡 Compare with cones:

- Cones = less convergence
👉 high precision (sharp vision)

🧠 BIG INTEGRATION:

The nervous system uses:

🟦 Divergence → spread signal

🟥 Convergence → combine signals
(summation)

🟡 Facilitation → prepare neurons

⬛ Inhibition → sharpen signals (prevents overspreading)

🧠 FINAL CLINICAL SUMMARY

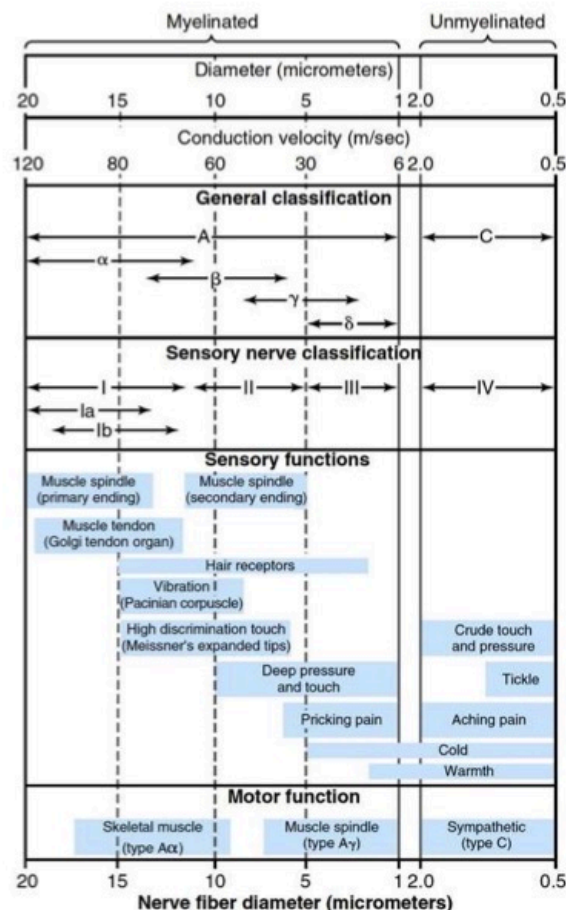
- Discharge zone → actual firing
- Facilitated zone → “ready neurons”
- Inhibitory zone → suppress noise
- Divergence → amplify & distribute
- Convergence → decision making
- Rods convergence → sensitivity > accuracy



To remember it better:

- Center = FIRE
- Surrounding = READY
- Inhibition = SHARPENS
- Divergence = SPREADS
- Convergence = DECIDES

The Diagram explanation of the different types of fibers and their properties :



What this diagram is about ?

 It classifies nerve fibers based on:

1. Diameter (size)
2. Myelination (myelin or not)
3. Conduction velocity (speed)
4. Function (what they carry)

1. The BIG RULE (memorize this first)

 Bigger + myelinated = faster conduction

 Smaller + unmyelinated = slower conduction

Why?


- Myelin → saltatory conduction (jumps)
- Bigger diameter → less resistance

2. Fiber types (General classification)

A fibers (FAST — myelinated)

Subtypes:

A α (Alpha)

-  FASTEST fibers
- Large diameter
- Very heavily myelinated

 Function:

- Motor to skeletal muscle
- Proprioception (muscle position)

- $A\beta$ (Beta)
- Slightly slower

👉 Function:

- Touch
- Pressure
- Vibration

$A\gamma$ (Gamma)

- Motor to muscle spindle

👉 Controls muscle tone

$A\delta$ (Delta)

- Smaller, slower

👉 Function:

- Fast pain (sharp)
- Cold
- Some touch

● B fibers

- Myelinated but small

👉 Function:

- Autonomic (preganglionic)

● C fibers (SLOWEST)

- ~~×~~ Unmyelinated
- Very small

👉 Function:

- Slow pain (aching, burning)
- Warmth

- Crude touch
- Postganglionic autonomic

3. Sensory classification (Roman numerals)

Same fibers, different naming system:

General	Sensory
Aα	I (Ia, Ib)
Aβ	II
Aδ	III
C	IV

Breakdown:

Type I (Ia, Ib)

- From:
- Muscle spindle (Ia)
- Golgi tendon organ (Ib)

 Function:

- Proprioception

Type II

- Touch + pressure

Type III

- Fast pain (A δ)

Type IV

- Slow pain (C fibers)

4. Sensory functions (middle of diagram)

Fast fibers (A α , A β):

- Proprioception
- Vibration
- Fine touch

👉 Precise, fast signals

Medium ($A\delta$):

- Sharp pain
- Cold

👉 Quick warning signals

Slow (C):

- Dull pain
- Warmth
- Itch

👉 Diffuse, emotional pain

💪 5. Motor part (bottom of diagram)

$A\alpha$:

- Skeletal muscle contraction

$A\gamma$:

- Muscle spindle control

C:

- Sympathetic (autonomic)

🧠 6. Clinical correlation (VERY IMPORTANT)

Example: Pain

Step 1 → You touch something hot

- $A\delta$ fibers → sharp pain (fast)
👉 “OUCH!”

Step 2 → seconds later

- C fibers → dull pain
👉 “Burning, aching”

Example: Reflex

- $A\alpha$ fibers → very fast
👉 Immediate muscle contraction

 7. Ultra-simple summary

FAST system:

- $A\alpha$, $A\beta$
👉 touch, position, movement

MEDIUM:

- $A\delta$
👉 sharp pain

SLOW:

- C
👉 dull pain, temperature

 To remember it better for exams:

👉 A = Accurate & fast

👉 C = Crude & slow

✓ Final takeaway

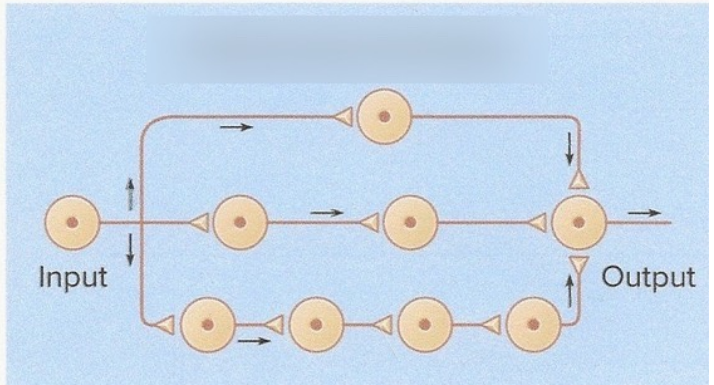
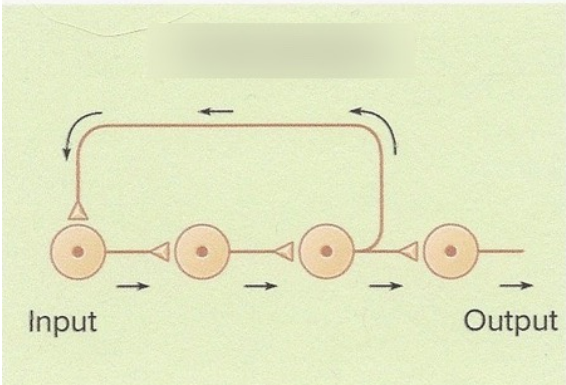
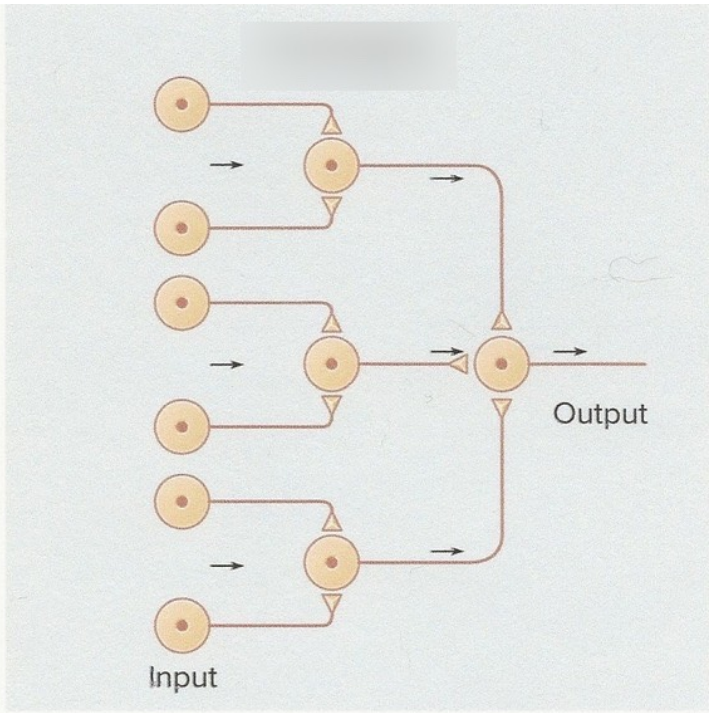
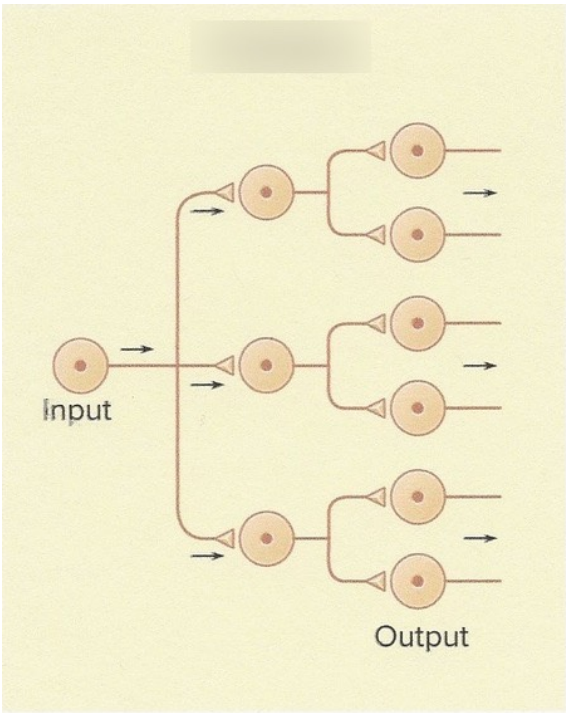
- Bigger + myelin = faster
- $A\alpha$ = motor + proprioception
- $A\beta$ = touch
- $A\delta$ = sharp pain
- C = slow pain + temperature

(A) alpha and (A) beta are the fastest then comes the (A) delta. On the other hand, the slowest fibers are the (C) fibers.

Neuronal Circuits part 2 notes:



1. Parallel afterdischarge



MicroNetwork Motifs

A. Feedforward excitation



D. Lateral inhibition

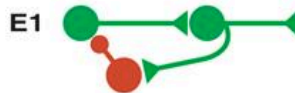


— Excitation
—● Inhibition

B. Feedforward inhibition



E. Feedback/Recurrent inhibition



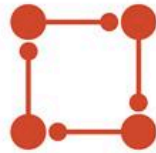
F. Feedback/Recurrent excitation



C. Convergence/divergence



E2



F2

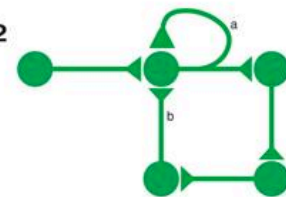
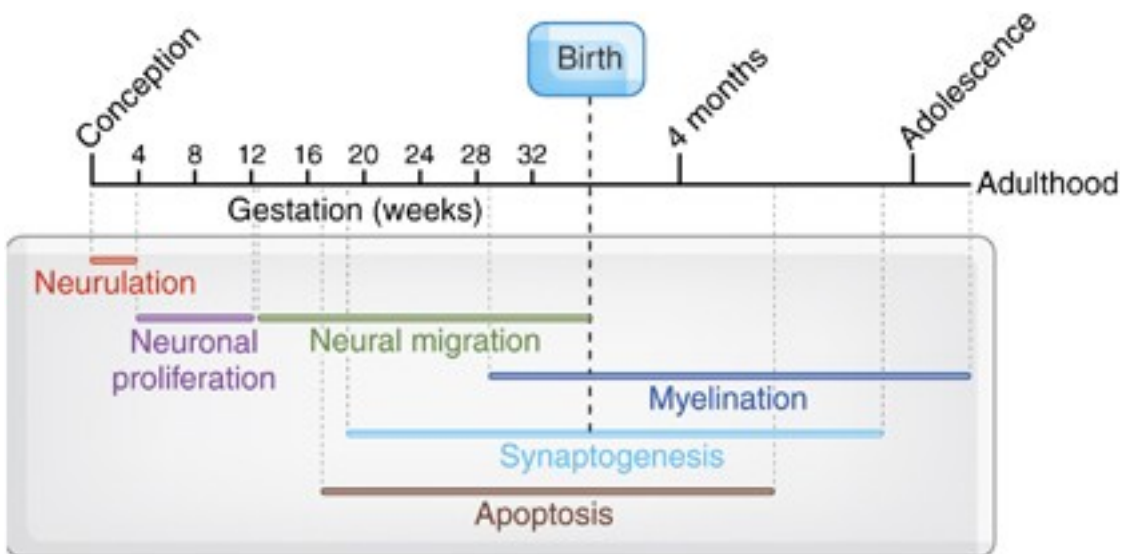
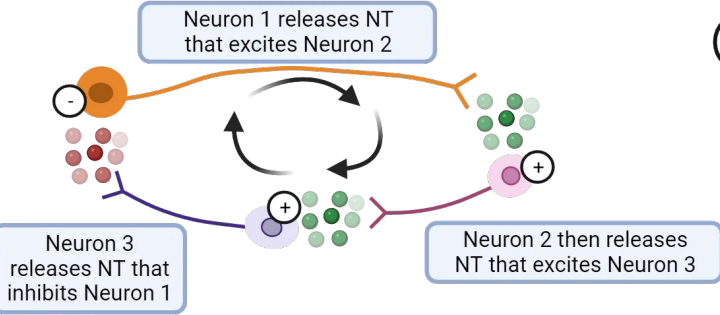
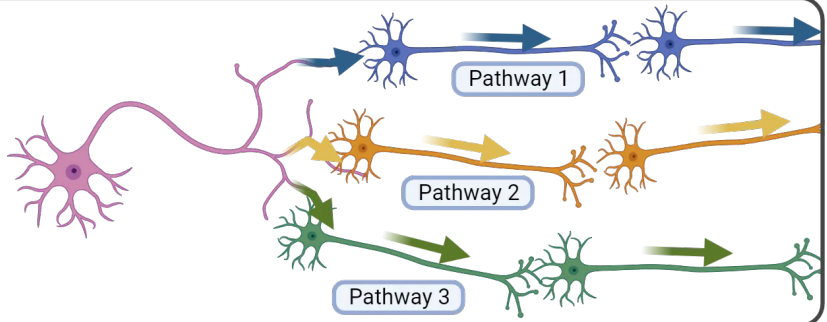


Figure 6

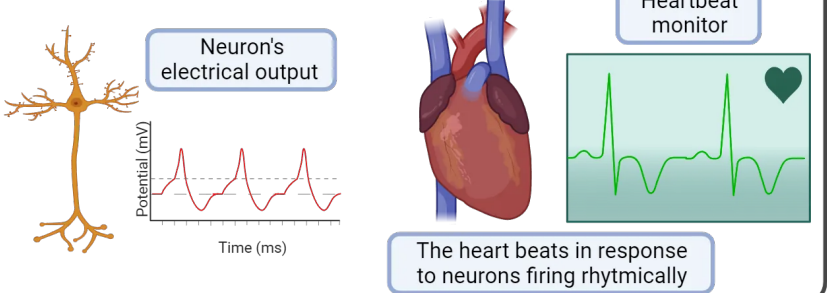


1 **Parallel processing:** Neurons send information along multiple pathways at the same time.



2 **Feedback:** Neural circuits often feature loops, this means neurons often produce outputs that can then feedback to influence their subsequent inputs.

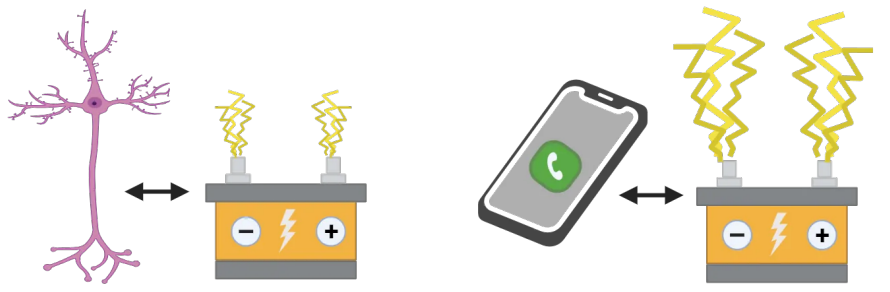
3 **Rhythms:** Neural networks often exhibit cyclical activity, and the behaviors they produce are often rhythmic as well (e.g. breathing)



Too much excitation: seizures, spastic paralysis
Moderate: Best operation
Too much inhibition: coma, flacid paralysis

4 **Moderate activity:** Both too much and too little activity is dysfunctional for neural circuits.

5 **Efficiency:** Neurons need relatively little energy relative to modern electronics.



💡 Idea:

One input → splits into multiple pathways → all meet again at one output.

 What happens:

- Each pathway has different length
- So signals arrive at different times

 Result:

 The output neuron keeps firing even after the stimulus stops

 Think of it like:


Throwing 3 balls at someone:

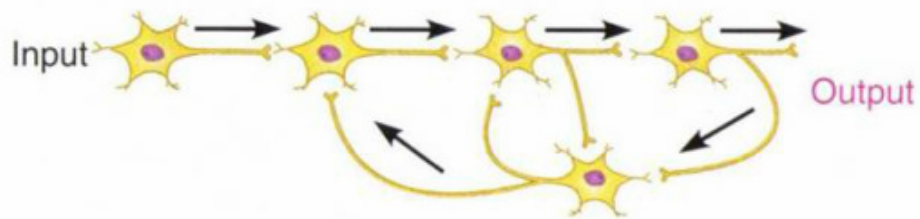
- One arrives fast
- One medium
- One slow

 The person keeps reacting longer

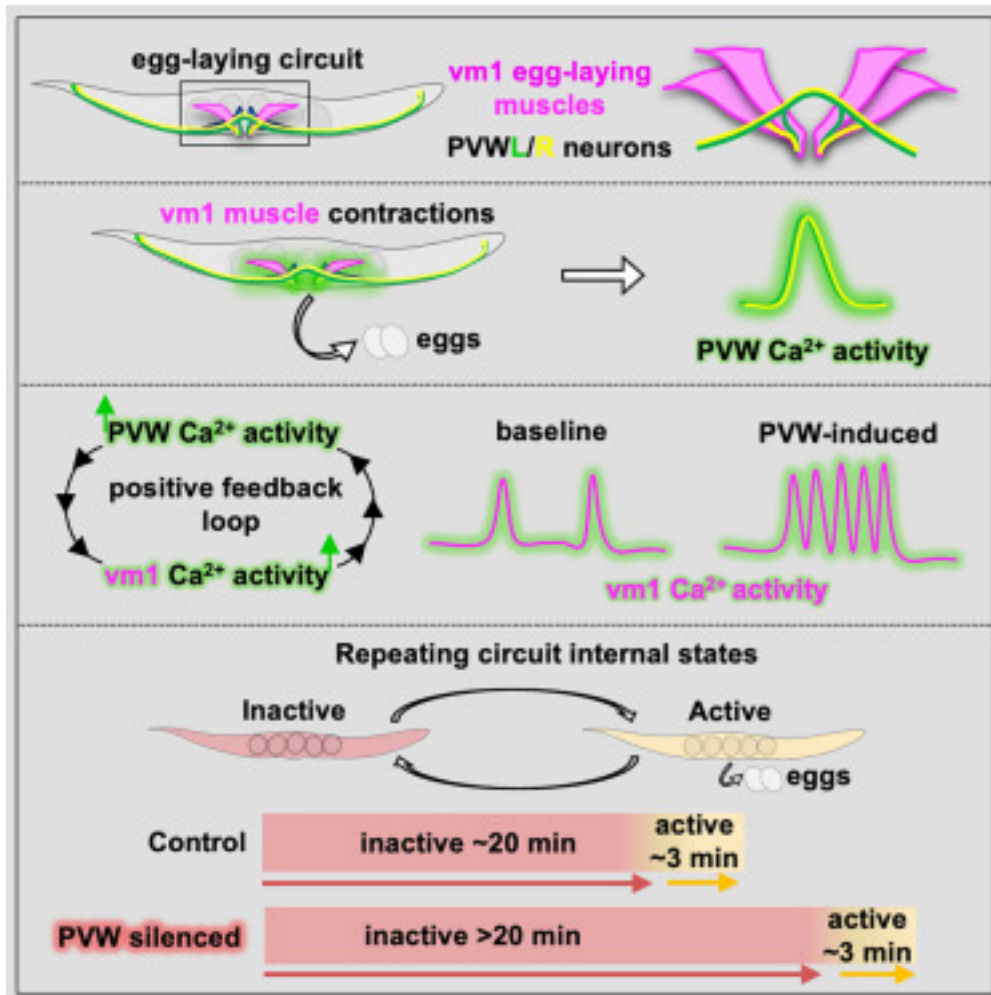
 Important:

- No feedback loop
- Just delayed arrivals

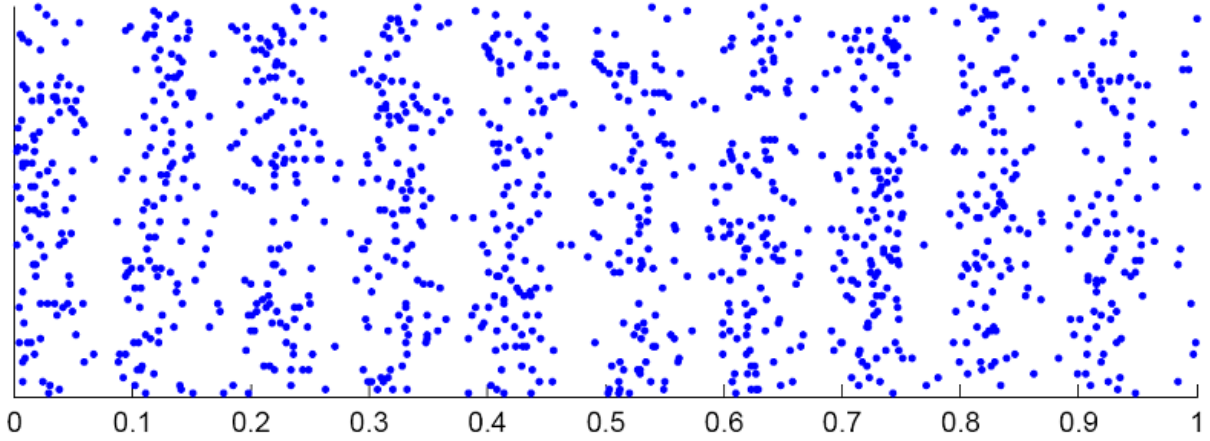
 2. Reverberatory (Oscillatory) circuits



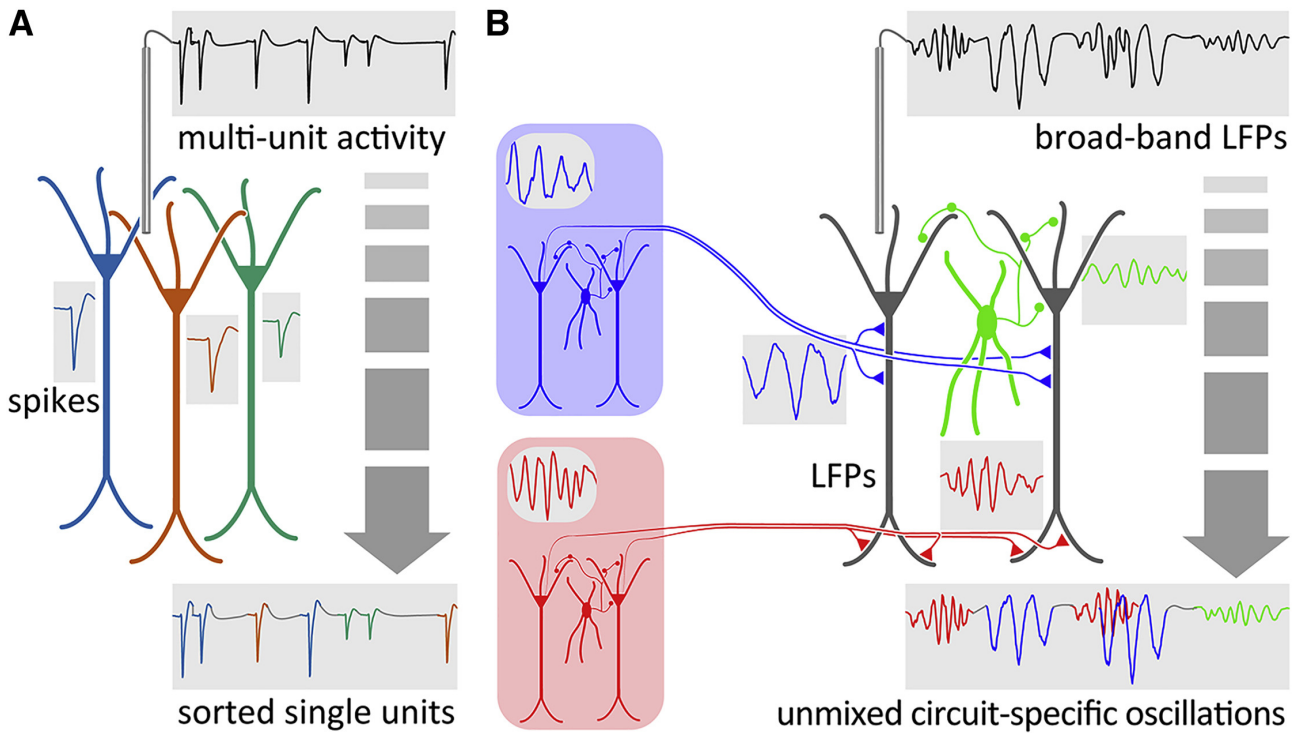
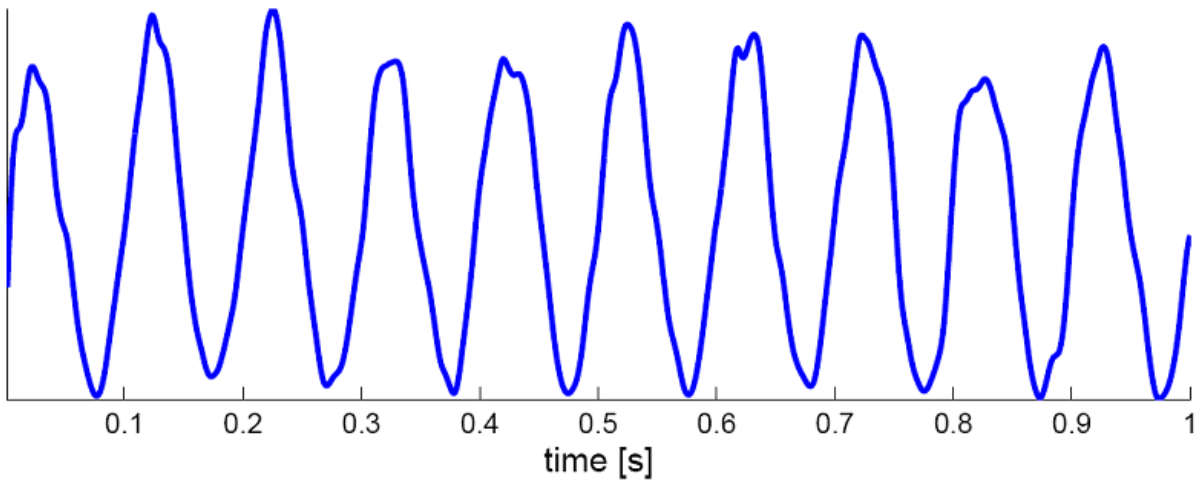
(e) Reverberating circuit



neuronal spiking



local field potential



Idea:

Signal loops back and re-stimulates itself

Mechanism:


- Output neuron sends a branch back to itself
- This is positive feedback

Result:

 Continuous repeated firing.

Think of it like:

A microphone near a speaker 

 Sound keeps looping → loud continuous noise

Delay concept:

- Short loop → fast repetition
- Long loop (more neurons) → slower repetition

+ - Modulation:

- Facilitation (excitatory input) → stronger + faster firing
- Inhibition → weakens or stops the loop

3. Continuous signal output

Idea:

Some neurons fire all the time, even without input.

Happens due to:

1. Intrinsic activity (neurons naturally active)

2. Reverberating circuits

4. Stability of neuronal circuits

Problem:

Brain is highly connected → signals could spread uncontrollably

Solution:

👉 Two stabilizers:

1. Inhibitory circuits

- Stop signals from spreading too much
- Like brakes

2. Synaptic fatigue

- Neurons get “tired”
- Neurotransmitter runs out

👉 Stops overactivity automatically

5. Fatigue of synapses

Causes:

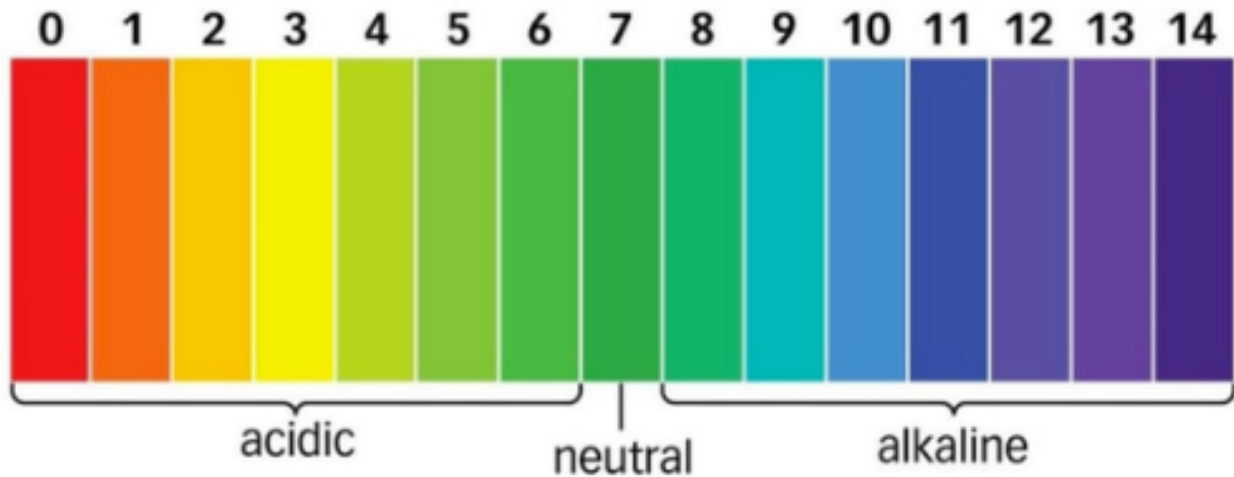
- ↓ neurotransmitter release
- ↓ receptor sensitivity
- Ion imbalance

Result:

👉 Signal becomes weaker over time.

6. pH effects (VERY important clinically)

pH scale :



● Alkalosis (\uparrow pH)

Effect:

👉 \uparrow excitability

Why:

- Neurons fire more easily

Clinical:

- Can cause seizures

Example:

👉 Hyperventilation \rightarrow \downarrow CO_2 \rightarrow \uparrow pH \rightarrow seizure risk

🔵 Acidosis (\downarrow pH)

Effect:

👉 \downarrow excitability

Clinical:

- Severe \rightarrow coma

🫁 7. Hypoxia (lack of oxygen)

Effect:

👉 Neurons stop working VERY fast

- Within seconds \rightarrow loss of consciousness

Why:

- Brain needs constant oxygen for ATP

💊 8. Drugs

Increase excitability:

- Caffeine, theophylline, theobromine
👉 Lower threshold \rightarrow easier firing

Decrease excitability:

- Anesthetics
👉 Raise threshold \rightarrow harder to fire

🧠 FINAL BIG PICTURE:

Concept	What it does
Parallel afterdischarge	Prolongs signal (delayed inputs)

Reverberatory circuit	Repeats signal (feedback loop)
Inhibitory circuits	Stop overactivity
Synaptic fatigue	Natural “shutdown”
Alkalosis	Overexcited brain (seizures)
Acidosis	Depressed brain (coma)
Hypoxia	Brain shuts down fast
Drugs	Can ↑ or ↓ activity

Alkalosis vs Acidosis :

Alkalosis

Decrease in CO_2 (e.g., hyperventilation in panic attacks) \rightarrow \uparrow blood pH \rightarrow \uparrow neuronal excitability \rightarrow may precipitate cerebral epileptic seizures.

Acidosis

Increase in CO_2 or accumulation of metabolic acids (e.g., diabetic or uremic) \rightarrow \downarrow blood pH \rightarrow \downarrow neuronal excitability \rightarrow can lead to coma (especially when severe).

To remember it:

- Alkalosis \rightarrow from alkaline \rightarrow high pH
- Acidosis \rightarrow from acidic \rightarrow low pH

Remember: it's for understanding the terms, not the cause.

Done by Omar Mahmoud