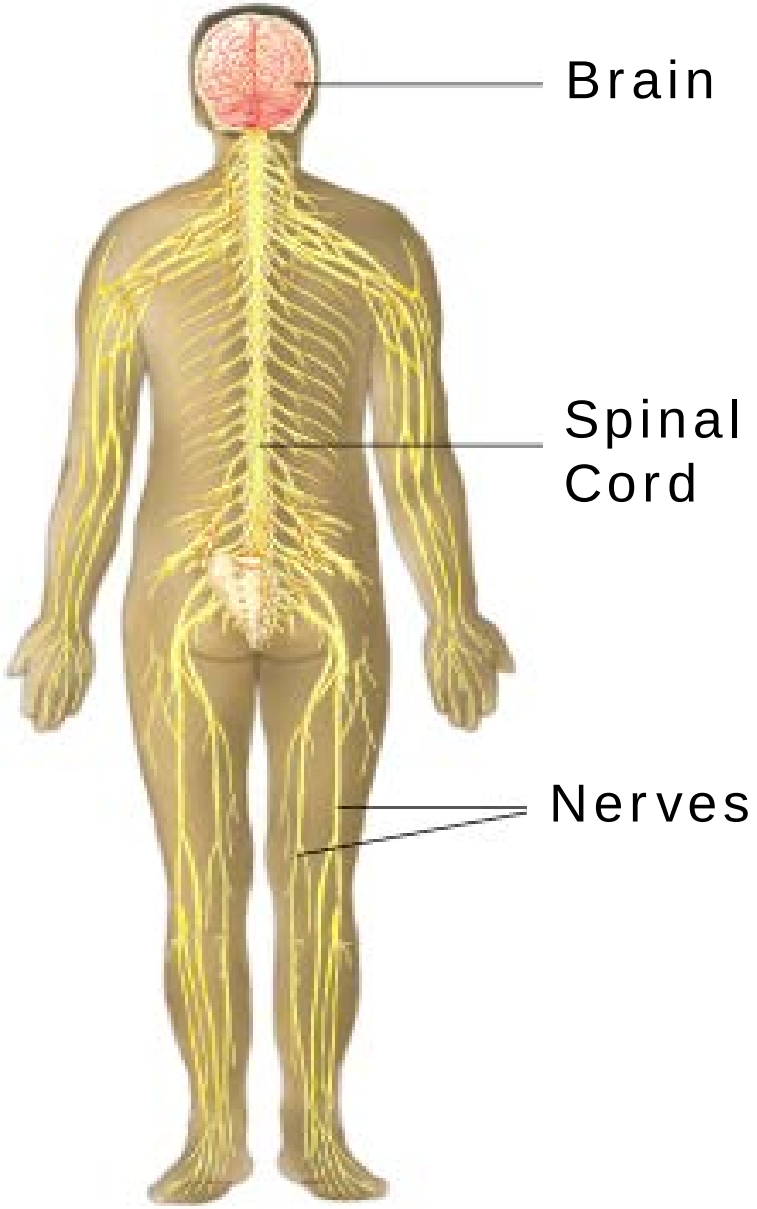
# The Nervous System



# 신경 소통: 개요

- 인체는 그 생존을 위한 두 가지 주 조절계를 가짐
  - **신경계**: 신경세포들에 의해 이루어지는 신경 소통
  - **내분비계**: 호르몬들에 의해 이루어지는 소통

- 신경과 근육은 흥분성 조직들

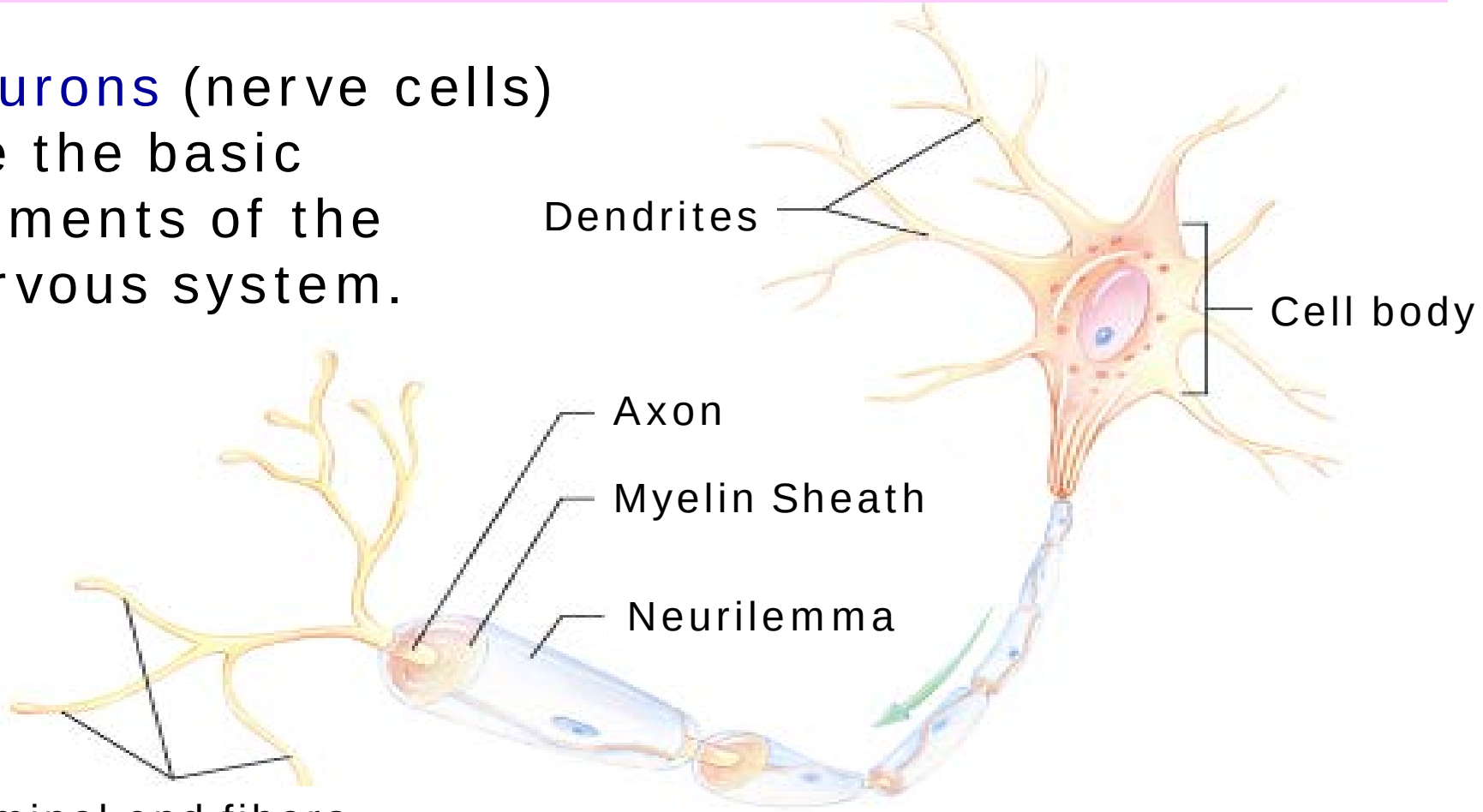
- 그들의 막전위의 신속한 변화 일으킬 수 있음

- 그들의 휴지전위를 전기신호로 변화시킬 수 있음
  - 전기신호가 신경계와 모든 근육들의 기능에 중요

# Structure and Function

All bodily activities, voluntary and involuntary, are controlled by the nervous system.

Neurons (nerve cells) are the basic elements of the nervous system.



# Structure and Function

A typical neuron is divided into three parts: the soma or cell body, dendrites, and axon.

## Cell Body

**The main processing center of the cell**

구형, 타원형 혹은 별 모양, 일반적으로 다른 세포보다 큼

신경세사와 미세소관들이 망상을 이룸

니슬소체 (Nissl body (RER), 호반소체) 함유

핵과 세포 소기관들이 존재

가는 돌기들인 여러 수상돌기들이 나 있으며, 하나의 굵은 돌기인 축삭이 나와 있음

# Dendrites

**Thin branching extensions of the cell body that conduct nerve impulses *to ward* the cell body.**

여러 개가 있으며 구심성 돌기임

니슬소체나 미토콘드리아를 볼 수 있으나, 골지체는 없음

안테나 모양의 가는 돌기 구조물들로서 입력 신호를 세포본체로 전달

수상돌기와 세포본체가 뉴런의 입력구역

# Axon

A single branch (in most neurons) which conducts nerve impulses *away* from the cell body.

Myelin sheath and neurilemma are coverings.

1개씩 있으며, 원심성 돌기(신경섬유)- 니슬소체 없음

축삭소구(axon hillock): 역치가 낮고 Na+통로가 많음, 활동전압 발생부위

신경섬유(nerve fiber)라고도 부름

하나의 길고 관으로 된 돌기로서 활동전위를 세포본체로부터 멀리 전도시키는 부위

뉴런의 전도구역

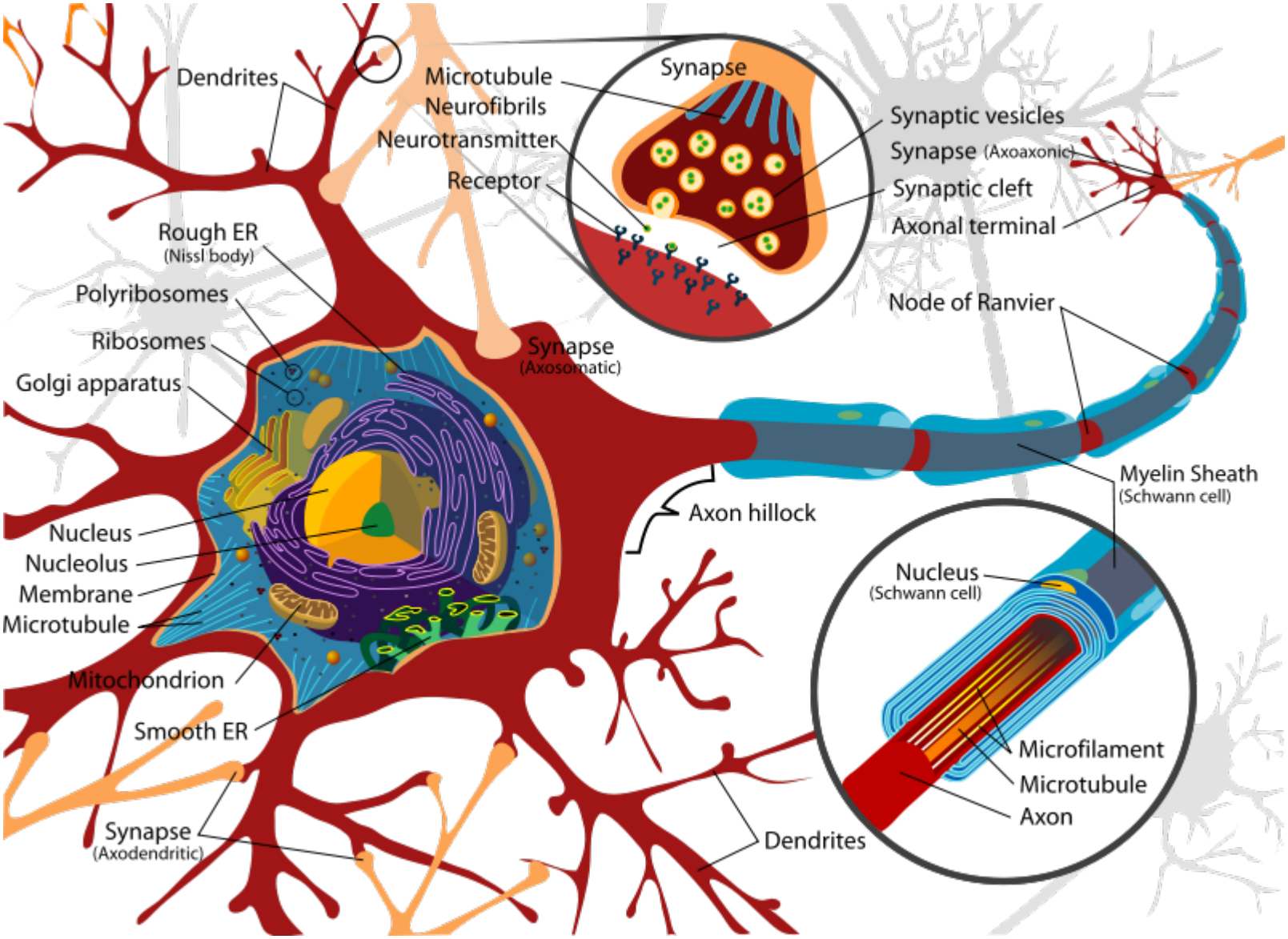
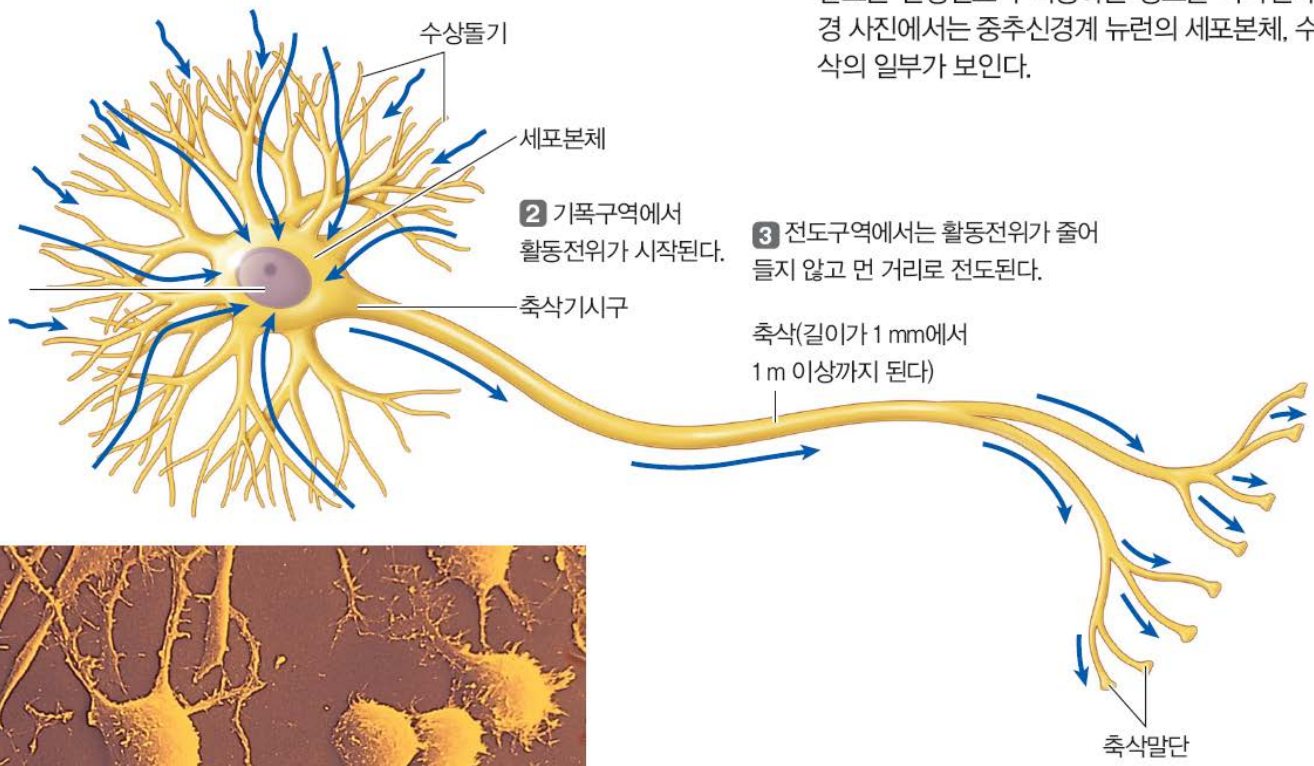
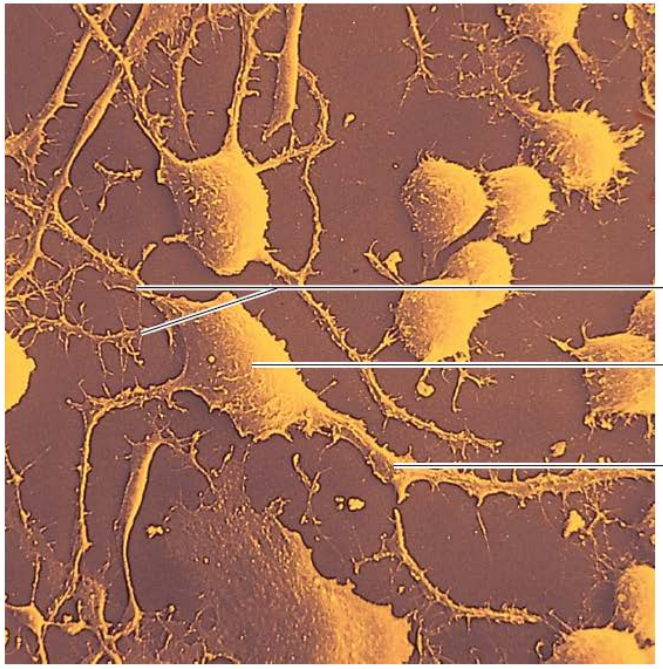



Diagram of a typical myelinated vertebrate motoneuron

**● 그림 4-8 일반적인 뉴런의 구조.** 대부분의 뉴런은 이 그림에 나타나 있는 기본적인 부위들로 이루어져 있다. 화살표는 신경신호가 이동하는 경로를 나타낸다. 전자현미경 사진에서는 중추신경계 뉴런의 세포본체, 수상돌기, 축삭의 일부가 보인다.



# Structural classification

a. 다극 뉴런 **(multipolar neuron): more than two dendrites**

**ex)** 골격근을 지배하는 운동 뉴런

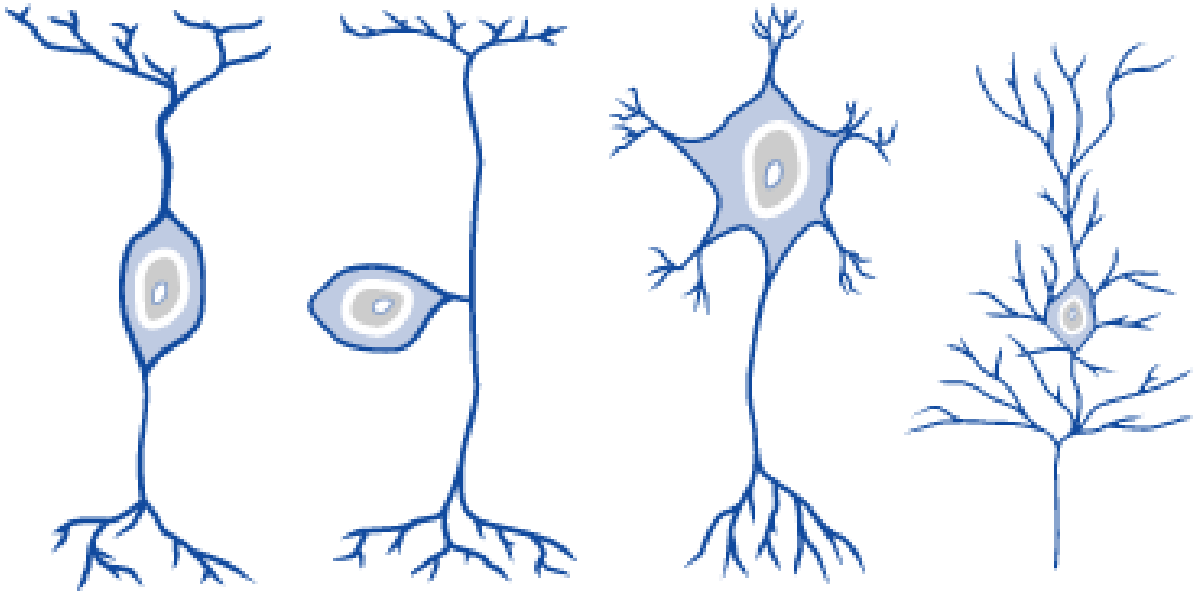
b. 이극 뉴런 **(bipolar neuron): axon and single dendrite on opposite ends of the soma.**

**ex)** 눈의 망막이나 귀의 와우신경절 구성

c. 단극 뉴런 **(unipolar neuron): dendrite and axon emerging from same process.**

**ex)** 척수 후근 신경절 구성

## Basic Neuron Types



Bipolar (Interneuron)

Unipolar (Sensory Neuron)

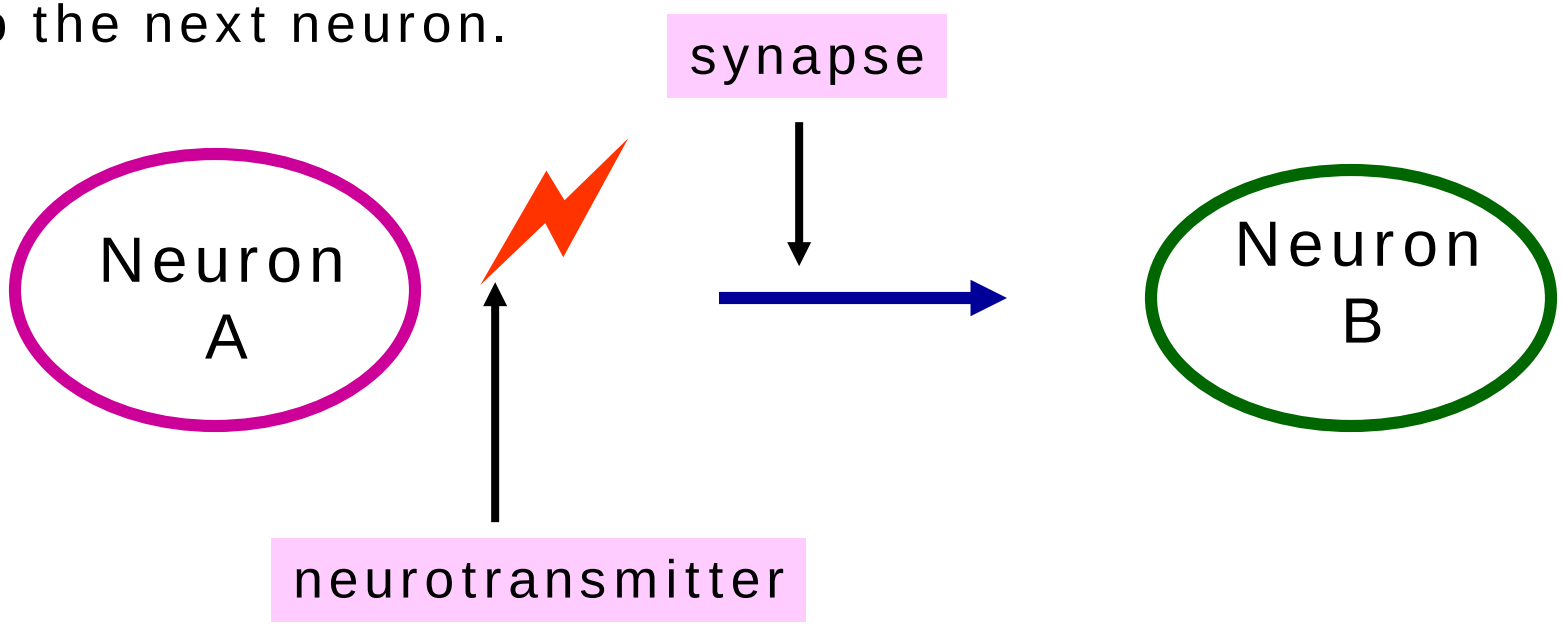
Multipolar (Motoneuron)

Pyrimidal Cell

# Structure and Function

## Impulse Transmission

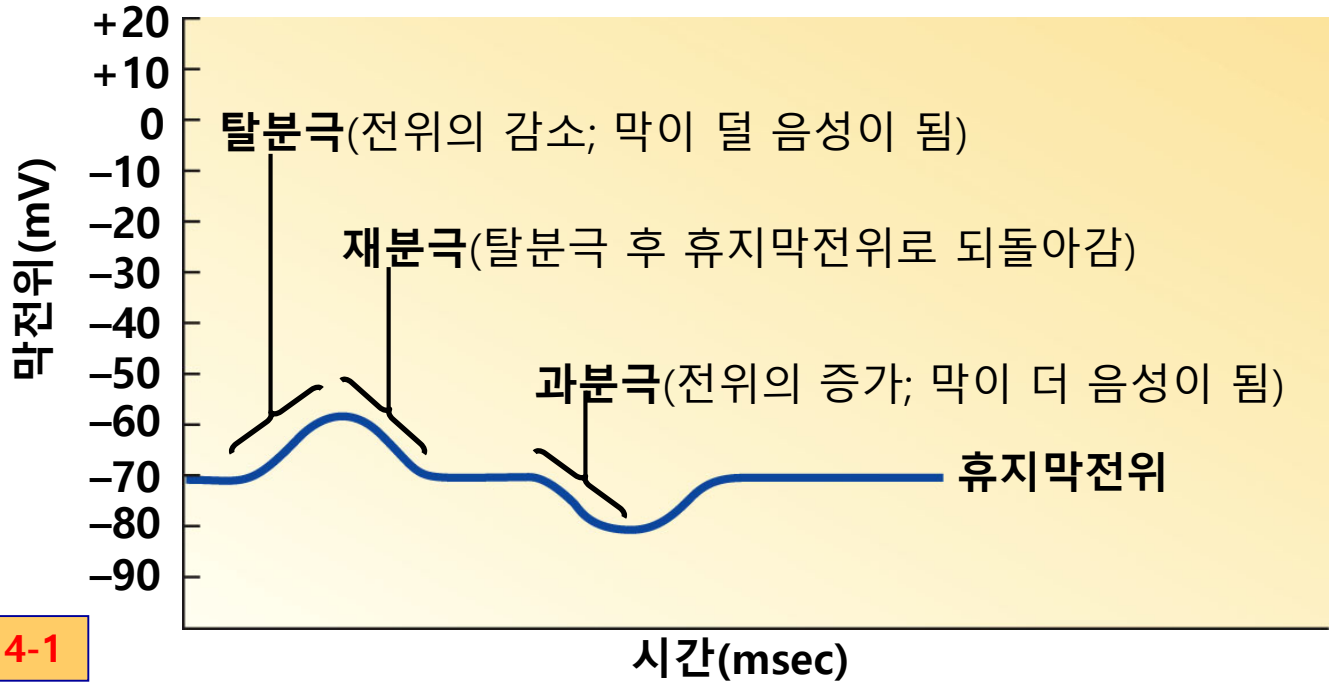
Terminal end fibers are located at the ends of the axon and they transmit impulses leaving the neuron across a synapse to the next neuron.




All neurons have two basic properties → excitability, conductivity

# Establishment of the Resting Membrane Potential

- **막의 전기적 상태**
  - **분극(polarization):** 0 mV가 아닌 막전위가 있는 상태
  - **탈분극(depolarization):** 막전위가 휴지전위 때보다 덜 분극된 상태
  - **재분극(repolarization):** 막전위가 탈분극된 후 휴지전위로 되돌아 온 것
  - **과분극(hyperpolarization)**
    - 막전위가 휴지전위보다 더 분극된 상태

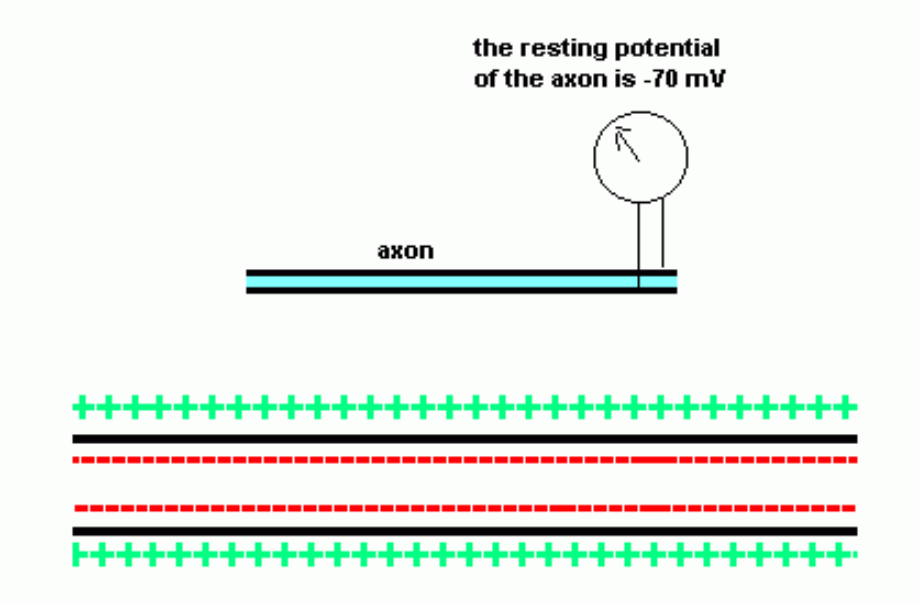


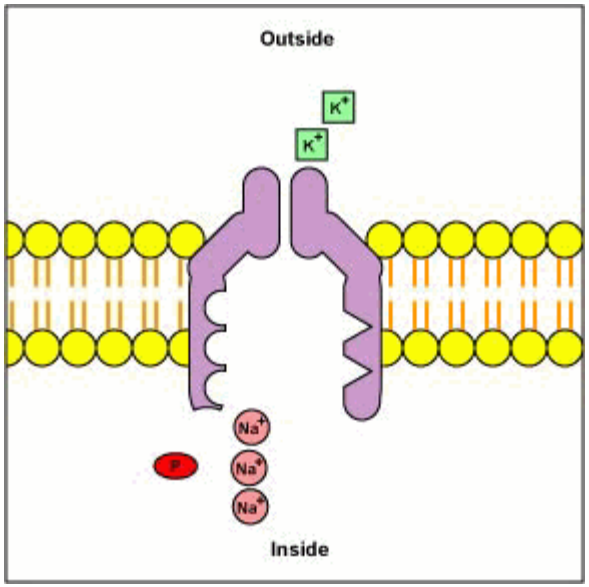

● 그림 4-1

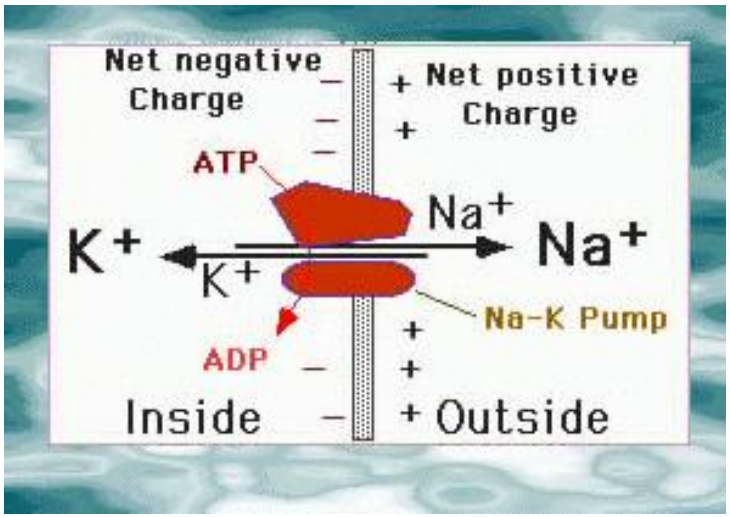
# Establishment of the Resting Membrane Potential

- Membranes are polarized or, in other words, exhibit a RESTING MEMBRANE POTENTIAL.
- This means that there is an unequal distribution of ions (atoms with a positive or negative charge) on the two sides of the nerve cell membrane.
- This POTENTIAL generally measures about 70 millivolts (with the INSIDE of the membrane negative with respect to the outside).
- So, the RESTING MEMBRANE POTENTIAL is expressed as -70 mV, and the minus means that the inside is negative relative to (or compared to) the outside.
- It is called a RESTING potential because it occurs when a membrane is not being stimulated or conducting impulses (in other words, it's resting).

# What factors contribute to this membrane potential?



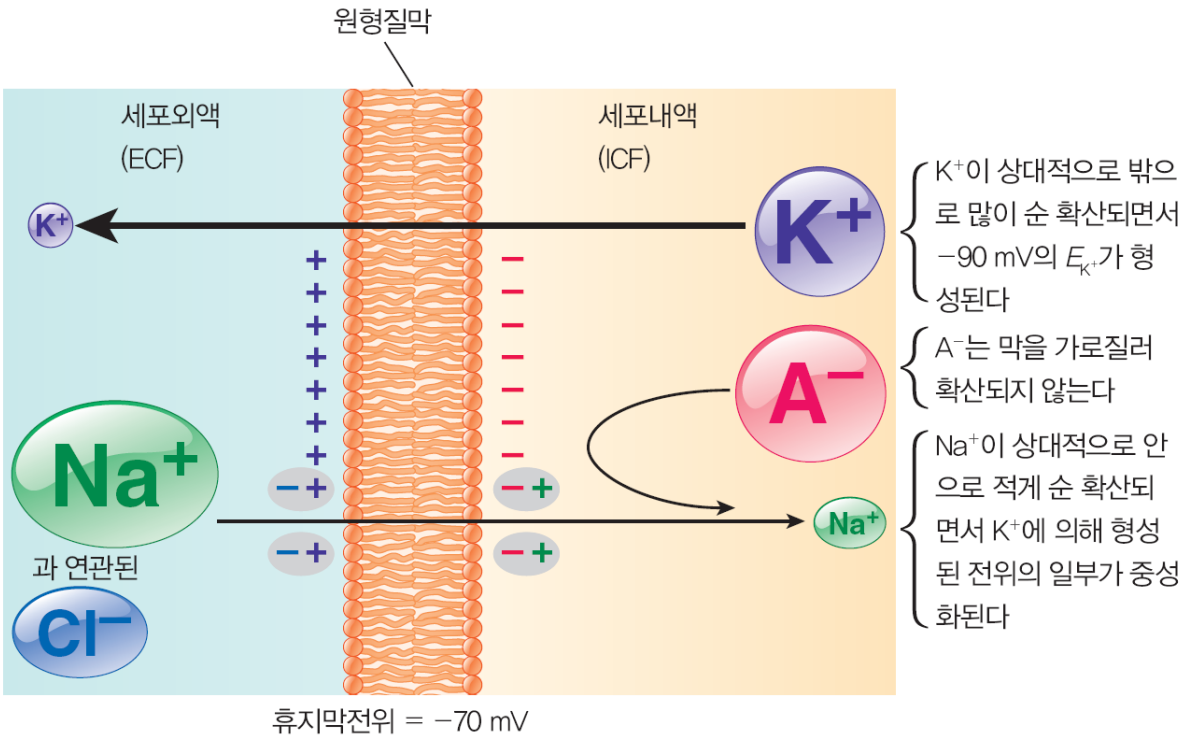
**1** $Na^+$-$K^+$ 펌프의 작용으로 $Na^+$은 세포 밖으로 $K^+$은 세포 안으로 수송됨에 따라 세포외액에서는 $Na^+$ 농도가 높게 그리고 세포내액에서는 $K^+$ 농도가 높게 유지된다.

**2** 원형질막을 사이에 두고 형성된 농도기울기에 의해서 $K^+$는 막전위를 $K^+$ 평형전위인 −90 mV로 되게 하려는 반면, $Na^+$는 $Na^+$ 평형전위인 +60 mV로 되게 하려는 경향을 가지게 된다.

**3** 하지만 $K^+$가 막을 더 잘 투과하기 때문에 휴지막전위에는 $K^+$이 주도적인 영향을 미친다. 그 결과 휴지막전위 (−70 mV)는 $Na^+$ 평형전위 ($E_{Na^+}$)보다는 $K^+$ 평형전위 ($E_{K^+}$)에 더 근접하게 된다.

**4** 휴지막전위가 형성되는 동안 비교적 많은 $K^+$이 외부로 순 확산됨에도 불구하고 −90 mV의 전위를 형성하지 못하는 이유는 $Na^+$이 휴지막을 조금씩 투과하면서 일어나는 비교적 적은 내부로의 $Na^+$의 순 확산이 $K^+$ 단독으로 형성할 수 있는 막전위의 일부를 중성화시키기 때문이며 그 결과 휴지막전위는 $E_{K^+}$보다 약간 작은 −70 mV로 형성된다.

**5** 양으로 하전된 이온이 외부로 순 이동하는 동안 음으로 하전된 세포 내부의 단백질($A^-$)은 막을 투과할 수 없기 때문에 세포 내부에 불균형하게 남아 있게 되면서 세포 내부는 외부에 비해 더 음으로 하전이 된다.




● **그림 3-21 휴지막전위 형성에 있어서 같이 이동하는 $K^+$과 $Na^+$의 영향.**

# Signals for Initiation of Action Potential

Stimulus → depolarization

- Chemical stimulation : neurotransmitter binds to receptor
- Mechanical stimulation
- Electrical stimulation

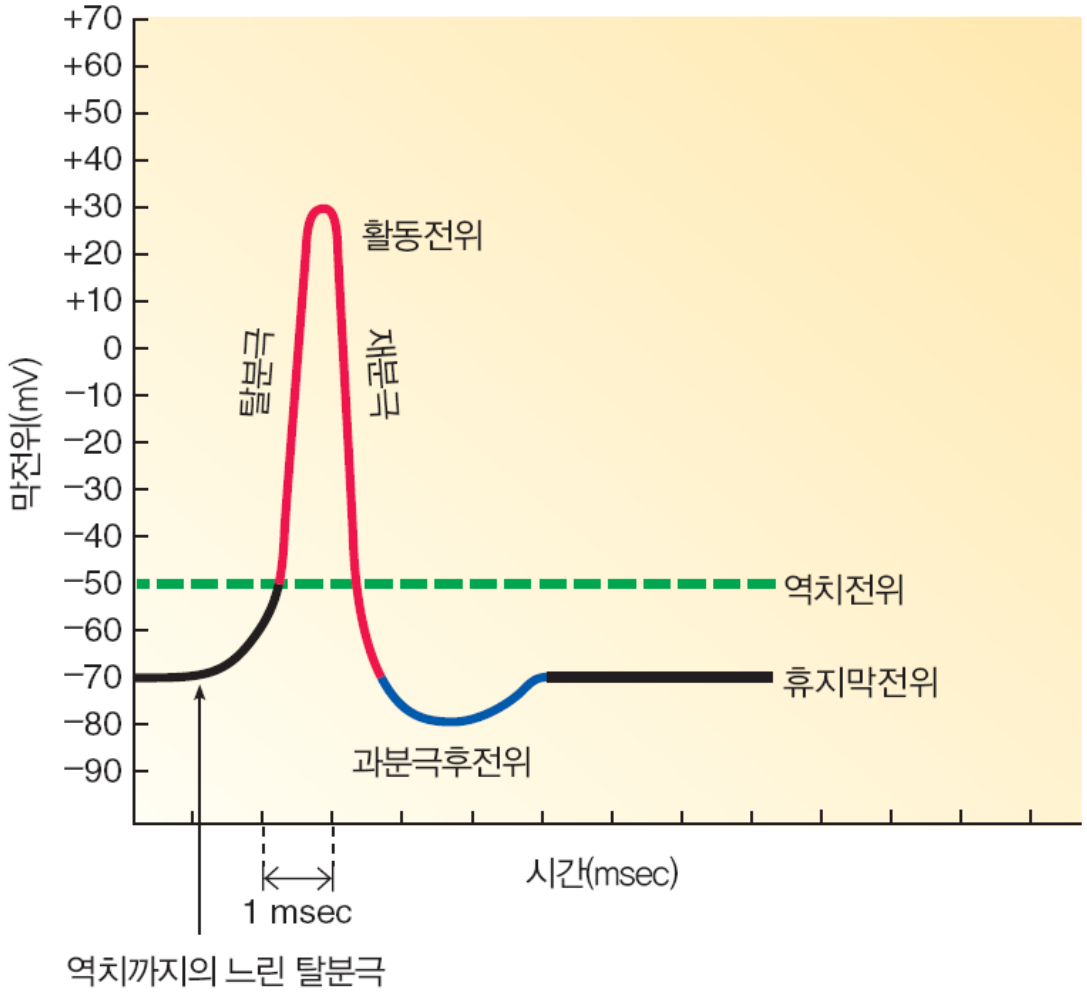
# The Nerve Impulse

- When a nerve is stimulated the resting potential changes.
- Examples of such stimuli are pressure, electricity, chemicals, etc.
- Different neurons are sensitive to different stimuli(although most can register pain).
- The stimulus causes sodium ion channels to open.
- The rapid change in polarity that moves along the nerve fiber is called the "ACTION POTENTIAL”
- This moving change in polarity has several stages:

# 활동전위(action potential)

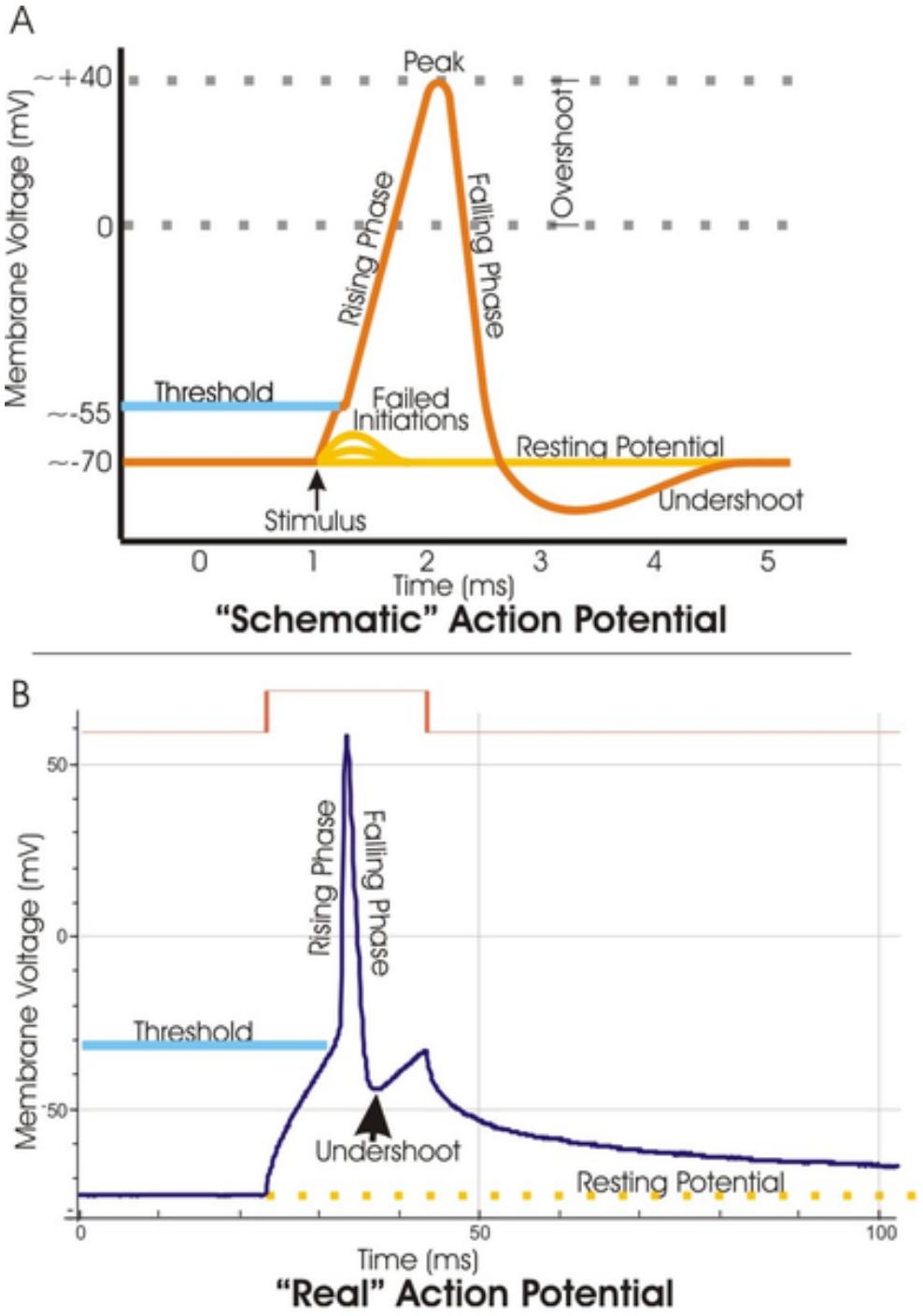
- 짧고 빠르며 큰(100 mV) 막전위 의 변화로서,
  이 기간에 전위가 실제로 역전됨
- 전체 흥분성 막 중 작은 부분에서만 일어남
- 초기 부위에서 나머지 세포막 전체로 이동하는데 크기가 줄어들지 않음

# 활동전위 동안 막전위의 변화




**역치전위 (threshold potential):** 흥분성 막이 흥분할 수 있는 최소한의 자극

● 그림 4-4 활동전위 동안 막전위의 변화.


A
Membrane Voltage (mV)
~+40
0
~-55
~-70
Peak
Rising Phase
Falling Phase
Overshoot
Threshold
Failed Initiations
Resting Potential
Stimulus
Undershoot
0
1
2
3
4
5
Time (ms)
"Schematic" Action Potential
B
Membrane Voltage (mV)
50
0
-50
Rising Phase
Falling Phase
Threshold
Undershoot
Resting Potential
0
50
100
Time (ms)
"Real" Action Potential

# Depolarization

- The upswing is caused when positively charged sodium ions(Na+) suddenly rush through open sodium gates into a nerve cell.
- The membrane potential of the stimulated cell undergoes a localized change from-65 millivolts to 0 in a limited area.
- As additional sodium rushes in, the membrane potential actually reverses its polarity so that the outside of the membrane is negative relative to the inside.

## Depolarization (cont.)

- During this change of polarity the membrane actually develops a positive value for a moment(+40 millivolts).
- The change in voltage stimulates the opening of additional sodium channels (called a voltage-gated ion channel).
- This is an example of a positive feedback loop.

# Repolarization

- (The downswing) is caused by the closing of sodium ion channels and the opening of potassium ion channels.
- Release of positively charged potassium ions (K+) from the nerve cell when potassium gates open.
- Again, these are opened in response to the positive voltage--they are voltage gated.
- This expulsion acts to restore the localized negative membrane potential of the cell (about -65 or -70 mV is typical for nerves).

## (2) 이온 이동에 의한 활동전위의 생성

- 막이 역치전위에 도달했을 때:
  - 막에 있는 **전압-개폐형 $Na^+$ 채널(그림 4-5)**의 입체구조 변화
  - $Na^+$들의 ICF로의 흐름에 의해 막전위 -70 mV에서 +30 mV로 역전
  - **전압-개폐형 $K^+$ 채널**(**그림 4-5**)을 통한 $K^+$들이 ECF로 흘러나감에 따라 막전위가 휴지 상태로 복원

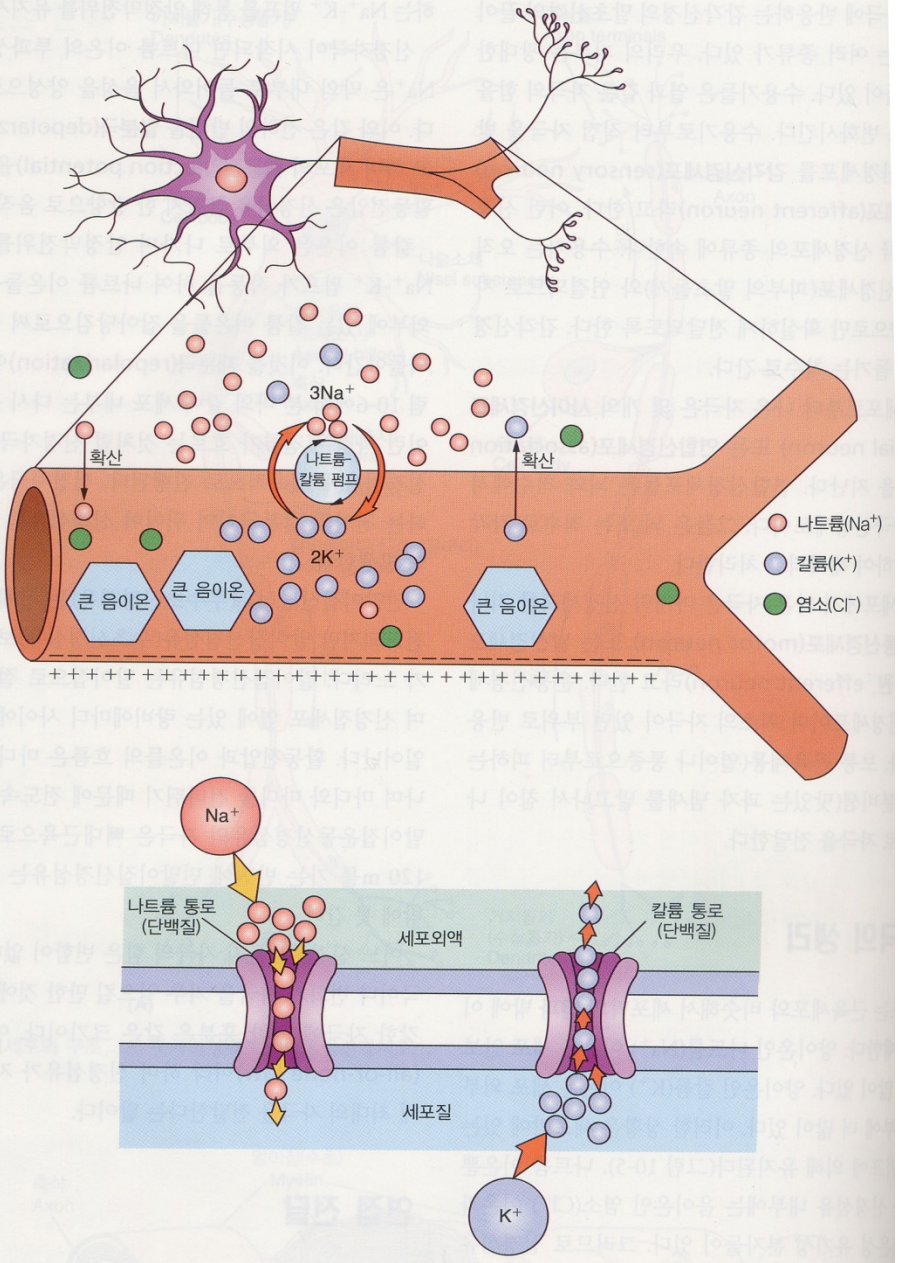
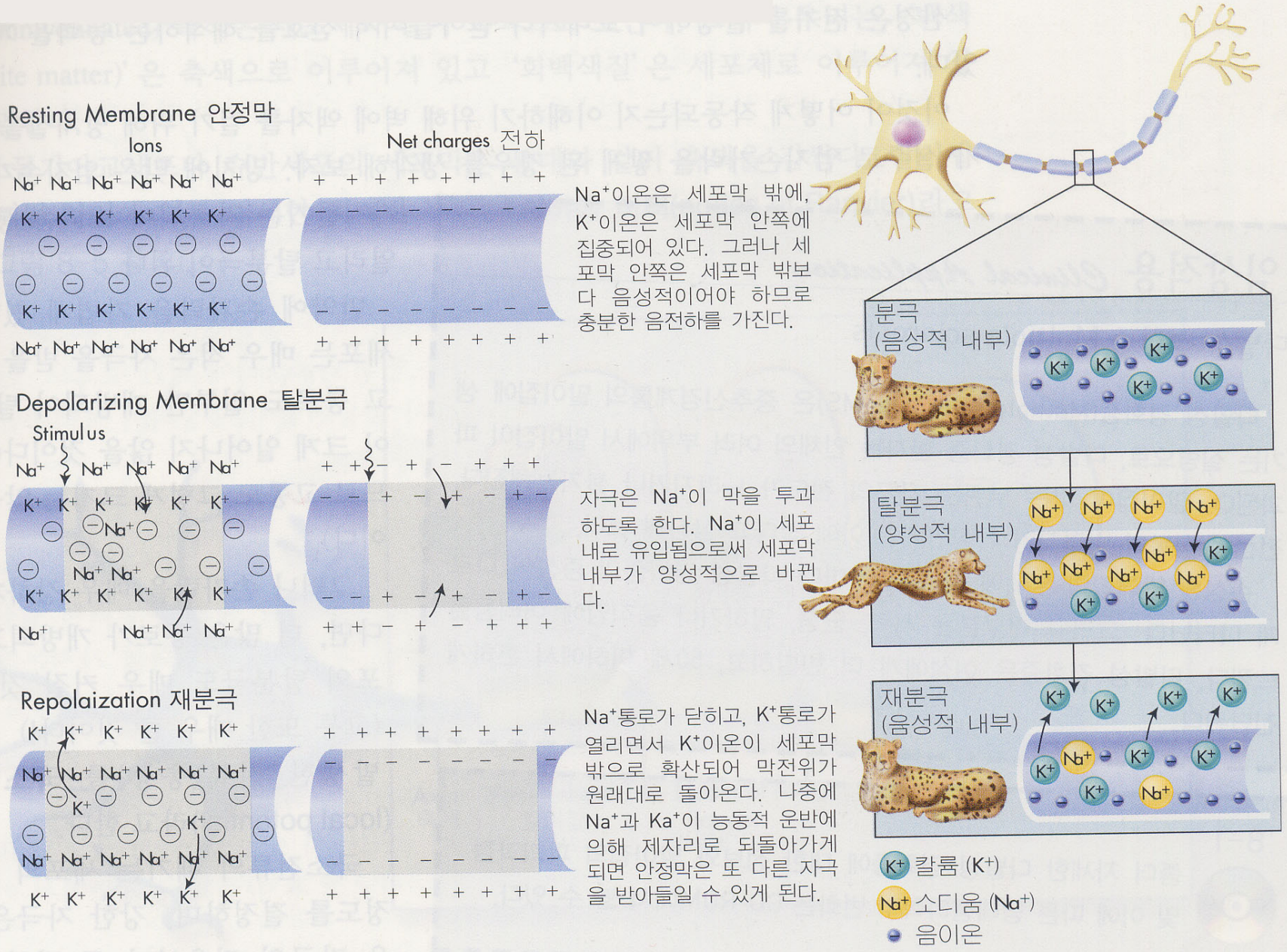
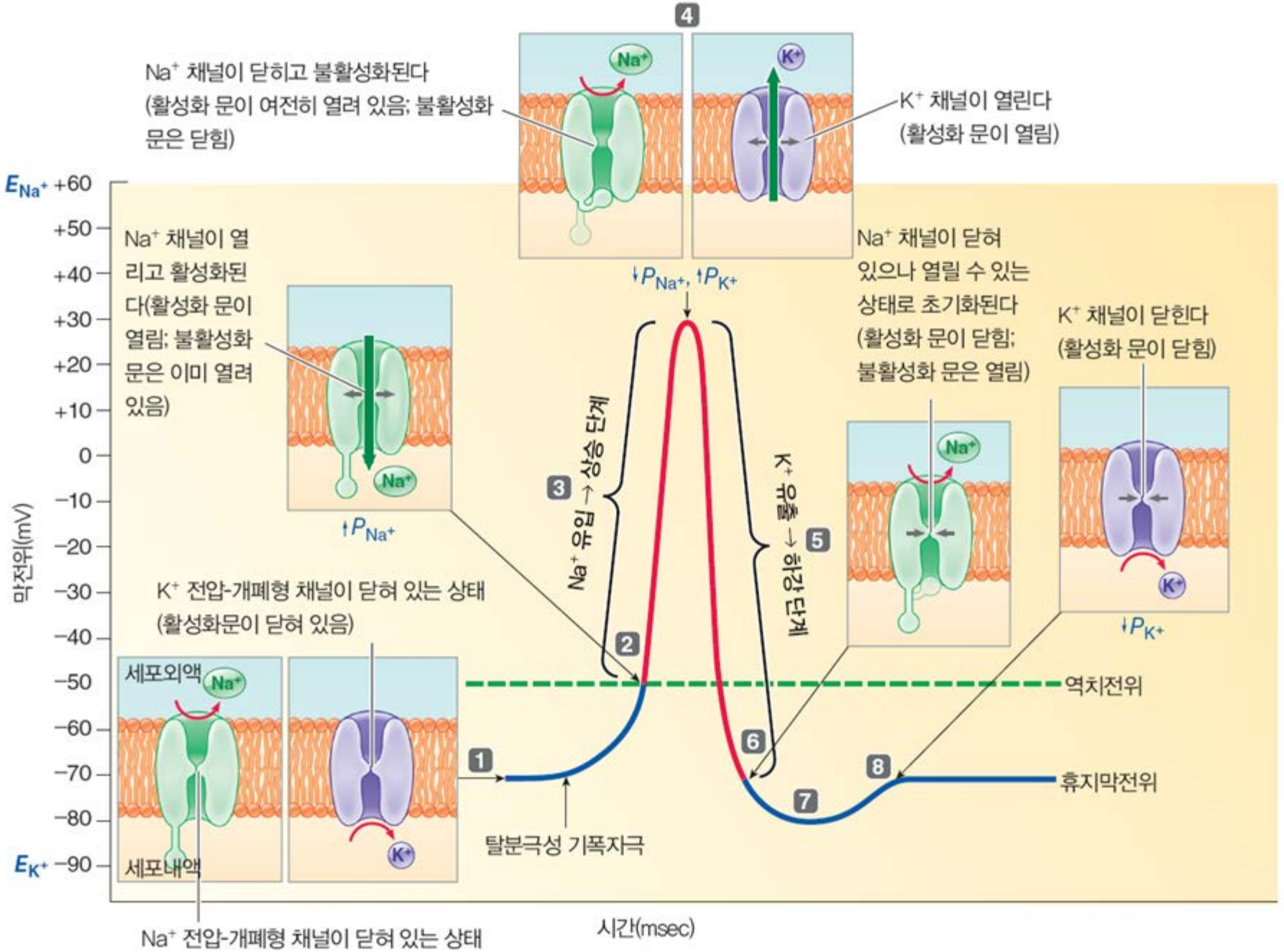



**그림 10-5.** 신경세포막의 나트륨-칼륨 펌프




〈그림 8-4〉 탈분극과 재분극




● **그림 4-7** 활동전위 동안 투과도 변화와 이온의 흐름.

# Action Potential

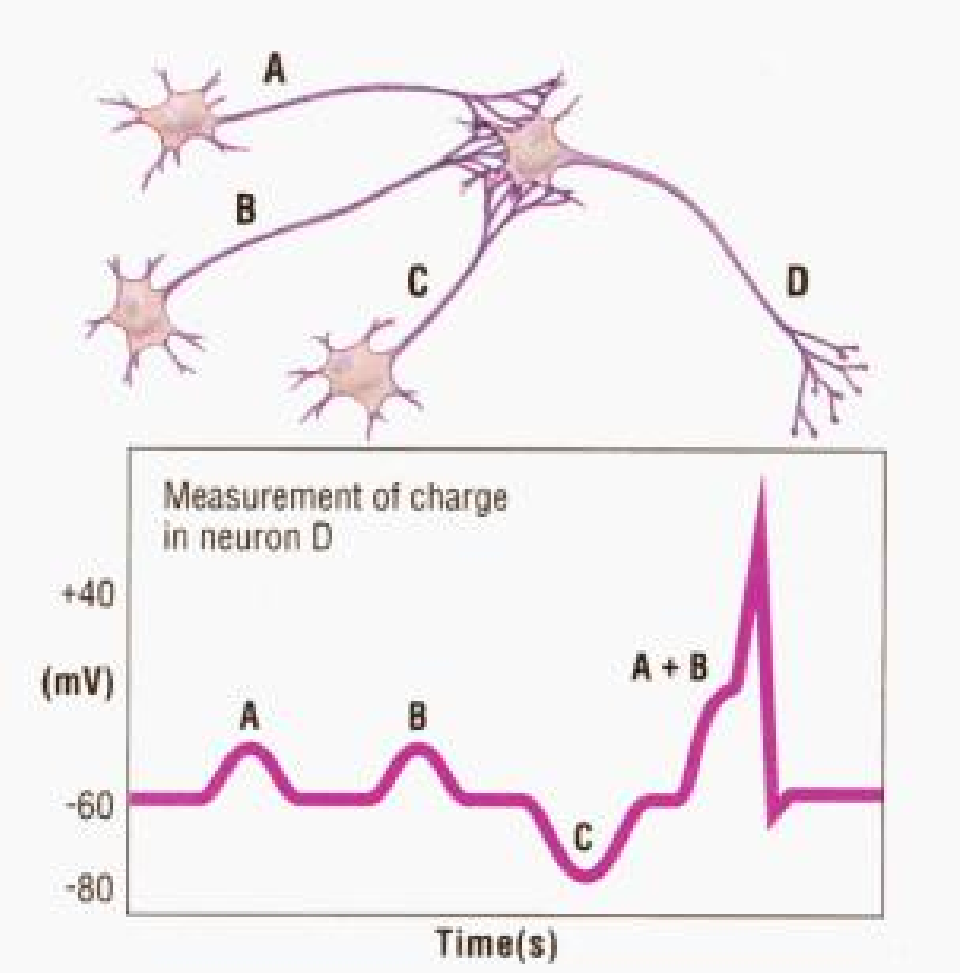
- **Threshold for action potential**

  If the membrane potential reaches the **threshold potential** (generally 5 - 15 mV less negative than the resting potential), the voltage-regulated sodium channels all open. Sodium ions rapidly diffuse inward, & depolarization occurs..

- **All-or-none**

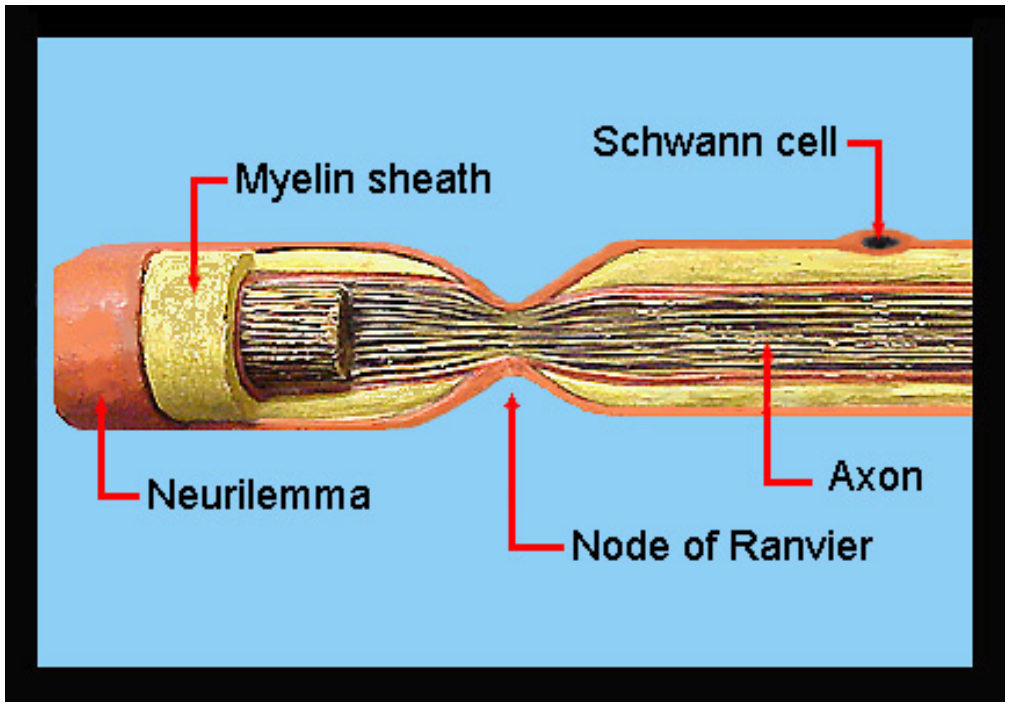
  action potentials occur maximally or not at all. In other words, there's no such thing as a partial or weak action potential. Either the threshold potential is reached and an action potential occurs, or it isn't reached and no action potential occurs.

- **Summation**


A
B
C
D
Measurement of charge
in neuron D
+40
(mV)
-60
-80
A
B
C
A + B
Time(s)

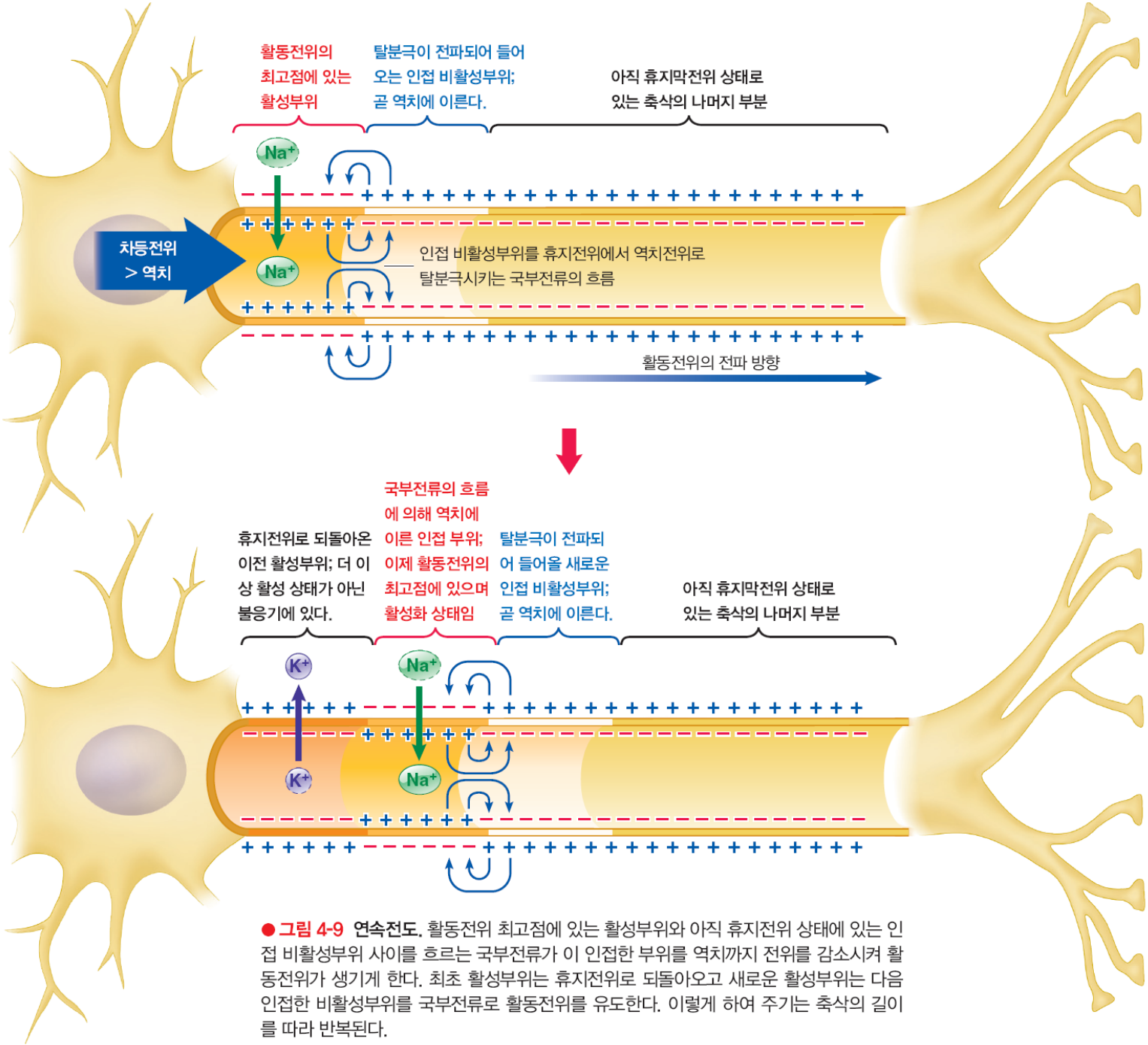
# Propagation of Action Potential

1. Unmyelinated neuron – local curcuit
2. Myelinated fiber
   - saltatory conduction : signal  jumps from node to node
   - rate of conduction ↑ (up to 100m/s)
   - conserves energy



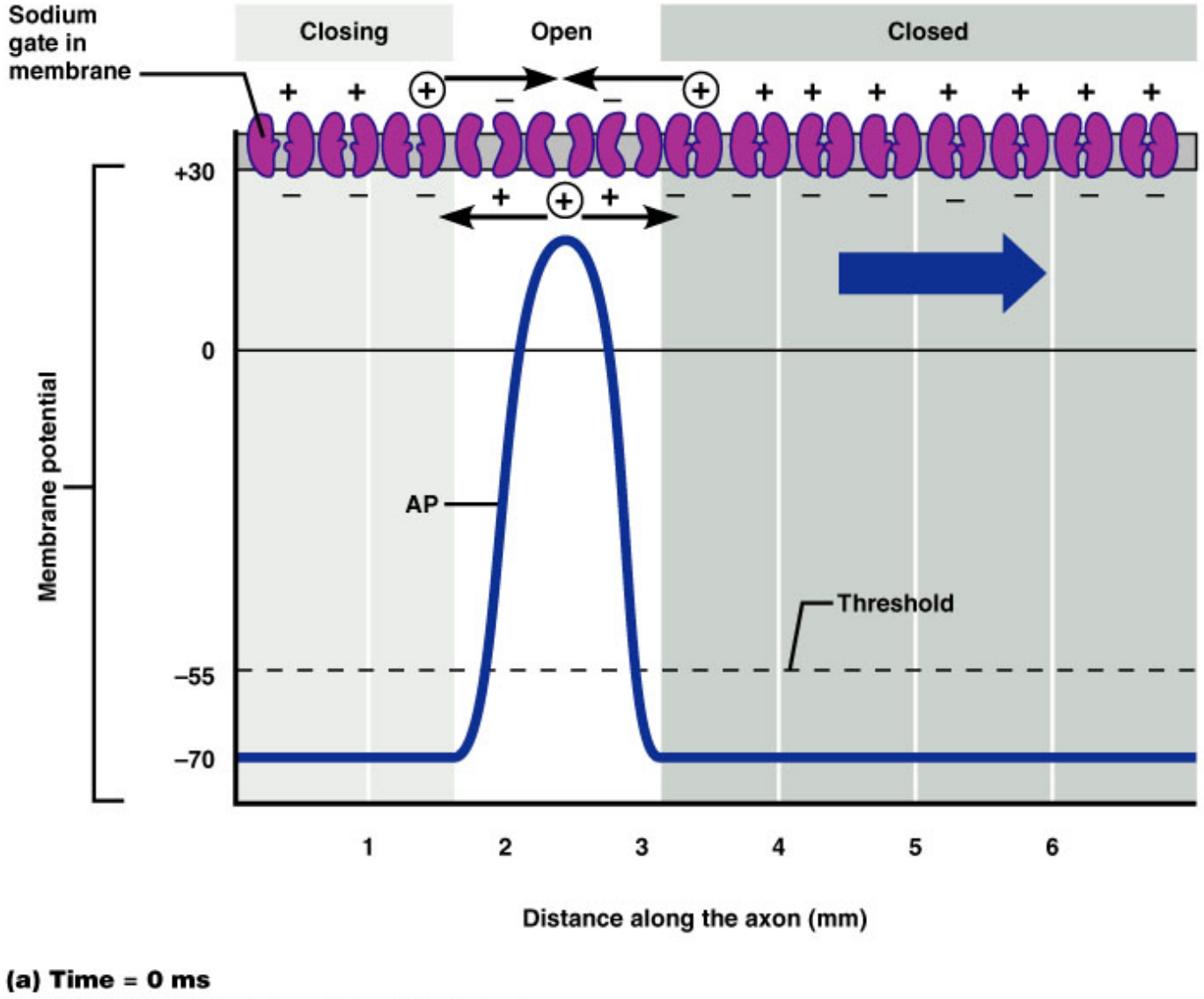
# (5) 신경충격(활동전위)의 전도

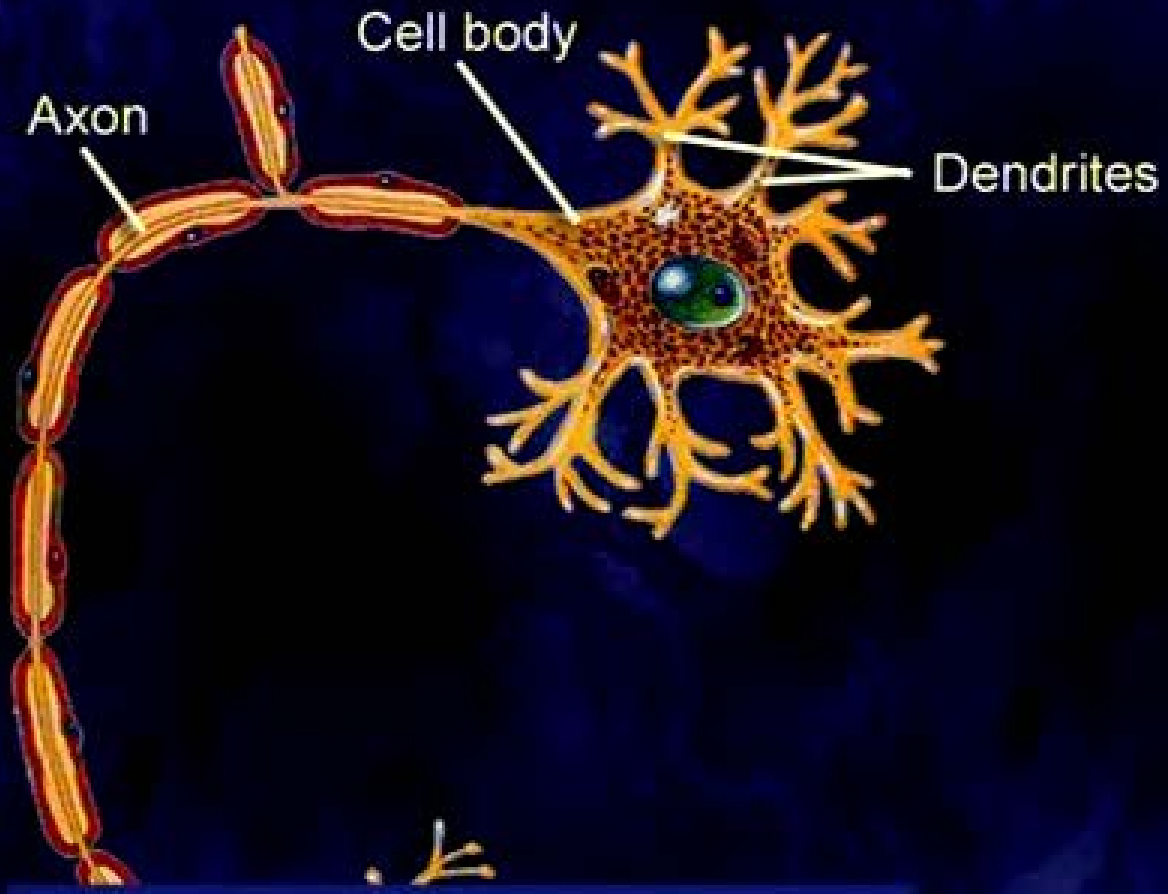
- 전도의 두 가지 형태
  - **연속전도(contiguous conduction)(그림 )**
    - 무수신경 섬유에서의 전도
    - 활동전위가 축삭막의 모든 부위를 따라가면서 축삭 끝까지 전파
  - **도약전도(saltatory conduction)(뒤에 설명)**
    - 유수신경 성유에서의 빠른 전도
    - 활동전위가 절연성의 수초로 덮인 부분을 넘어서 축삭 끝까지 전파



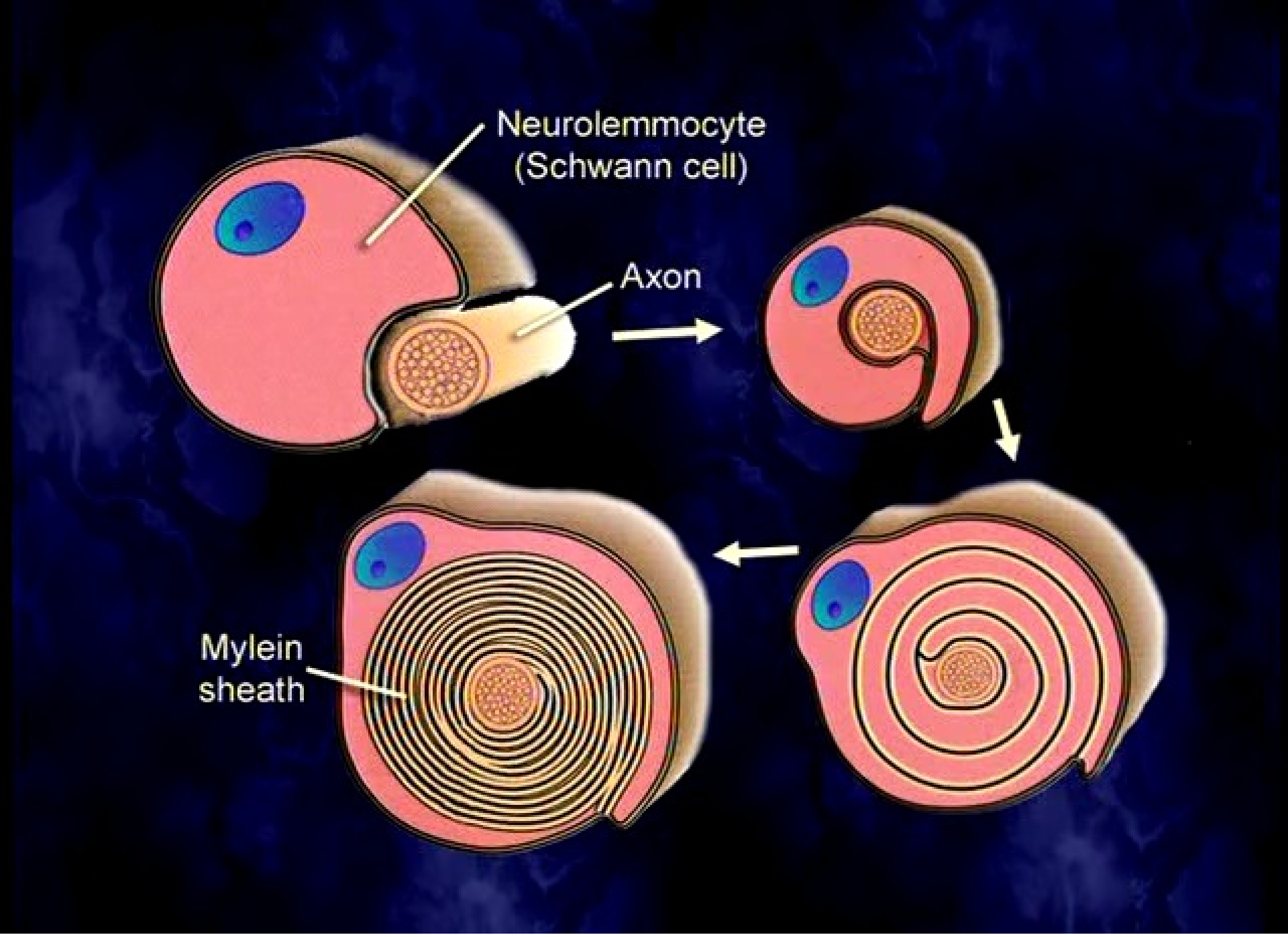

● **그림 4-9 연속전도.** 활동전위 최고점에 있는 활성부위와 아직 휴지전위 상태에 있는 인접 비활성부위 사이를 흐르는 국부전류가 이 인접한 부위를 역치까지 전위를 감소시켜 활동전위가 생기게 한다. 최초 활성부위는 휴지전위로 되돌아오고 새로운 활성부위는 다음 인접한 비활성부위를 국부전류로 활동전위를 유도한다. 이렇게 하여 주기는 축삭의 길이를 따라 반복된다.

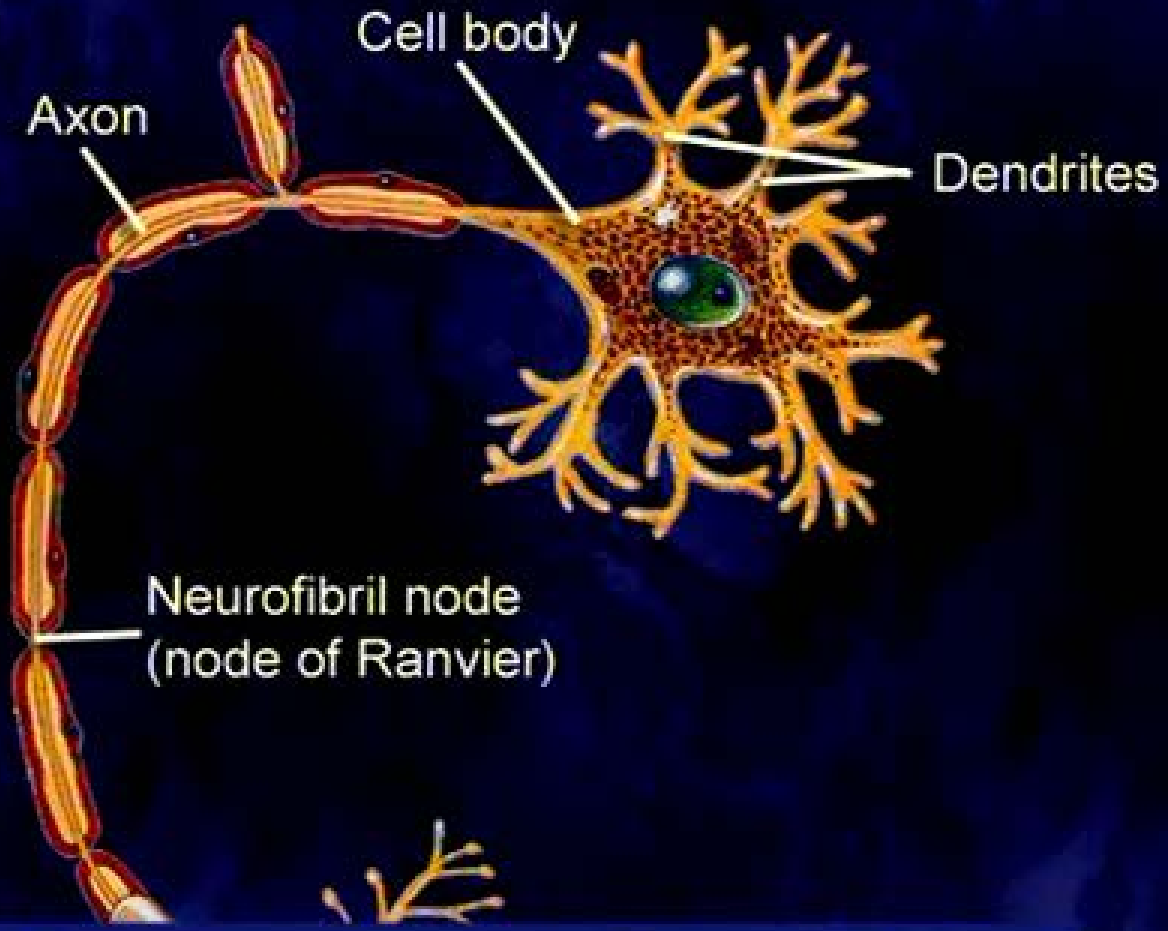
# Propagation of Action Potential



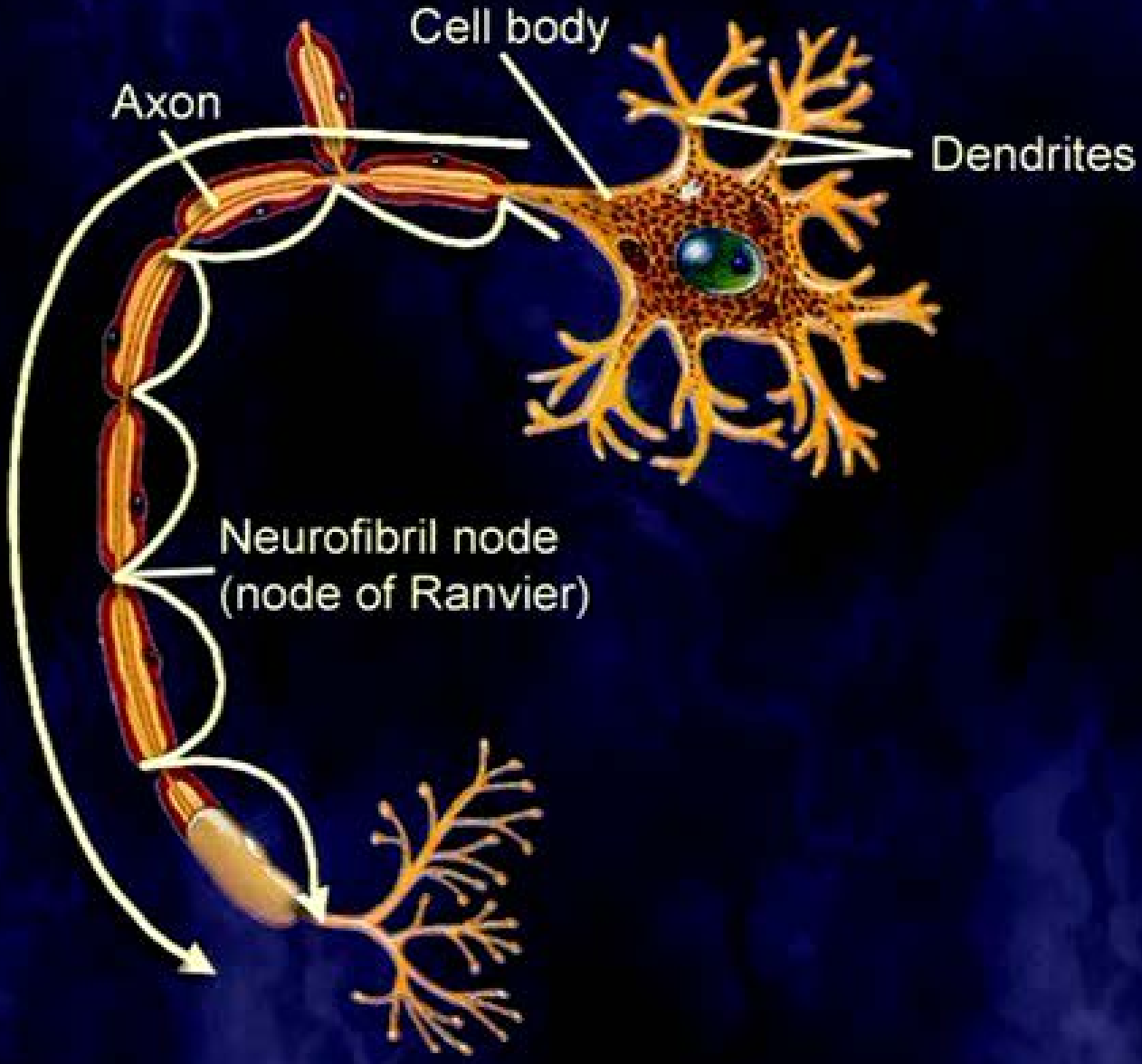



myelinated

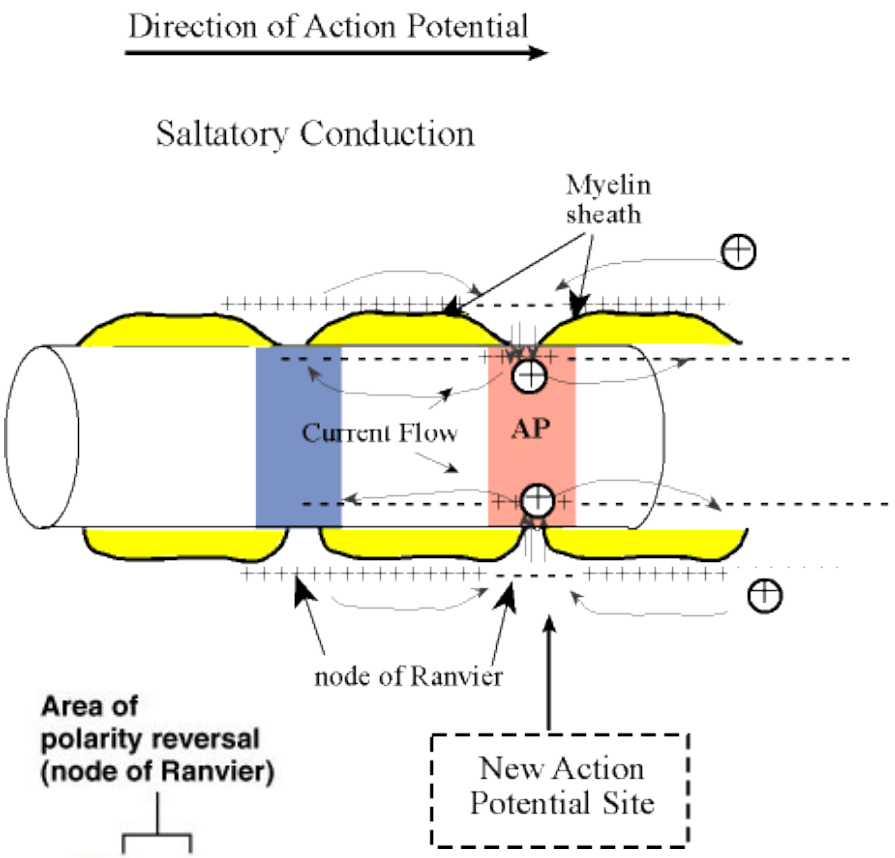

Neurolemmocyte
(Schwann cell)
Axon
Mylein
sheath

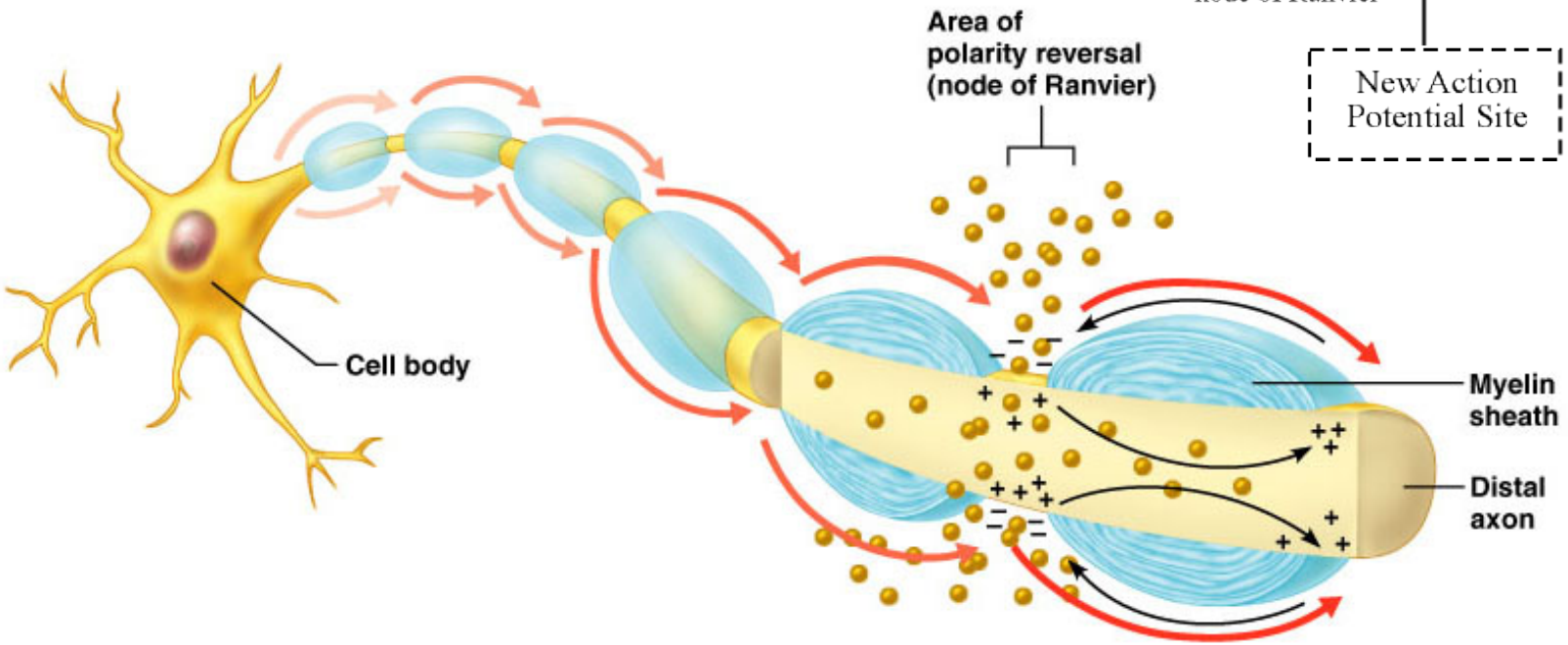



# saltatory conduction


Cell body
Axon
Dendrites
Neurofibril node
(node of Ranvier)

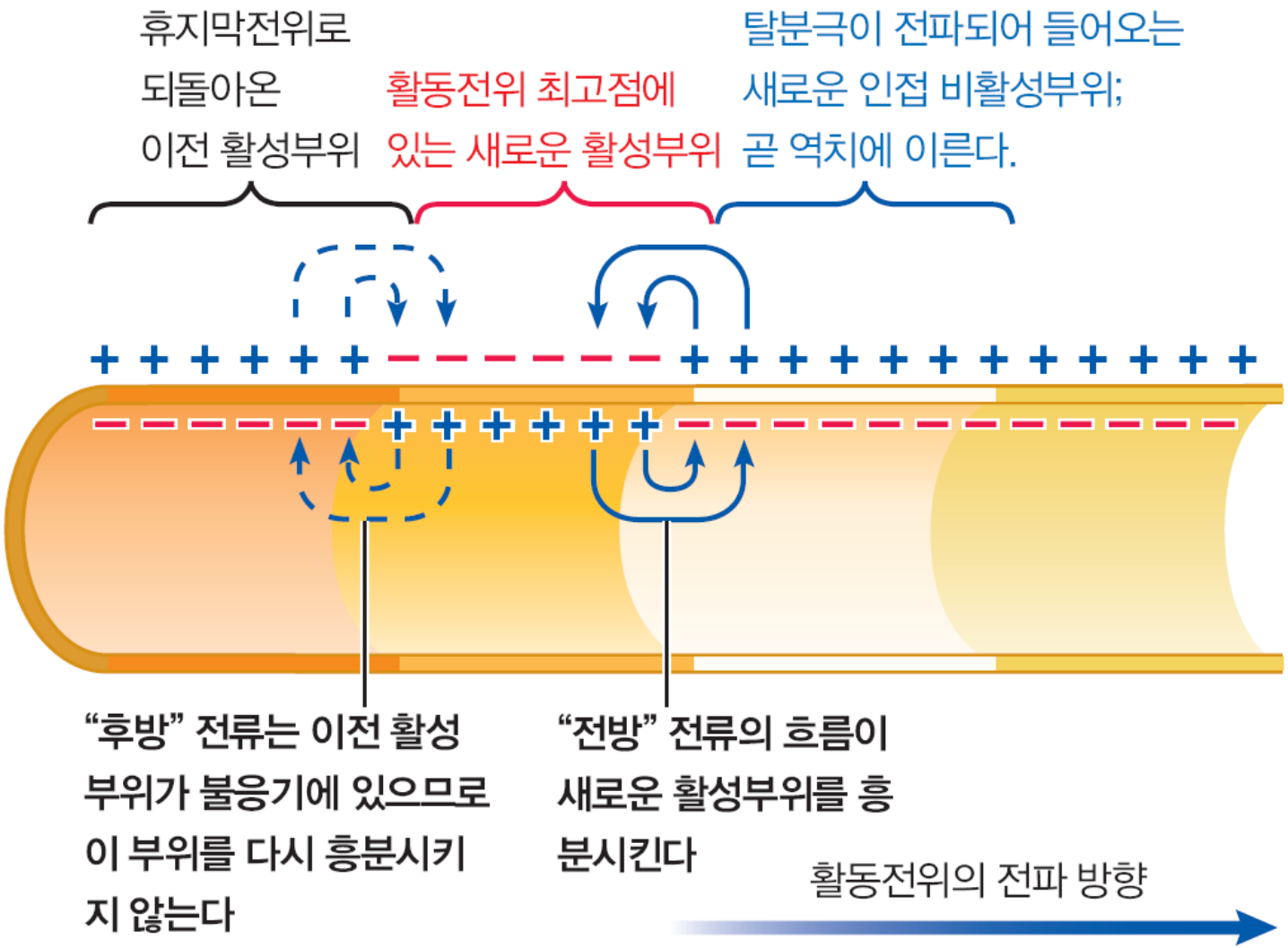
# Saltatory conduction (도약전도)



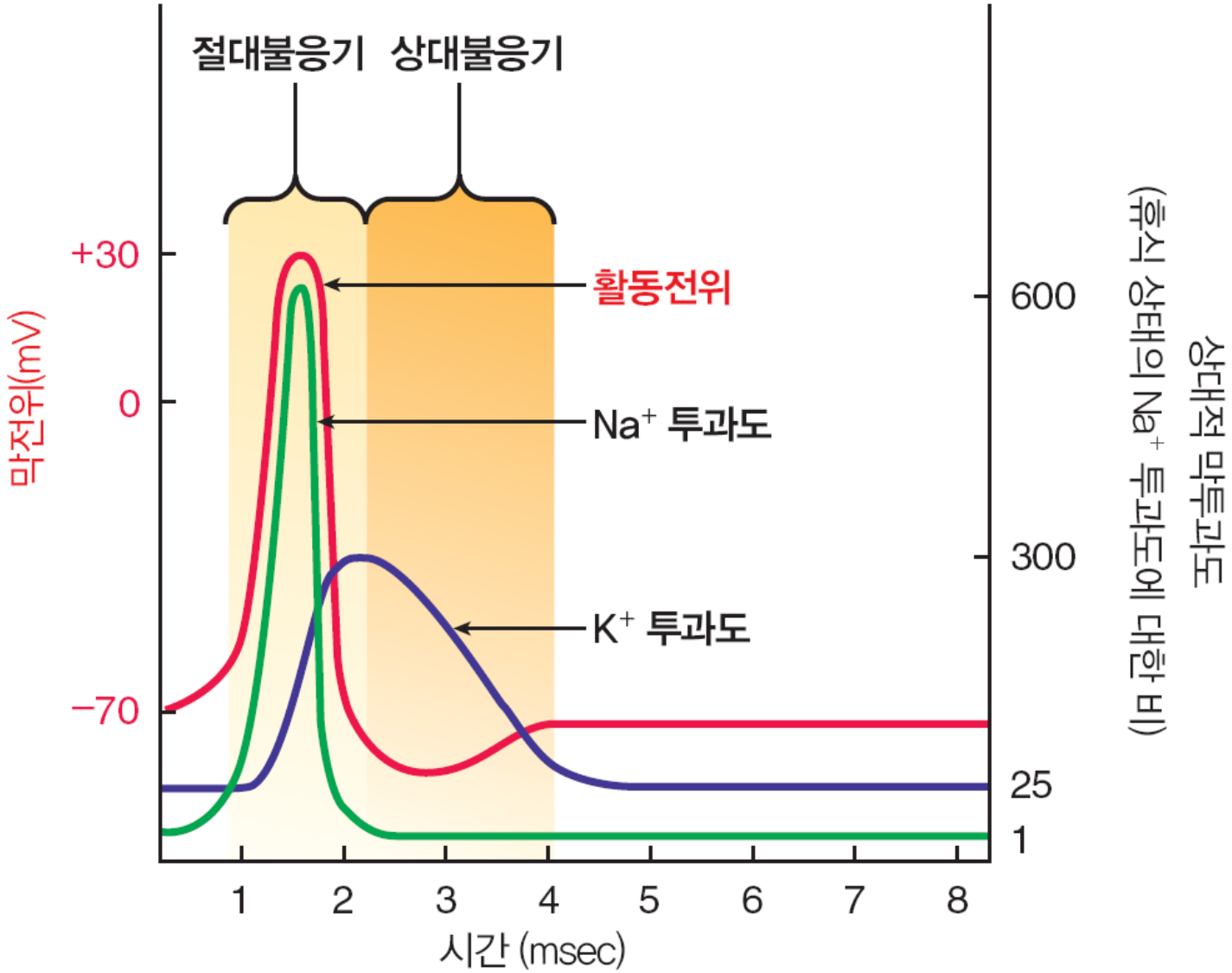



# 불응기와 실무율

- **불응기(refractory period)**
  - 방금 활동전위가 생긴 부위에서는 정상적인 방법으로는 새로운 활동전위가 개시될 수 없는 시기(**그림**)
    - **절대불응기**: 직전에 활성화된 막 부위가 새로운 자극에 대해 완전히 불응하는 시기
    - **상대불응기**: 절대불응기에 이어 나타나는 시기로서, 이 시기에는 기폭자극이 처음 줄 때보다 강하게 주면 두 번째 활동전위가 생길 수 있음




● **그림 4-10 불응기 의미.** 불응기는 "후방" 전류가 일어나지 않게 한다. 활동전위 동안과 조금 후에는 정상적인 자극으로는 새로운 활동전위가 생기지 않는다. 따라서 불응기는 활동전위가 축삭을 따라 확실하게 전방으로만 전파되도록 한다.



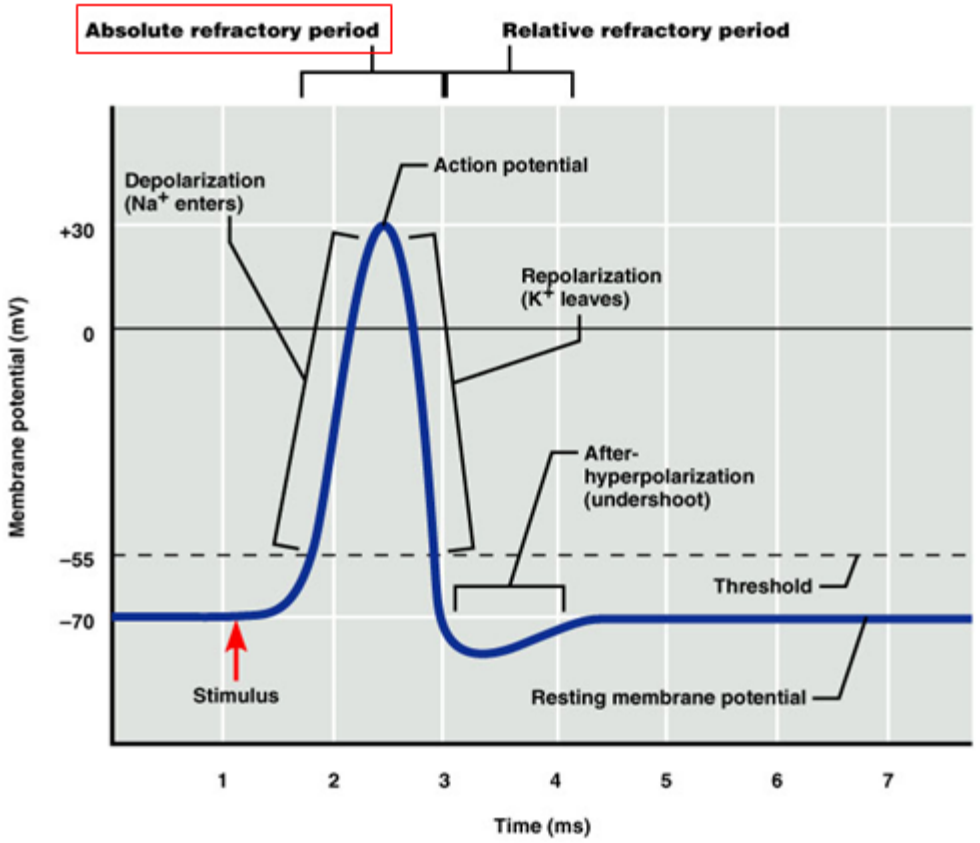

● **그림 4-11 절대불응기와 상대불응기.** 절대불응기동안 활동전위가 방금 일어났던 막 부위에서는 다시 흥분되지 않는다. 이 기간에서는 $Na^+$ 문들이 휴식 상태로 있지 않다. 상대불응기 동안에는 막은 보통 필요한 것보다 강한 자극에 의해서만 다시 흥분될 수 있다. 이 기간에서는 활동전위 동안 열렸던 $K^+$ 문들이 아직 닫히지 않고 있으며 일부 전압-개폐형 $Na^+$ 채널들은 아직 불화성화 상태에 있다.

# Refractory phase

- is a short period of time after the depolarization stage.
- Shortly after the sodium gates open they close and go into an inactive conformation. The sodium gates cannot be opened again until the membrane is repolarized to its normal resting potential. The sodium-potassium pump returns sodium ions to the outside and potassium ions to the inside.
- During the refractory phase this particular area of the nerve cell membrane cannot be depolarized.
- This refractory area explains why action potentials can only move forward from the point of stimulation.

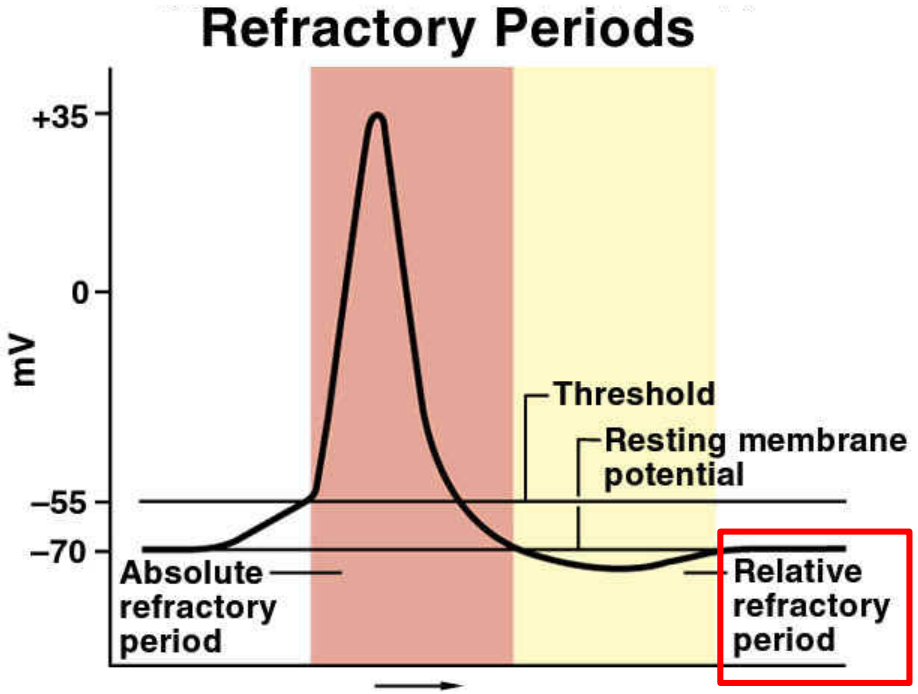
# ABSOLUTE -

- **During an action potential, a second stimulus will not produce a second action potential (no matter how strong that stimulus is)**
- **corresponds to the period when the sodium channels are open (typically just a millisecond or less)**



# RELATIVE -

- **while membrane is hyperpolarized**
- **large depolarization required to reach threshold**
  **→ action potential possible**
- **another action potential can be produced, but only if the stimulus is greater than the threshold stimulus**
- **corresponds to the period when the potassium channels are open (several milliseconds)**

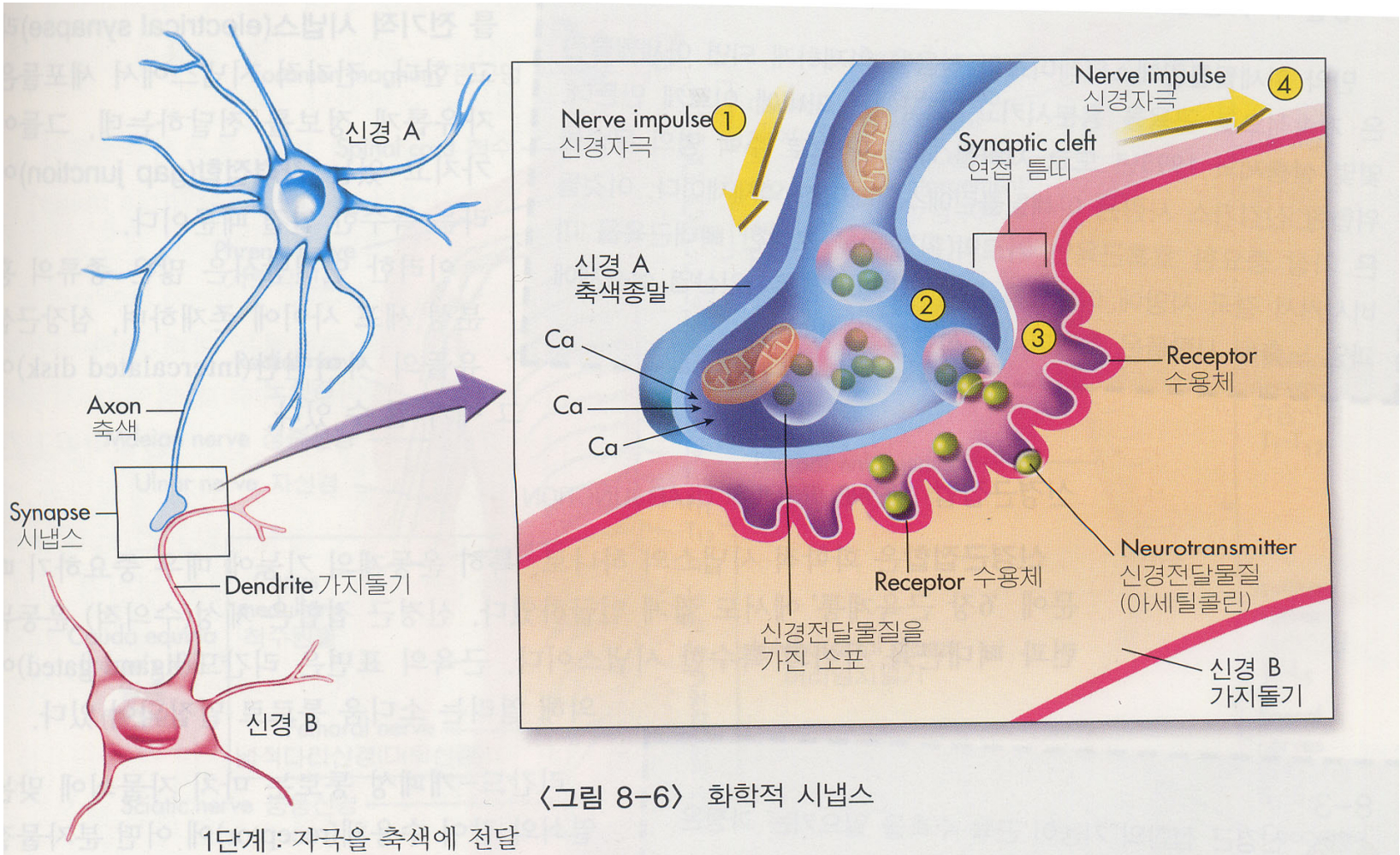


# Monte Pilatus

# Chemical Synapses

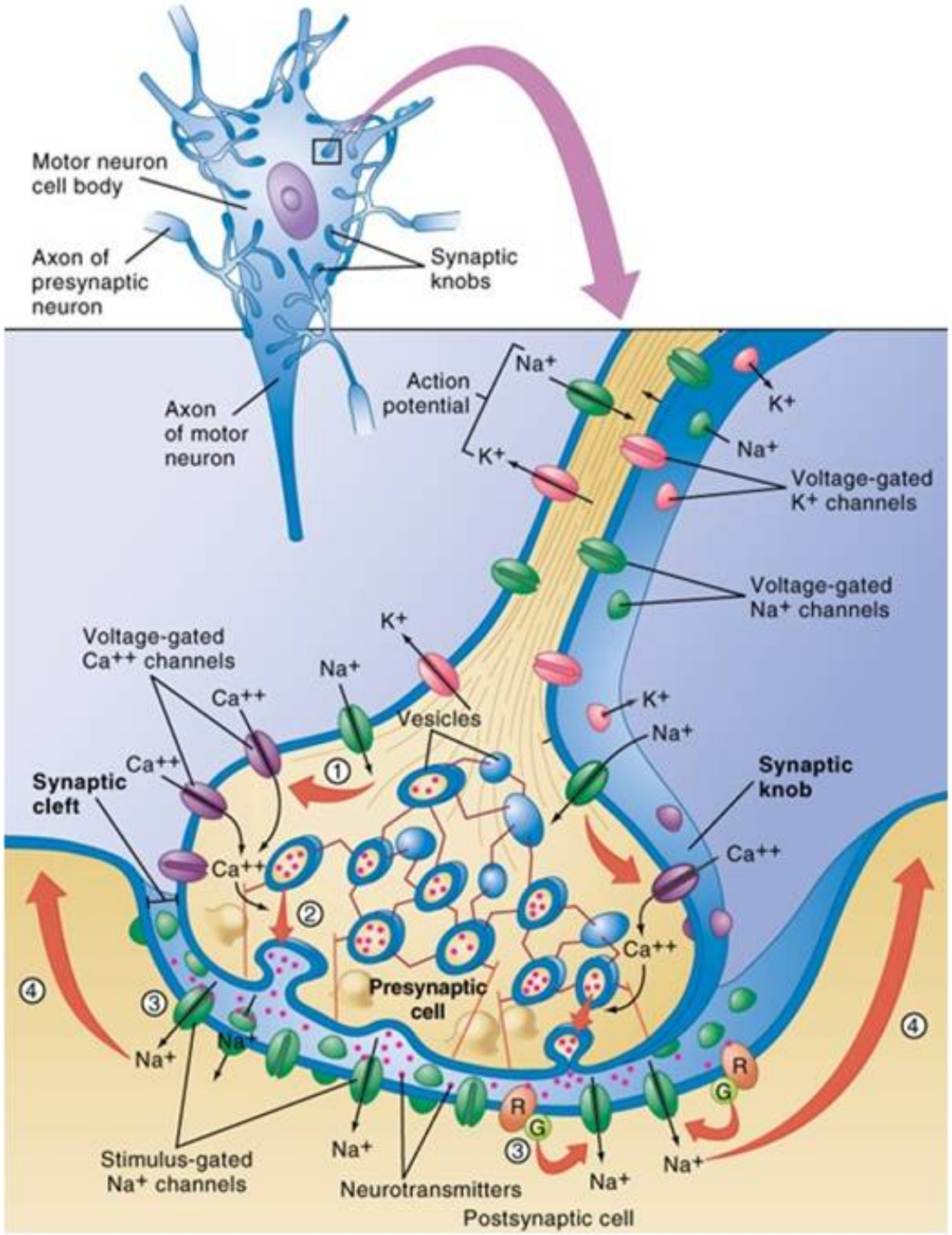
- **Chemical synapses** are specialized junctions through which neurons signal to each other and to non-neuronal cells such as those in muscles or glands.
- Chemical synapses allow neurons to form circuits within the central nervous system.
- They allow the nervous system to connect to and control other systems of the body.
- At a chemical synapse, one neuron releases neurotransmitter molecules into a small space (the synaptic cleft) that is adjacent to another neuron.
- These molecules then bind to the neuroreceptors on the receiving cell's side of the synaptic cleft.
- Finally, the neurotransmitters must be cleared out of the synapse efficiently so that the synapse can be ready to function again as soon as possible.

# Chemical Synapses



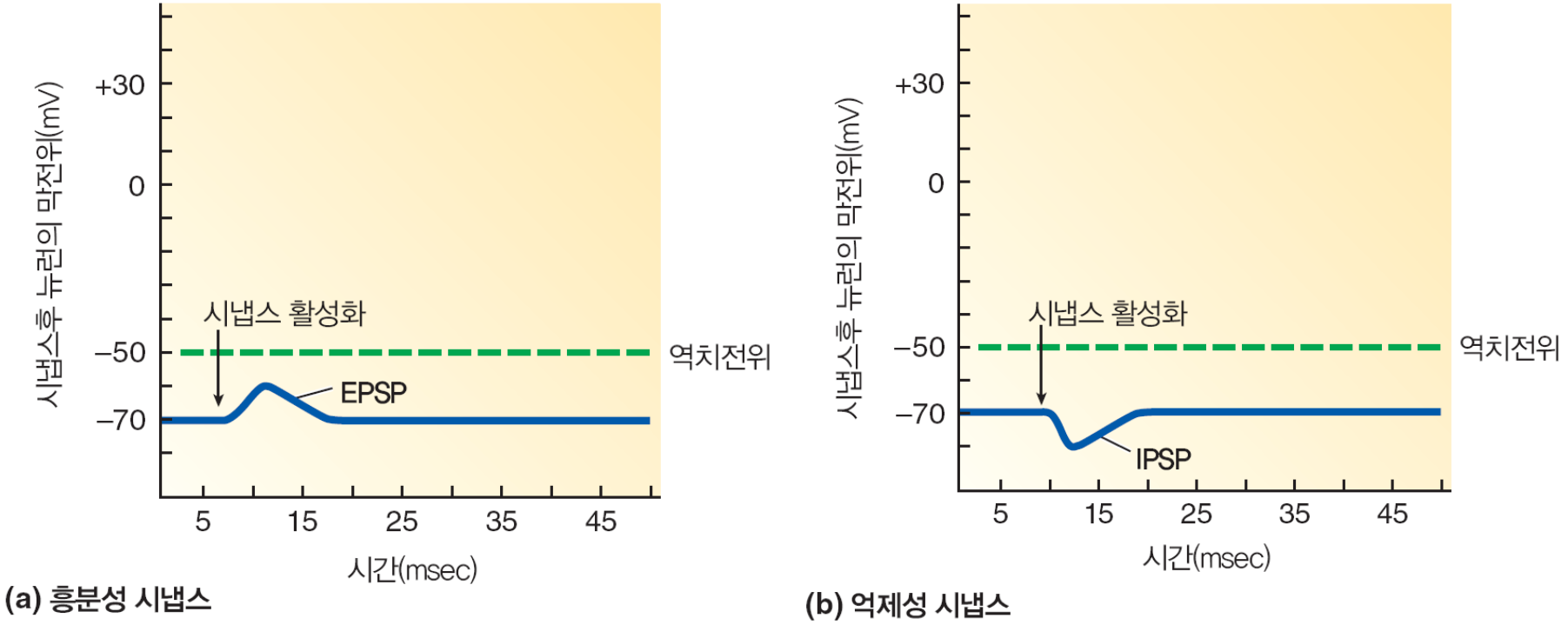

〈그림 8-6〉 화학적 시냅스

1단계 : 자극을 축색에 전달
2단계 : 소포들이 자극을 받아서 신경전달물질을 유리(세포외 반출, exocytosis)
3단계 : 신경전달물질이 시냅스 공간으로 유리되어 시냅스후세포의 수용체들과 결합
4단계 : 자극이 수상돌기를 따라 이동


Motor neuron cell body
Axon of presynaptic neuron
Synaptic knobs
Axon of motor neuron
Action potential
Na+
K+
Voltage-gated K+ channels
Voltage-gated Na+ channels
Voltage-gated Ca++ channels
Ca++
Vesicles
Synaptic cleft
Synaptic knob
Presynaptic cell
Stimulus-gated Na+ channels
Neurotransmitters
R
G
Postsynaptic cell
①
②
③
④

# (2) 흥분성 시냅스와 억제성 시냅스

- 시냅스에서의 신호는 시냅스후 뉴런을 흥분시키거나(**EPSP;** excitatory postsynaptic potential), 억제시키는데(**IPSP;** inhibitory postsynaptic potential), 이는 **신경전달물질**에 의해 결정(그림)



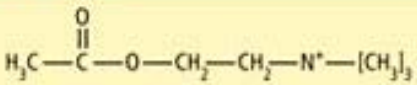
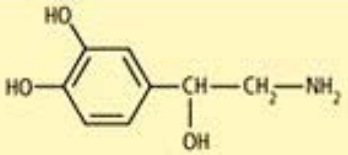
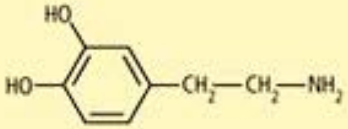
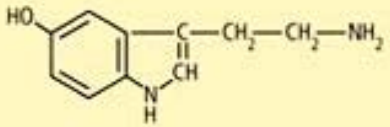
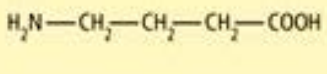
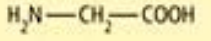
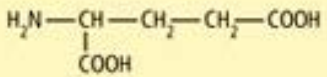
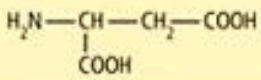

● **그림 4-15 시냅스후 전위.** (a) 흥분성 시냅스전 입력의 활성으로 생긴 흥분성 시냅스후 전위(EPSP)는 시냅스후 뉴런을 역치에 가깝게 한다. (b)억제성 시냅스 전 입력의 활성화로 생긴 억제성 시냅스후 전위(IPSP)는 시냅스후 뉴런을 역치에서 멀게 한다.

# Neurotransmitter

- **Neurotransmitters are endogenous chemicals that transmit signals from a neuron to a target cell across a synapse.**
- **Neurotransmitters are packaged into synaptic vesicles clustered beneath the membrane on the presynaptic side of a synapse, and are released into the synaptic cleft, where they bind to receptors in the membrane on the postsynaptic side of the synapse.**
- **Release of neurotransmitters usually follows arrival of an action potential at the synapse, but may also follow graded electrical potentials.**

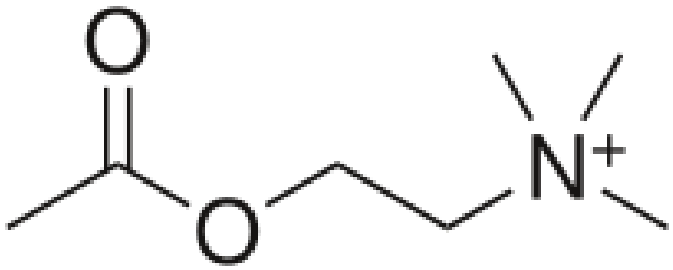
# Neurotransmitters

**Table 48.1 Major Neurotransmitters**

| Neurotransmitter | Structure | Functional Class | Secretion Sites |
|---|---|---|---|
| **Acetylcholine** |  | Excitatory to vertebrate skeletal muscles; excitatory or inhibitory at other sites | CNS; PNS; vertebrate neuromuscular junction |
| **Biogenic Amines** | | | |
| Norepinephrine |  | Excitatory or inhibitory | CNS; PNS |
| Dopamine |  | Generally excitatory; may be inhibitory at some sites | CNS; PNS |
| Serotonin |  | Generally inhibitory | CNS |
| **Amino Acids** | | | |
| GABA (gamma aminobutyric acid) |  | Inhibitory | CNS; invertebrate neuromuscular junction |
| Glycine |  | Inhibitory | CNS |
| Glutamate |  | Excitatory | CNS; invertebrate neuromuscular junction |
| Aspartate |  | Excitatory | CNS |
| **Neuropeptides** (a very diverse group, only two of which are shown) | | | |
| Substance P | Arg—Pro—Lys—Pro—Gln—Gln—Phe—Phe—Gly—Leu—Met | Excitatory | CNS; PNS |
| Met-enkephalin (an endorphin) | Tyr—Gly—Gly—Phe—Met | Generally inhibitory | CNS |

# Acetylcholine

- **Acetylcholine is distinguished as the transmitter at the neuromuscular junction connecting motor nerves to muscles.**
- **The paralytic arrow-poison curare acts by blocking transmission at these synapses.**
- **Acetylcholine also operates in many regions of the brain, but using different types of receptors.**

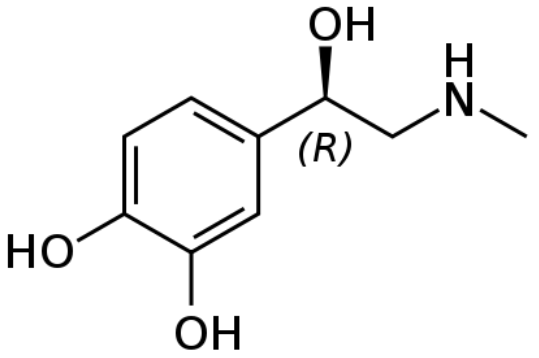


*(Catecholamine)*

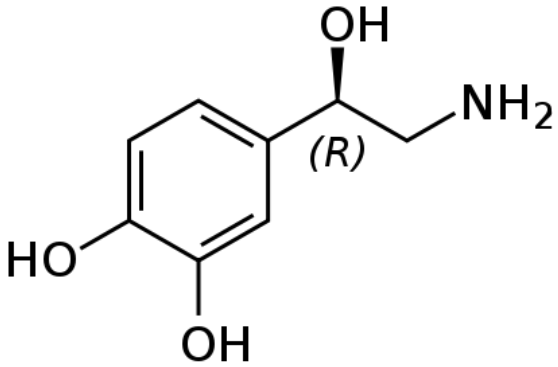
# Biogenic amines

## (Catecholamine)

- **Epinephrine** (also known as **adrenaline**) is a hormone and a neurotransmitter. It increases heart rate, constricts blood vessels, dilates air passages and participates in the fight-or-flight response of the sympathetic nervous system.

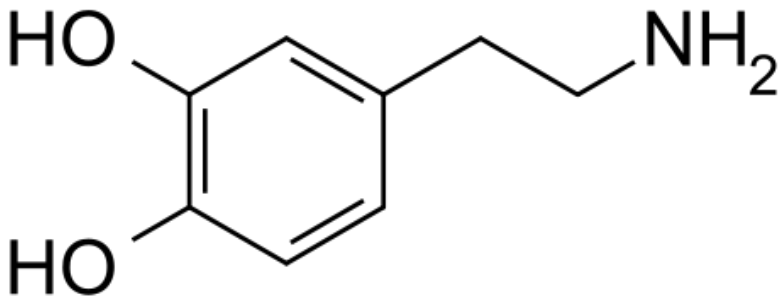



- **Norepinephrine** (abbreviated **norepi** or **NE**) is the US name for **noradrenaline**, a catecholamine with multiple roles including as a hormone and a neurotransmitter. An increase in norepinephrine from the sympathetic nervous system increases the rate of contractions.



*(Catecholamine)*

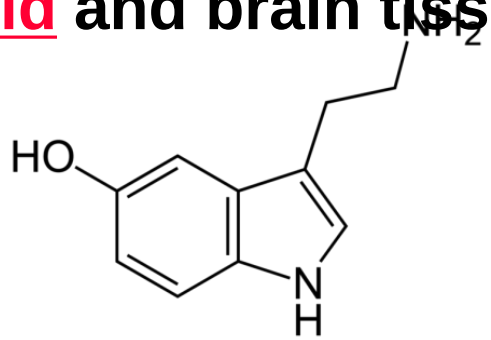
- **Dopamine has a number of important functions in the brain.**
- **It plays a critical role in the reward system, but dysfunction of the dopamine system is also implicated in Parkinson's disease and schizophrenia (정신분열증).**



*(Non-Catecholamine)*

# Serotonin

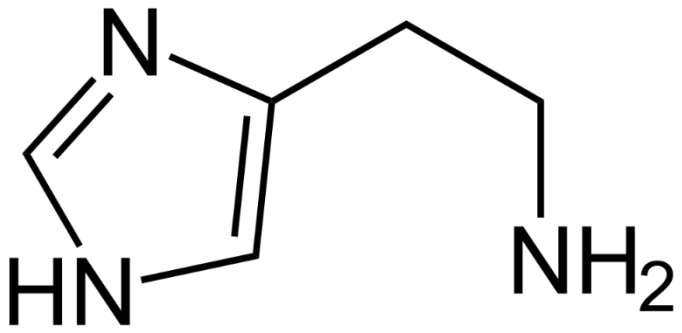
- Serotonin is a monoamine neurotransmitter.
- Most is produced by and found in the intestine (approximately 90%), and the remainder in central nervous system neurons.
- It functions to regulate appetite, sleep, memory and learning, temperature, mood, behaviour, muscle contraction, and function of the cardiovascular system and endocrine system.
- It is speculated to have a role in depression, as some depressed patients are seen to have lower concentrations of metabolites of serotonin in their cerebrospinal fluid and brain tissue.



*(Non-Catecholamine)*

# Histamine

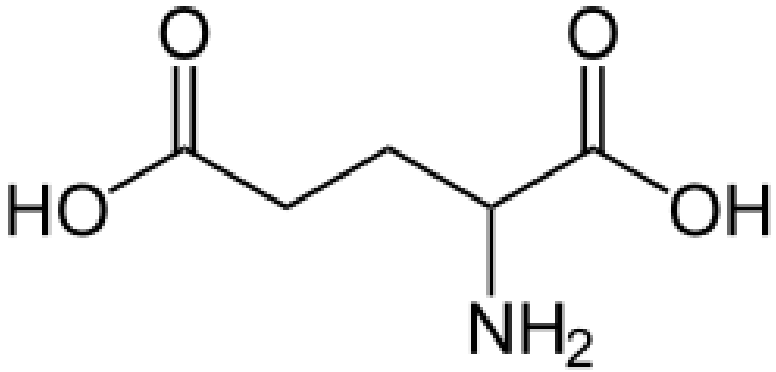
- **Histamine is an organic nitrogen compound involved in local immune responses as well as regulating physiological function in the gut and acting as a neurotransmitter.**
- **Histamine triggers the inflammatory response. As part of an immune response to foreign pathogens, histamine is produced by basophils and by mast cells found in nearby connective tissues.**
- **Histamine increases the permeability of the capillaries to white blood cells and some proteins, to allow them to engage pathogens in the infected tissues.**



# Amino acids

## Glutamate

- **Glutamate is used at the great majority of fast excitatory synapses in the brain and spinal cord.**
- **It is also used at most synapses that are "modifiable", i.e. capable of increasing or decreasing in strength.**
- **Modifiable synapses are thought to be the main memory-storage elements in the brain.**
- **Excessive glutamate release can lead to excitotoxicity causing cell death.**

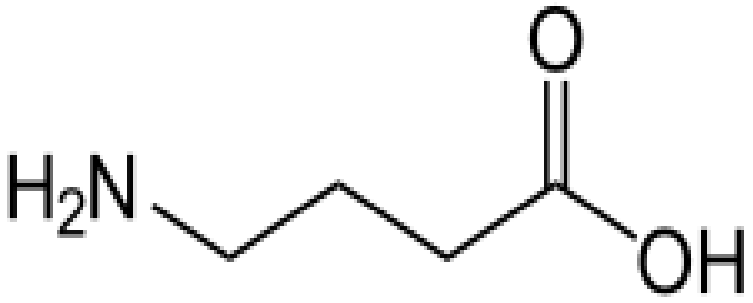


# Amino acids



Gamma aminobutyric acid (GABA)

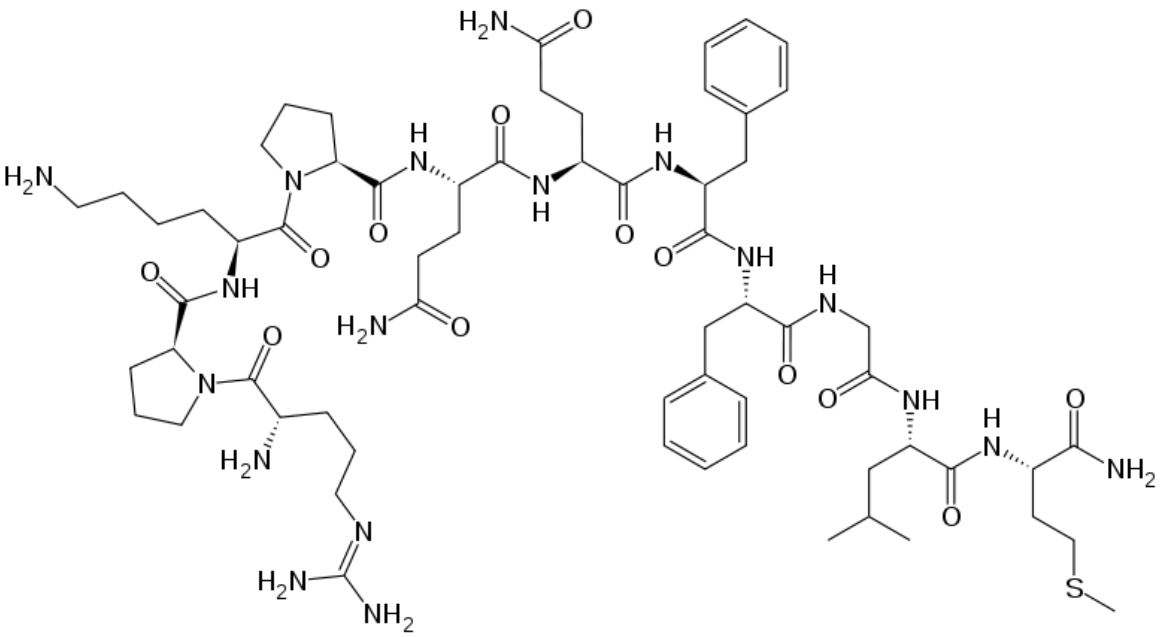
- **GABA is used at the great majority of fast inhibitory synapses in virtually every part of the brain.**
- **Many sedative/tranquilizing drugs act by enhancing the effects of GABA.**
- **Correspondingly glycine is the inhibitory transmitter in the spinal cord.**



# Neuropeptides

- **Substance P is a neuropeptide responsible for transmission of pain from certain sensory neurons to the central nervous system.**
- **The deduced amino acid sequence of substance P is as follows**

**Arg Pro Lys Pro Gln Gln Phe Phe Gly Leu Met**



- **acetylcholine = ACH** - An excitatory neurotransmitter that is a derivative of the amine, choline; released by motor neurons at the neuromuscular junction, by all preganglionic autonomic visceral motor neurons, by all parasympathetic postganglionic visceral motor neurons, by sympathetic postganglionic visceral motor neurons for sweat glands, and by a variety of neurons in the CNS; this neurotransmitter is rapidly cleared from synapses by the enzyme acetylcholinesterase.
- **glutamate** - A salt or ester of the amino acid, glutamic acid, it often functions as an excitatory neurotransmitter in the CNS.
- **aspartate** - A salt or ester of the amino acid, aspartic acid, it sometimes functions as an excitatory neurotransmitter in the CNS.
- **gamma aminobutyric acid (GABA)** - An amino acid that is found in the CNS; it acts as an inhibitory neurotransmitter.

- **glycine** - The simplest amino acid; it acts as an inhibitory neurotransmitter in the spinal cord and brain stem.
- **norepinephrine** (noradrenalin) - A catecholamine, both a hormone and neurotransmitter; it may be excitatory or inhibitory, depending on its target cell's response; it is secreted by the adrenal medulla and by the postganglionic nerve endings of the sympathetic nervous system to cause vasoconstriction and increases in heart rate, blood pressure, and the glucose level of the blood; this neurotransmitter is rapidly cleared from synapses by the enzymes catechol-o-methyl-transferase (COMT) and monoamine oxidase (MAO) .
- **dopamine** - A monoamine excitatory neurotransmitter formed in the brain by the decarboxylation of L-dopa and essential to the normal functioning of the CNS; it is a precursor to norepinephrine and epinephrine. It may be used as a drug to treat hypotension and bradycardia.  A reduction in its concentration within the brain is associated with Parkinson's disease.

〈표 8-1〉 일반적인 신경전달물질

| 신경전달물질 | 위치 | 기능 | 설명 |
|---|---|---|---|
| 아세틸콜린<br>Acetylcholine | 중추, 말초신경계통 | 대부분 흥분성이나 몇몇 내장효과기에서는 억제성 | 뼈대근육의 신경근 접합과 많은 자율신경계통 시냅스(연접)에서 발견 |
| 노에피네피린<br>Norepinephrine | 중추, 말초신경계통 | 수용체에 따라서 흥분성 혹은 억제성 | 내장기관과 심장근에서 발견 |
| 에피네피린<br>Epinerphrine | 중추, 말초신경계통 | 수용체에 따라서 흥분성 혹은 억제성 | 행동과 감정에 관계된 경로에서 발견 |
| 세로토닌<br>serotonin | 중추신경계통 | 대부분 억제성 | 체온, 감각인지, 감성, 수면 등의 조절과 관련된 경로에서 발견 |
| 엔돌핀<br>Endorphins | 중추신경계통 | 대부분 억제성 | 통증을 유발하는 신경전달물질의 유리를 억제 |

# Structure and Function

## Three Types of Neurons

- Efferent (motor)

Conveys information from the CNS to muscles and glands

- Afferent (sensory)

Carry information from sensory receptors to the CNS

- Interneurons

Carry and process sensory information

## Other Cells (Neuroglia)

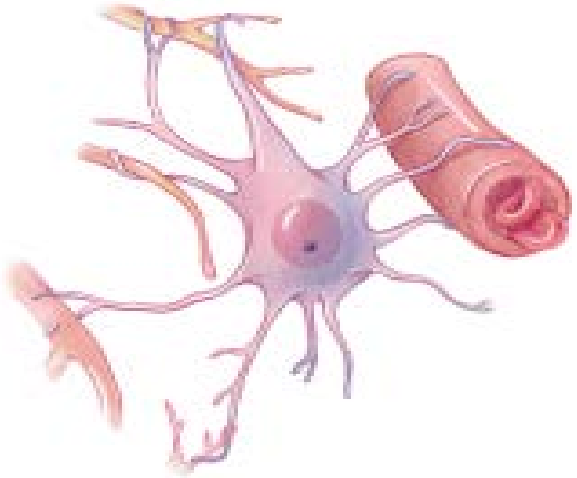
Support, protect, connect and remove debris from the nervous system

Direction

- Afferent neurons convey information from tissues and organs into the central nervous system and are sometimes also called sensory neurons.
- Efferent neurons transmit signals from the central nervous system to the effector cells and are sometimes called motor neurons.
- Interneurons connect neurons within specific regions of the central nervous system.
- Afferent and efferent also refer generally to neurons that, respectively, bring information to or send information from the brain region.

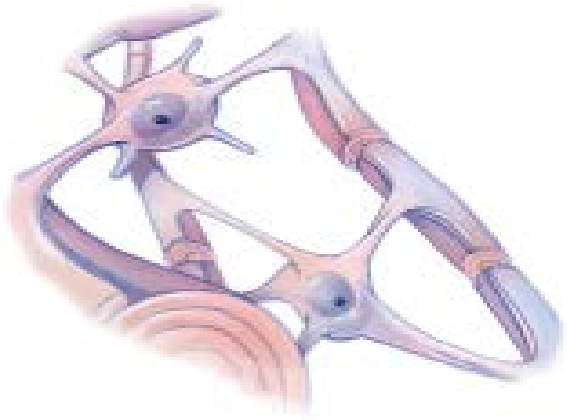
# Structure and Function

## Types of Neuroglial Cells



### Astrocytes

- Star-shaped cells that maintain the nutrient and chemical levels in neurons



### Oligodendroglia

- Produce myelin and help in supporting the neurons

### Microglia

- Phagocytes, they remove debris

# Overview of the entire nervous system

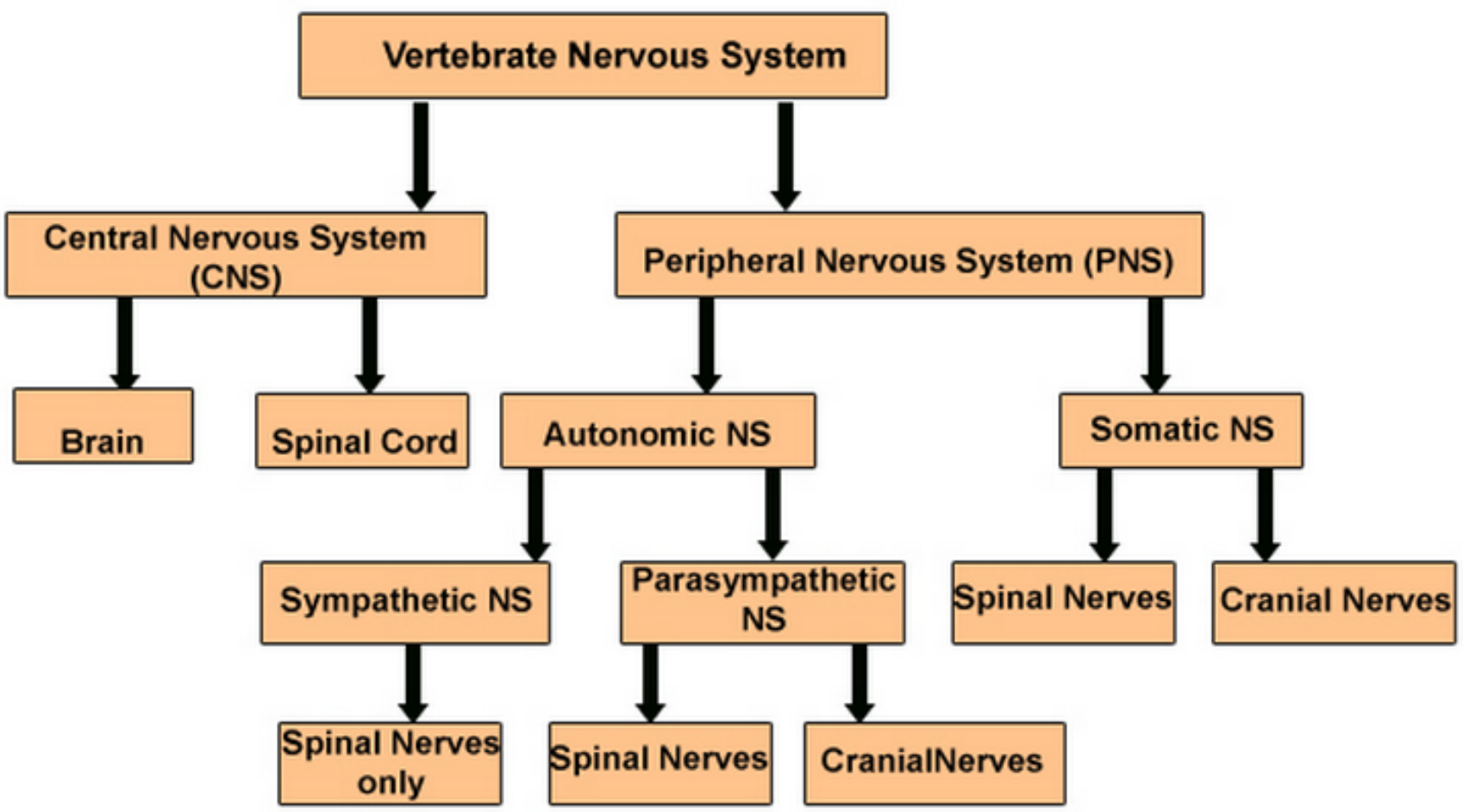
The nervous system has three main functions:

- sensory input,
- integration of data
- motor output.

- Sensory input is when the body gathers information or data, by way of neurons, glia and synapses.
- The nervous system is composed of excitable nerve cells (neurons) and synapses that form between the neurons and connect them to centers throughout the body or to other neurons.

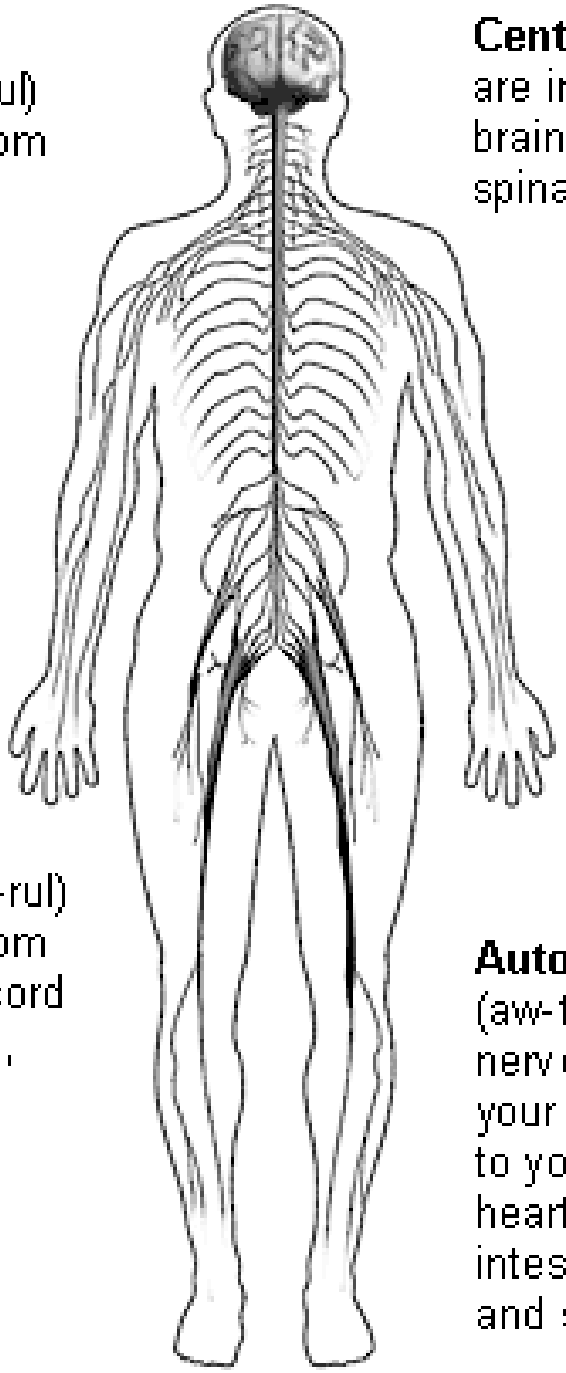
- These neurons operate on excitation or inhibition, and although nerve cells can vary in size and location, their communication with one another determines their function. These nerves conduct impulses from sensory receptors to the brain and spinal cord.
- The data is then processed by way of integration of data, which occurs only in the brain.
- After the brain has processed the information, impulses are then conducted from the brain and spinal cord to muscles and glands, which is called motor output.
- Glia cells are found within tissues and are not excitable but help with myelination, ionic regulation and extracellular fluid.

# Vertebrate Nervous System Divisions



**Cranial** (KRAY-nee-ul) nerves go from your brain to your eyes, mouth, ears, and other parts of your head.

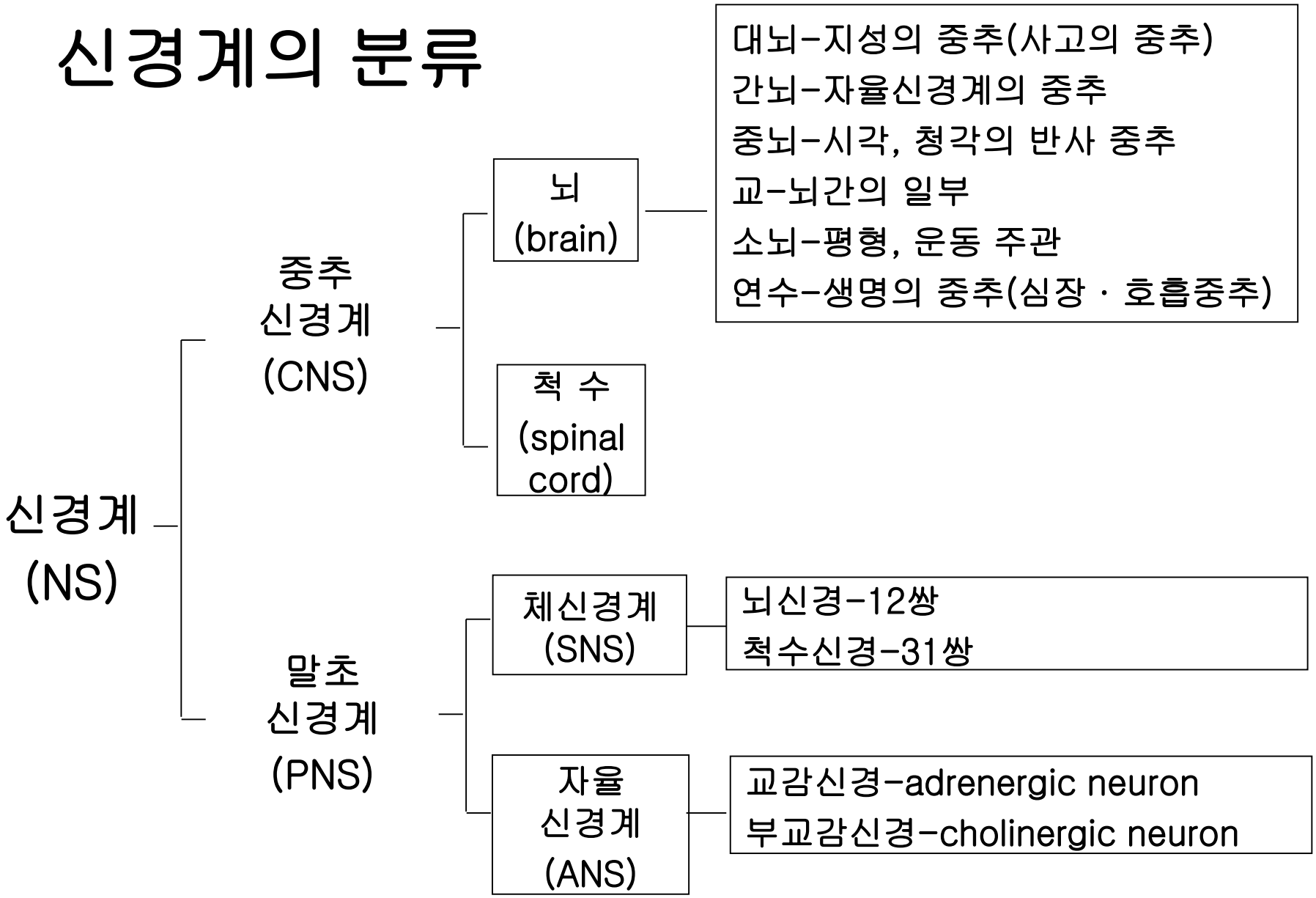
**Central** nerves are in your brain and spinal cord.



**Peripheral** (puh-RIF-uh-rul) nerves go from your spinal cord to your arms, hands, legs, and feet.

**Autonomic** (aw-toh-NOM-ik) nerves go from your spinal cord to your lungs, heart, stomach, intestines, bladder, and sex organs.

# 신경계의 분류


신경계
(NS)
중추
신경계
(CNS)
말초
신경계
(PNS)
뇌
(brain)
척 수
(spinal
cord)
체신경계
(SNS)
자율
신경계
(ANS)
대뇌-지성의 중추(사고의 중추)
간뇌-자율신경계의 중추
중뇌-시각, 청각의 반사 중추
교-뇌간의 일부
소뇌-평형, 운동 주관
연수-생명의 중추(심장 · 호흡중추)
뇌신경-12쌍
척수신경-31쌍
교감신경-adrenergic neuron
부교감신경-cholinergic neuron


DEXIA