

생활체육인 진료를 위해 필요한 운동생리학 및 영양학

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김창업

과학과 경험 사이...

불완전한 과학과 주관적인 경험 사이에 필요한 적절한 전문가적 판단

- 운동생리학/영양학자들의 과학적 실험결과 vs. 현장 전문가들의 경험과 노하우
- 과학적 연구들은 외적타당도(현실 일반에 적용가능성)에 제약이 있고, 현장의 경험은 편향된 믿음으로 왜곡될 수 있다.
- 연구 논문들은 대개 짧은 기간 진행되거나, 개개인의 다양성이 충분히 반영되지 못함
- 현장 전문가의 경험 기반의 주장들은 객관적으로 근거가 부족한 믿음에 불과한 것으로 드러나는 경우도 많음

과학과 경험 사이...

불완전한 과학과 주관적인 경험 사이에 필요한 적절한 전문가적 판단

- 운동생리학, 영양학 분야 수많은 연구결과들이 서로간 일치하지 않으며 대립되는 주장을 지지
- 최신연구결과 몇건을 바탕으로 그것이 정답이라고 믿을 수는 없음
- 불확실한 부분에 대해선 더 많은 연구와 경험을 바탕으로 한 전문가 집단의 consensus가 이루어지길 기다려야 하며 지나친 확신은 위험
- 학계의 최신 임상연구성과들 + 기전적 이해를 바탕으로 한 전문가 의견 + 현장전문가들의 경험을 종합적으로 참고

탄수화물/지질/단백질

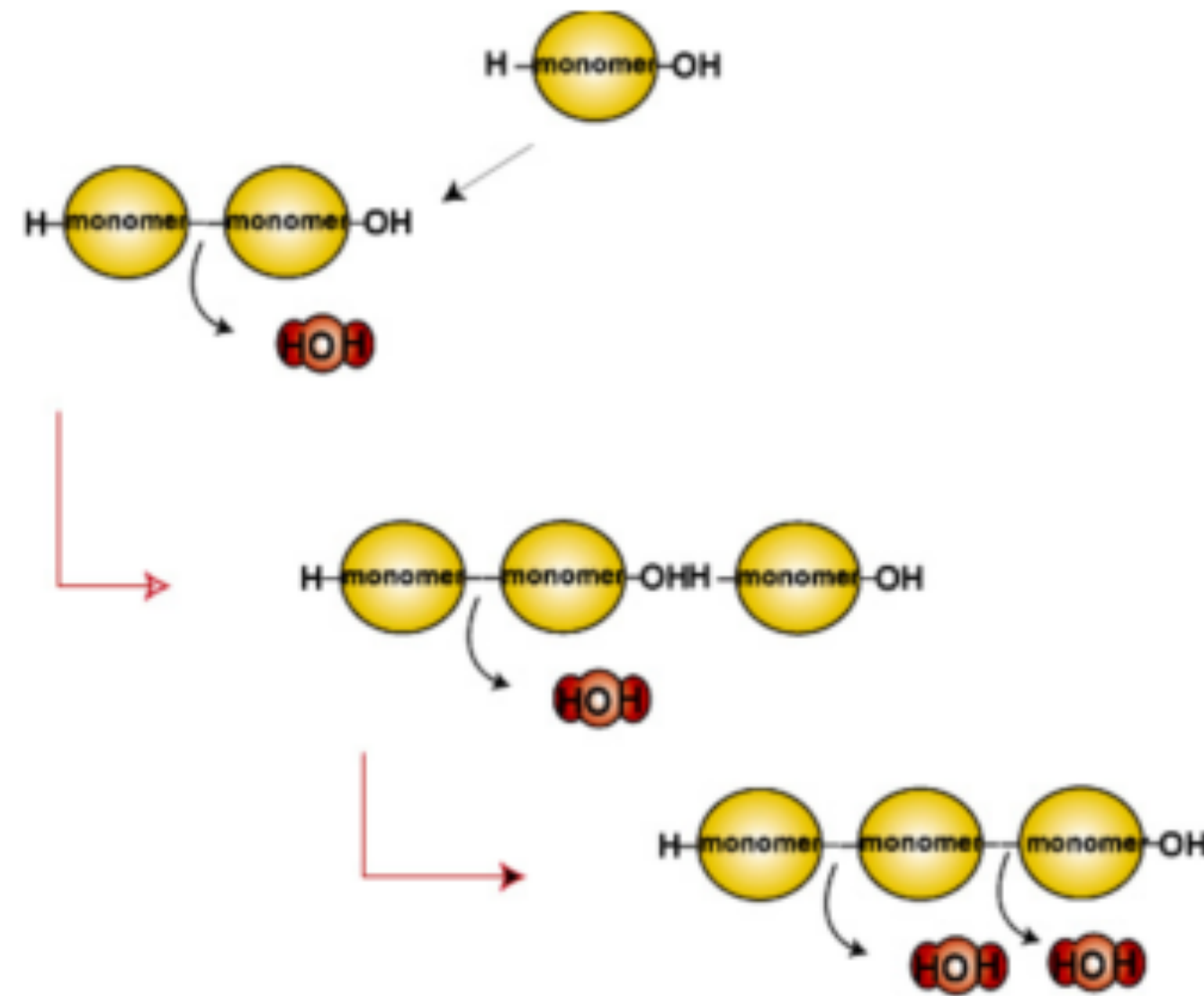
Macromolecule

- 탄수화물, 지질, 단백질, 핵산.
- 지질을 제외한 3가지는 monomer(단위체)가 모여 polymer(중합체)를 형성.
- 세포가 중합체를 만들고 분해하는 화학기작은 기본적으로 모든 종류에서 동일 (탈수축합 반응, 가수분해 반응)

중합체의 합성과 분해

Mono: 1
Di: 2
Oligo: 3-10
Poly: many

TWO CHEMICAL REACTIONS INVOLVED IN THESE METABOLIC PROCESSES:



Condensation: removes 1 molecule of H₂O when two monomers are joined together

Hydrolysis: Adds 1 molecule of H₂O when two monomers are broken apart.

1. CONDENSATION: (also called "Dehydration Synthesis")

Assembly of a polymer –**Anabolism!!**

As each two monomers are joined together to form the polymer chain, a molecule of water is removed.

2. HYDROLYSIS: (hydro-"water" lysis-"break apart")

Disassembly of large polymers back into monomers (reverse of condensation!)

This is "**Catabolism!**" A molecule of water is added back to break apart each two monomers in the polymer.

One hydrogen is added back to one monomer and the hydroxyl group is added back to the other monomer.

Most life forms on this planet use the same basic "building blocks", i.e, same basic

탄수화물

CARBOHYDRATES

“cellular energy and building material”

MONOMER: Monosaccharide

- single sugar molecules also called “simple sugars”

-Molecules are composed of **carbon, hydrogen and oxygen**

General formula: $(\text{CH}_2\text{O})_n$ “carbon hydrates” (hence name of carbohydrates)

n = number of carbons in chain

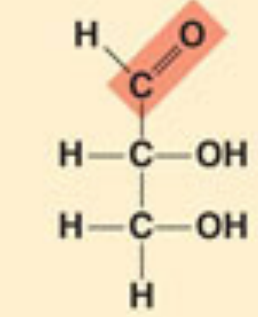
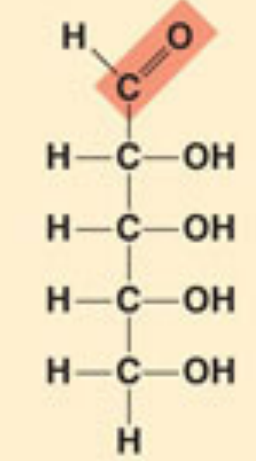
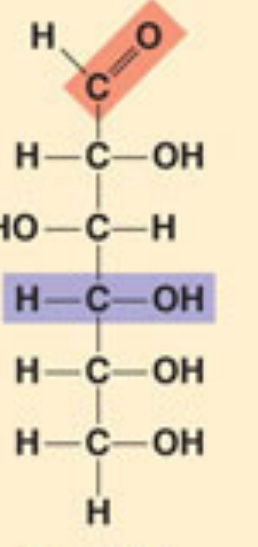
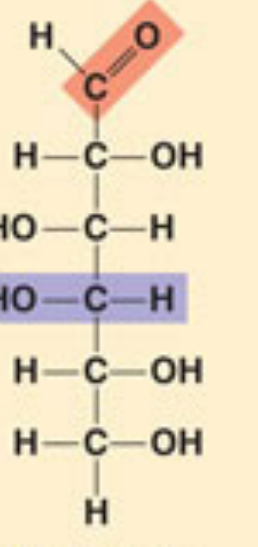
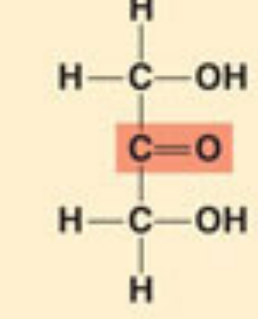
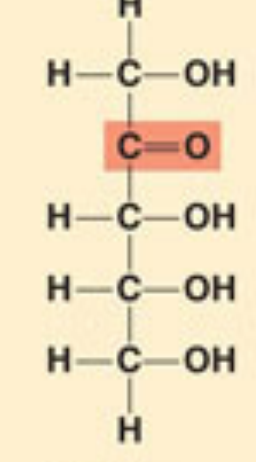
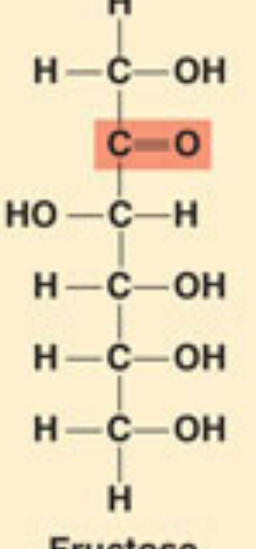
- vary from 3 to 7 carbons in chain
(3C, 5C, 6C most common chain lengths)

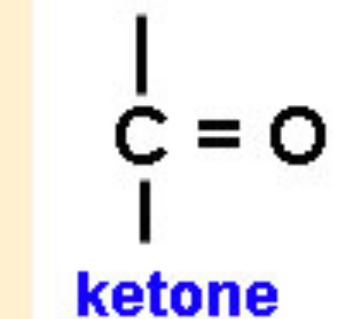
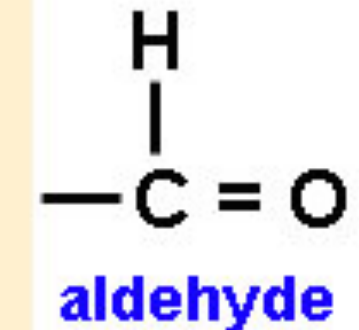
Glucose: most common monosaccharide “a 6 carbon sugar”
 $(\text{CH}_2\text{O})_n \longrightarrow \text{C}_6\text{H}_{12}\text{O}_6$

Carbohydrates are “Polar molecules” - readily dissolve in water

Sugar Hallmarks:

- **Hydroxyl group** on each carbon in chain except one
- **Carbonyl group** on that one carbon

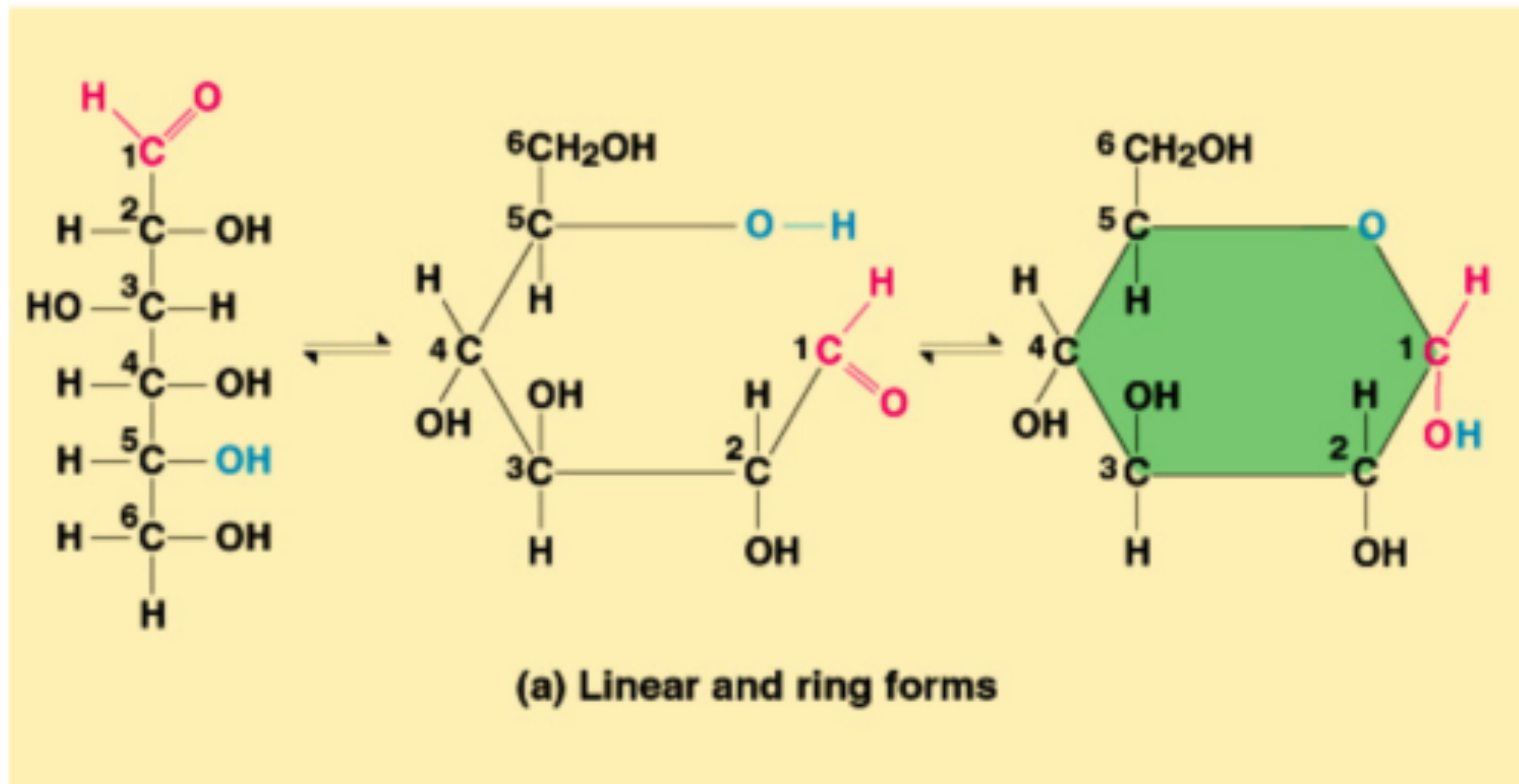
	Trioses ($\text{C}_3\text{H}_6\text{O}_3$)	Pentoses ($\text{C}_5\text{H}_{10}\text{O}_5$)	Hexoses ($\text{C}_6\text{H}_{12}\text{O}_6$)	
Aldoses	 Glyceraldehyde	 Ribose	 Glucose	 Galactose
Ketoses	 Dihydroxyacetone	 Ribulose	 Fructose	

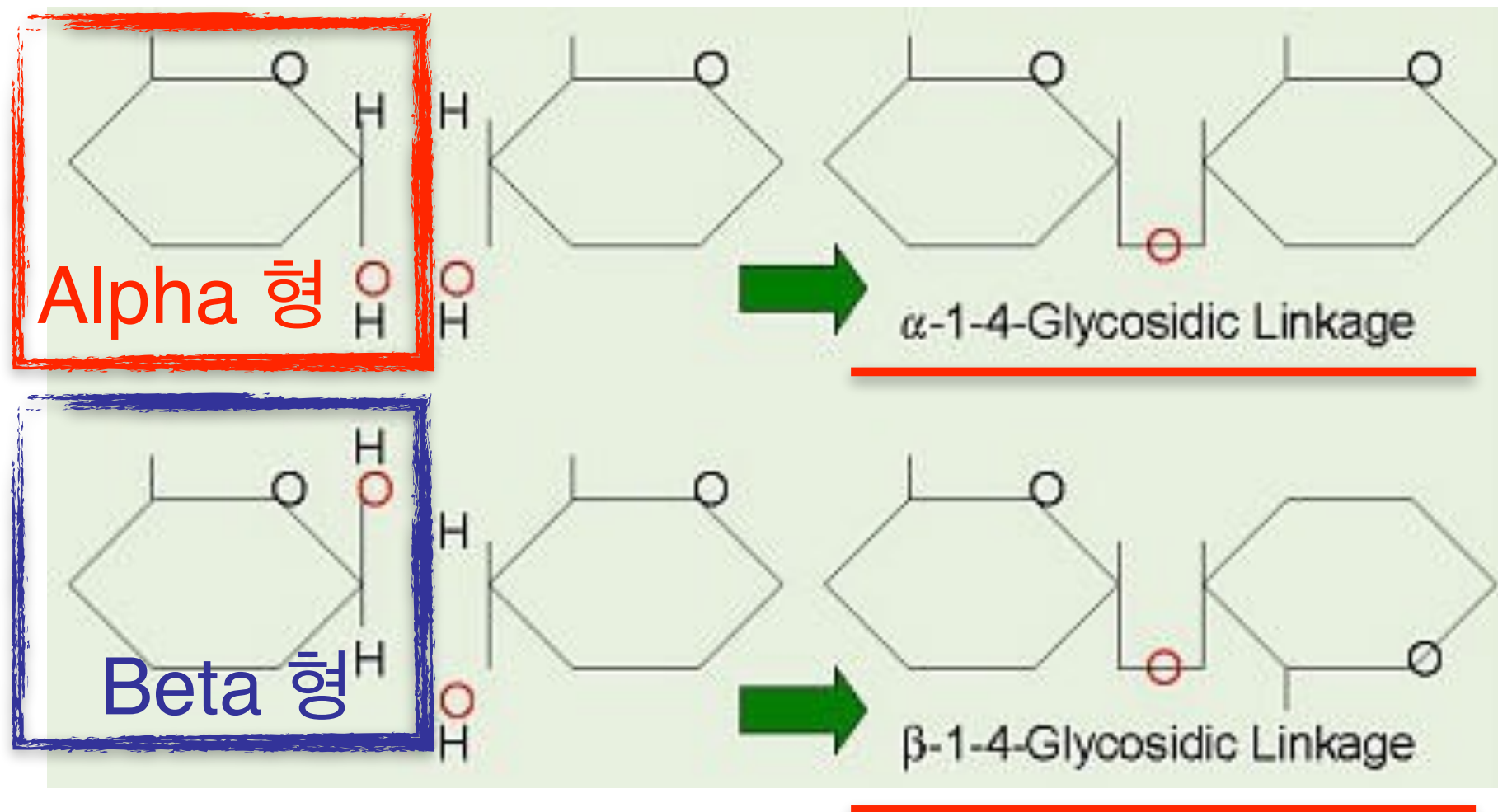


In aqueous solutions, sugars assume a "Ring Form:"

When glucose forms a ring, the carbonyl carbon breaks the double bond and keeps a single bond with its oxygen, and forms a single bond with the oxygen of the 5-carbon. (illustrations are figure 5.4 in text – if they do not show on web)

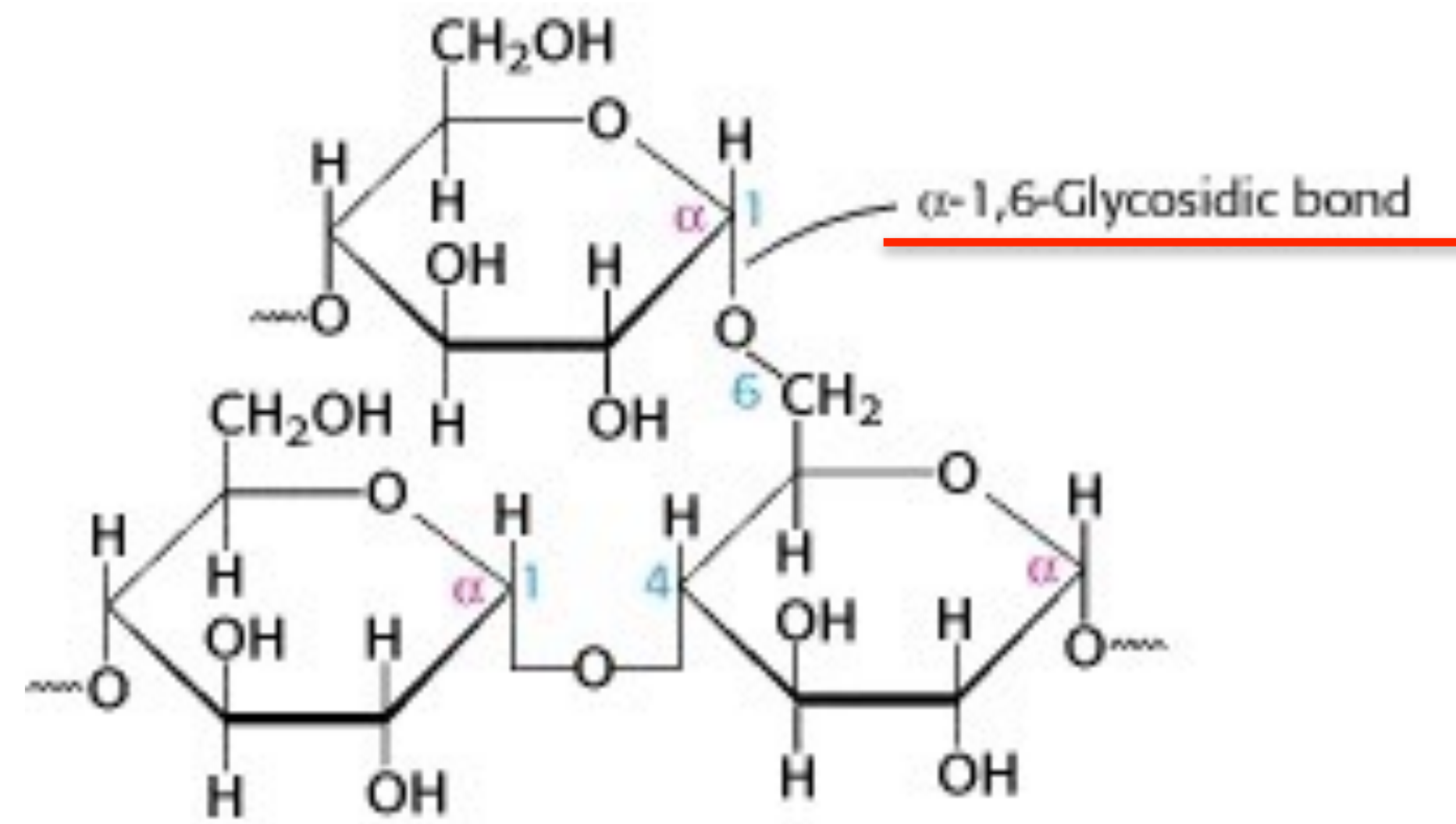
Look at the graphic below showing how the linear form (carbon chain) closes up to form the closed ring:



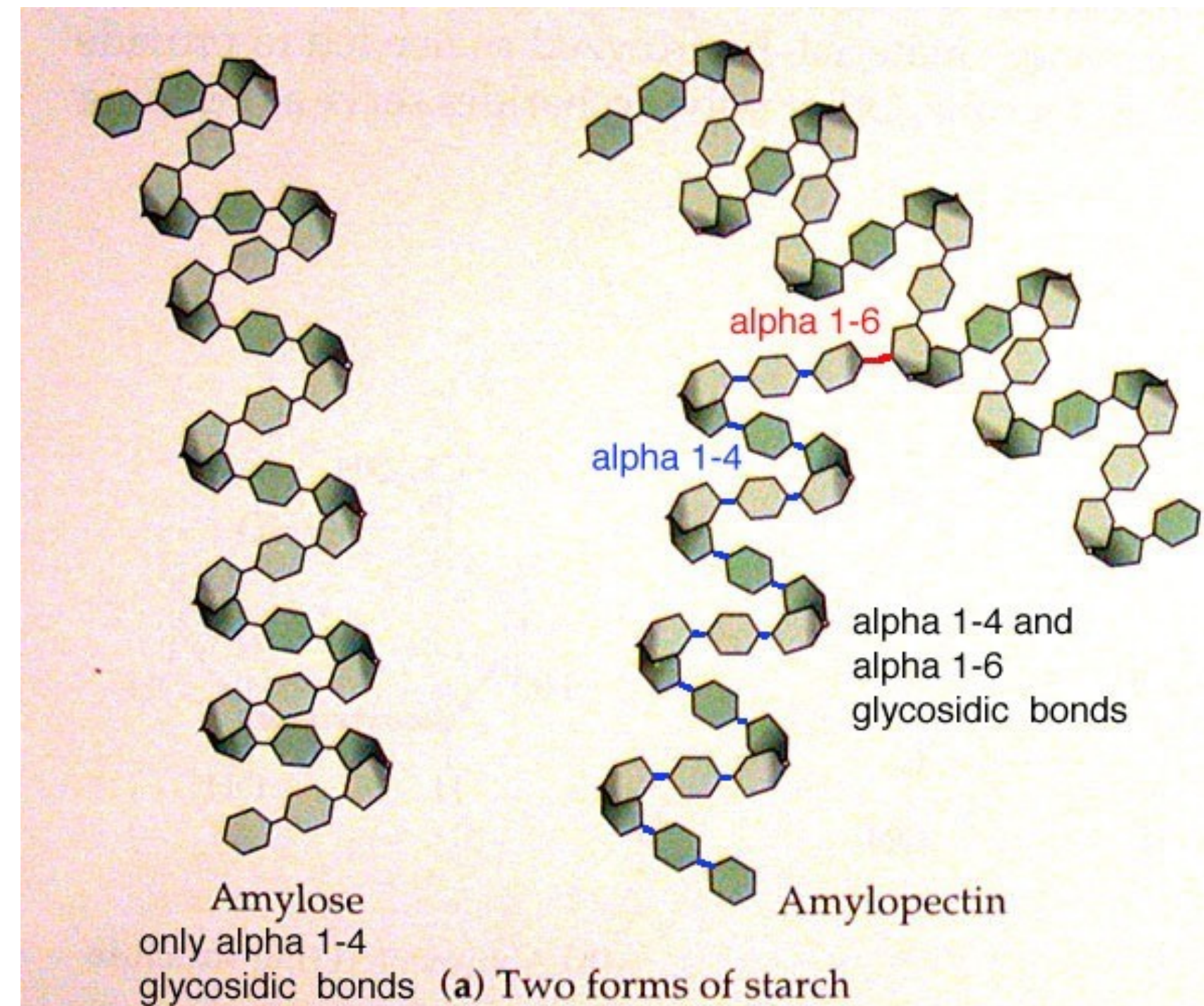
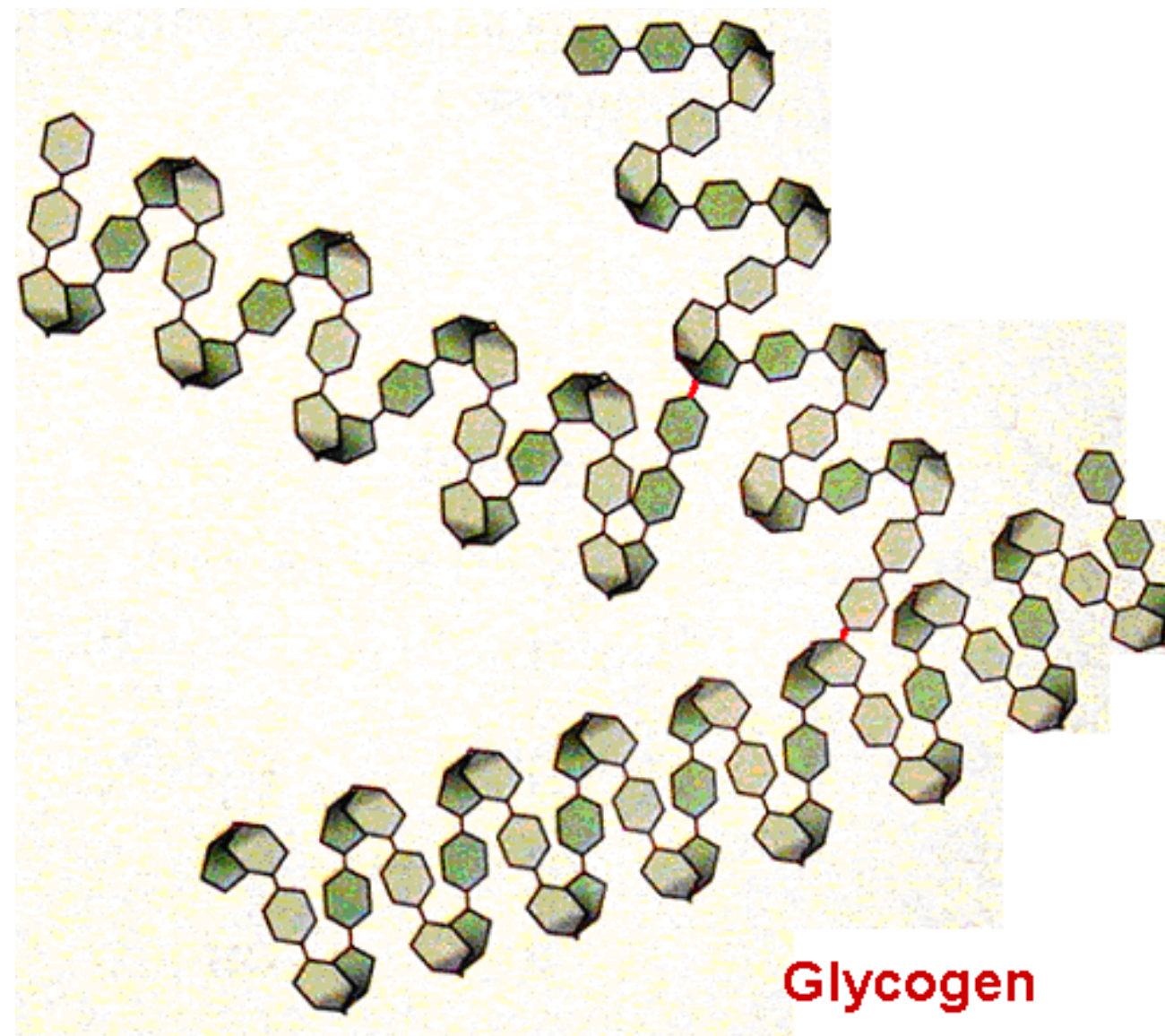


➡ 나선형. 저장다당류(starch, glycogen)

➡ 직선형. 구조다당류 (cellulose)

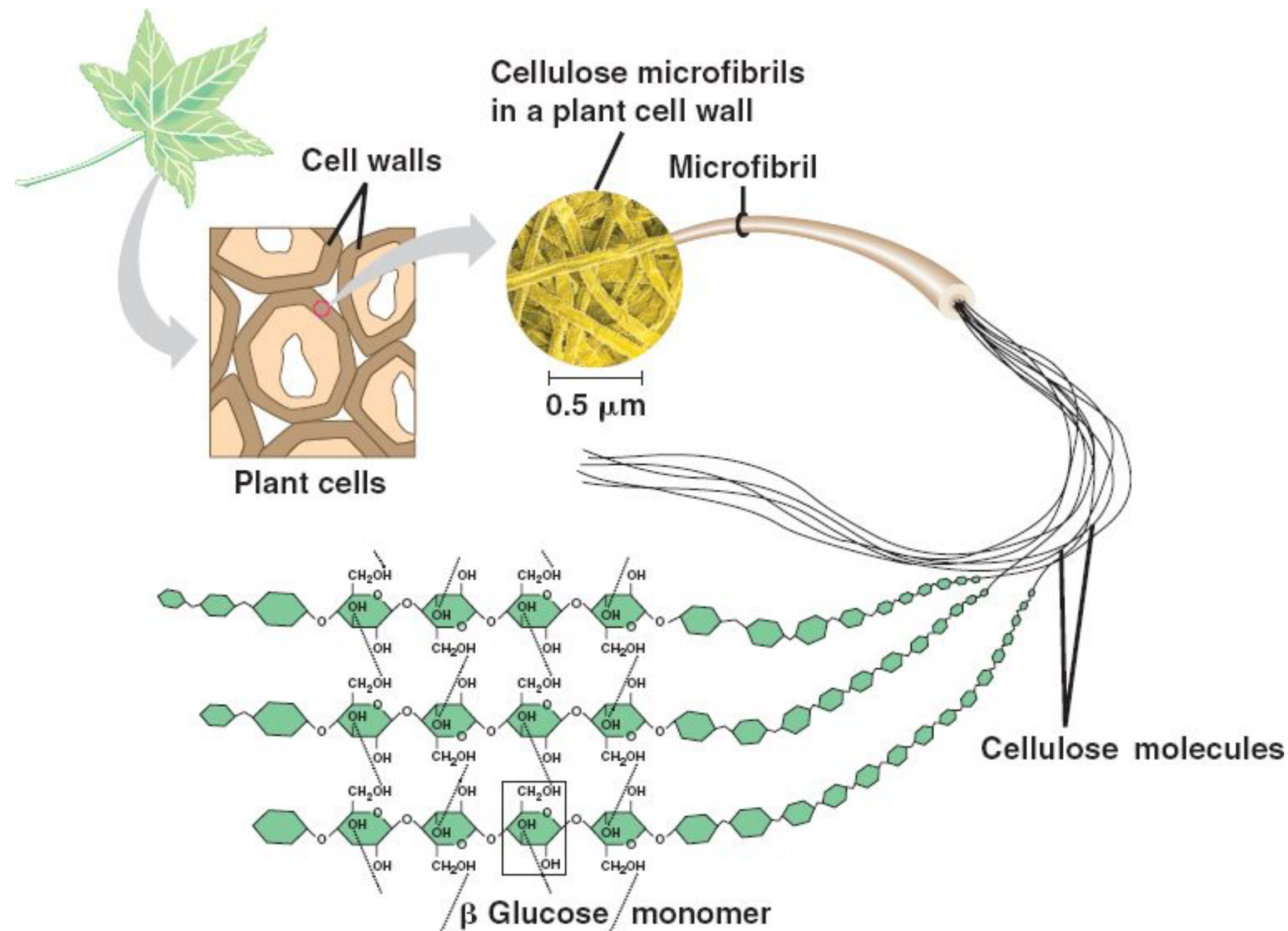


저장다당류: Glycogen & Starch



기립지물인 식물은 녹말로 충분
동물은 글리코겐 최대비축량으로도 부족. 지방 필요

구조 다당류: Cellulose



팬더는 하루 14시간 대나무 식사.
위, 대장 구조는 육식동물인채 채식으로 연명하기 위해 (먹은 대나무 대부분 대변으로 배출)

Cellulose의 beta 결합을 가수분해할수 있는 효소를 가지고 있는 생명체는 극히 적다

-> 장내미생물이 대신 소화가능(반추동물들은 여러개의 위안에 장내미생물 많음. 소가 풀먹고 힘쓰는 이유)

-> 장내미생물과의 상호작용을 통해 건강에 다양한 영향

-> 장벽을 감싸며 격자구조를 만들어 필터처럼 작용. 당의 흡수를 낮춤(혈당지수를 낮춤)

-> 섬유질..쾌변.(사람은 셀룰로오스를 잘 소화하지 못하므로)

Lipids

General characteristics:

- 3 large and diverse groups of molecules
- are NOT polymers
- Groups differ structurally
- Share common characteristic: **NON-POLAR** (hydrophobic) compounds

Three Groups of Lipids:

1. **Fats**
2. **Phospholipids**
3. **Steroids**

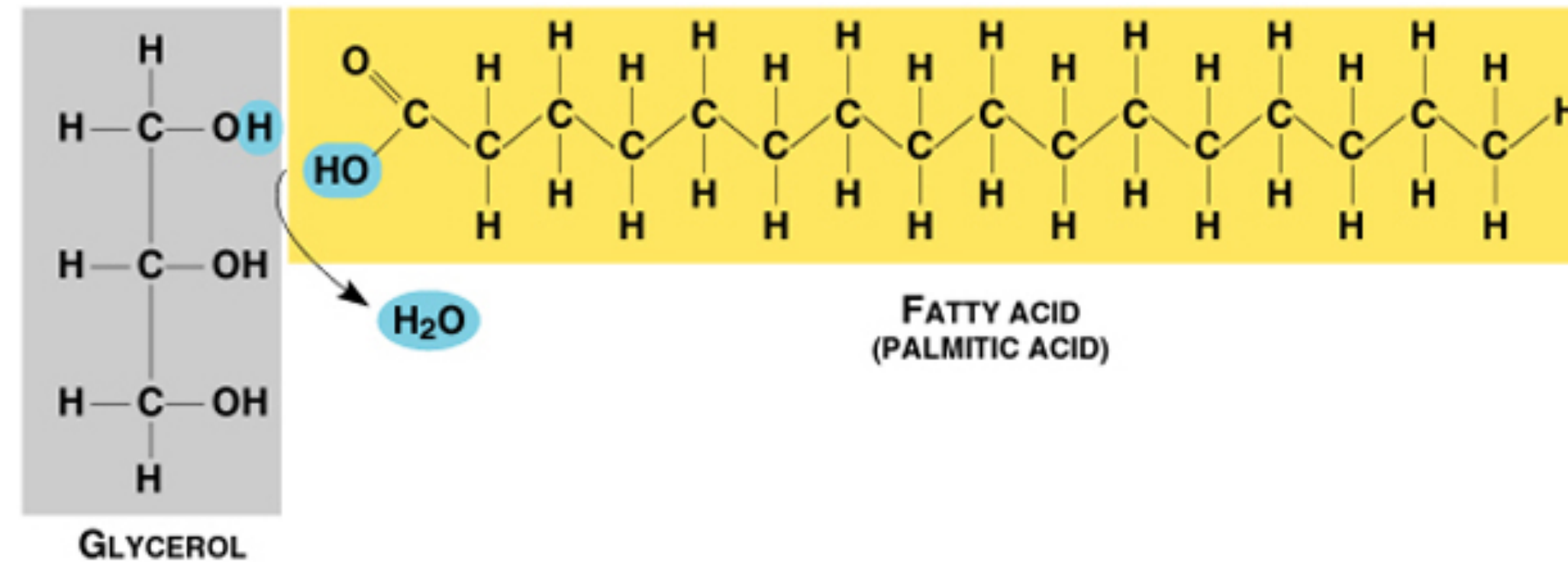
GROUP 1: The FATS

Fats and Oils - energy reserves for animals (2.5X more energy per gram of fat than gram of carbohydrate)

- **insulation**

- Nonpolar
- Composed of only carbon, hydrogen and oxygen
- Basic structure of fats and oils: **TRIGLYCERIDE** (triacylglycerol)

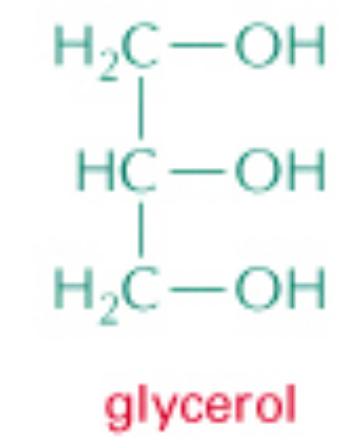
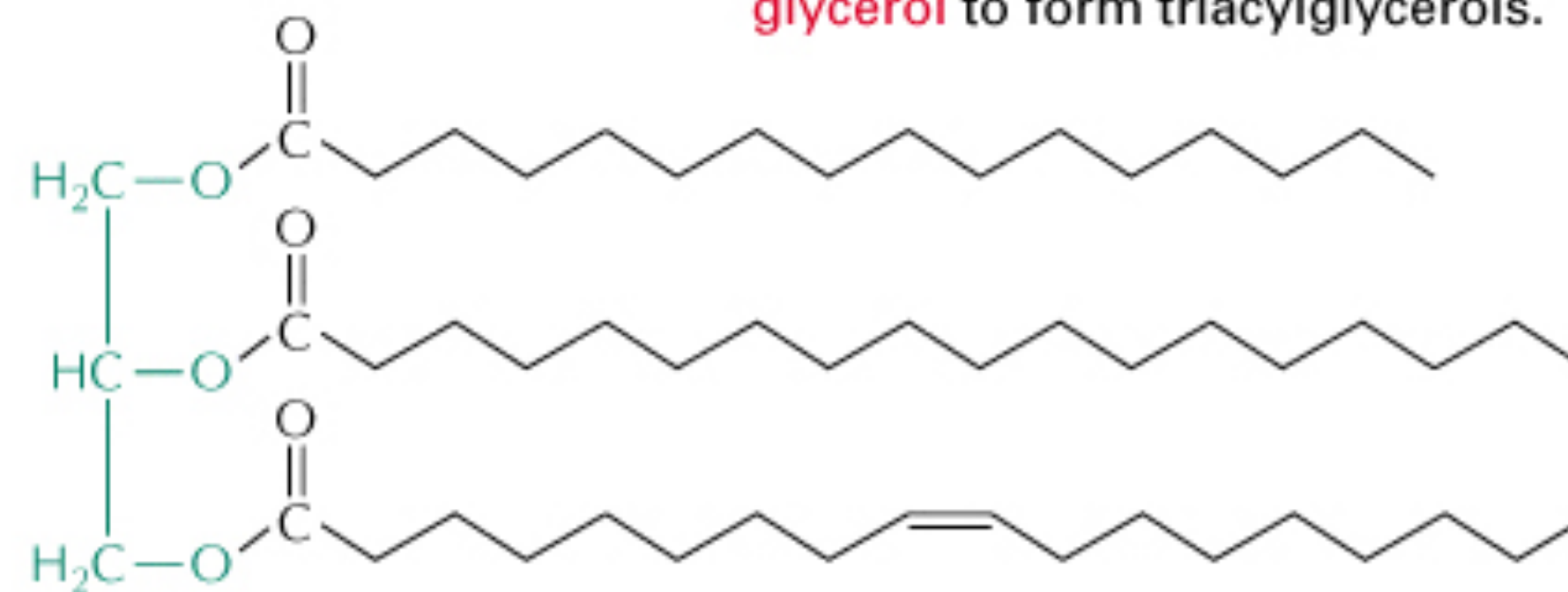
중성지방



(a) Dehydration synthesis
(condensation reaction)

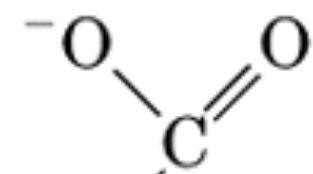
TRIACYLGLYCEROLS

Fatty acids are stored as an energy reserve (fats and oils) through an ester linkage to **glycerol** to form triacylglycerols.

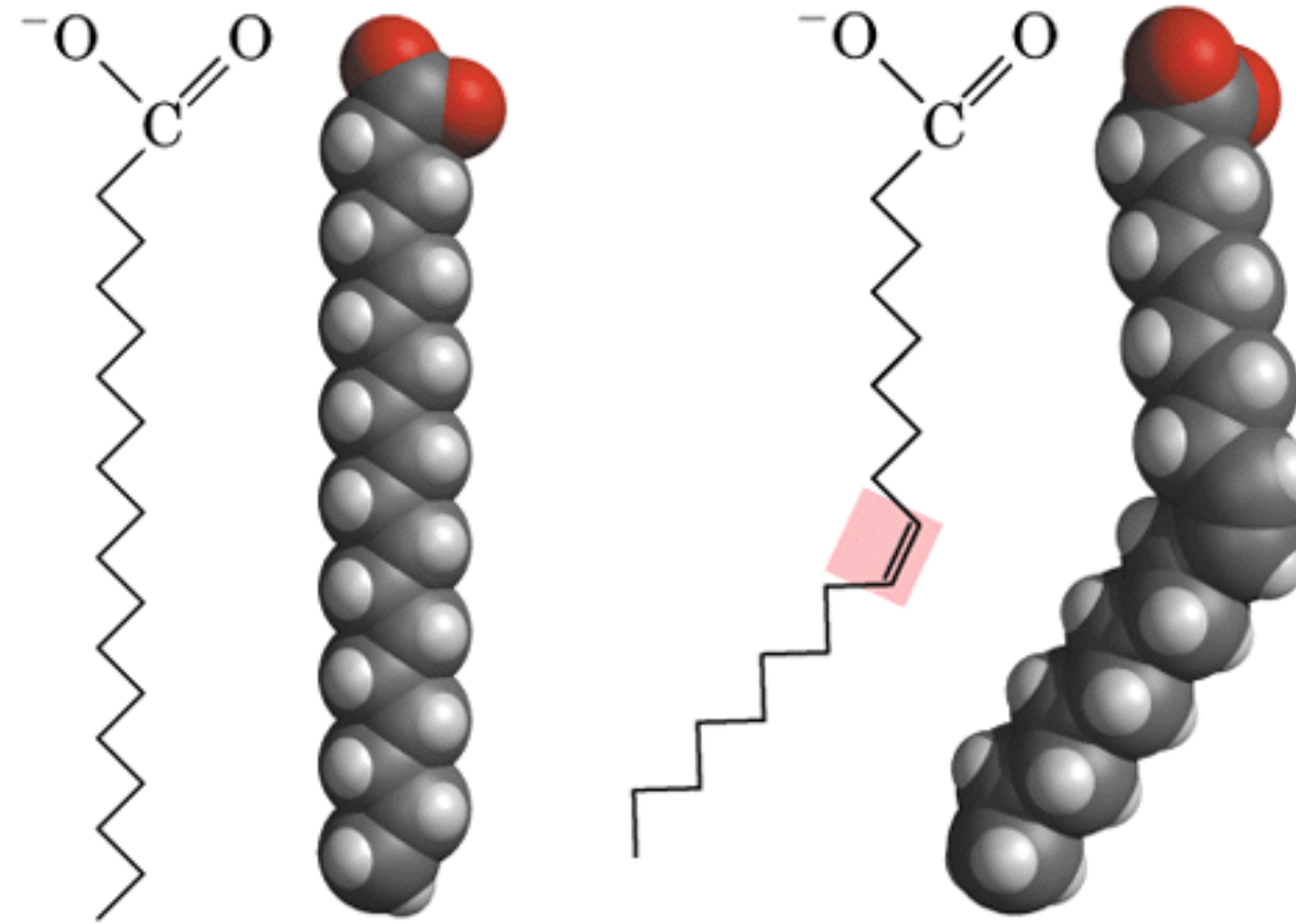


포화지방산 & 불포화지방산

Carboxyl group

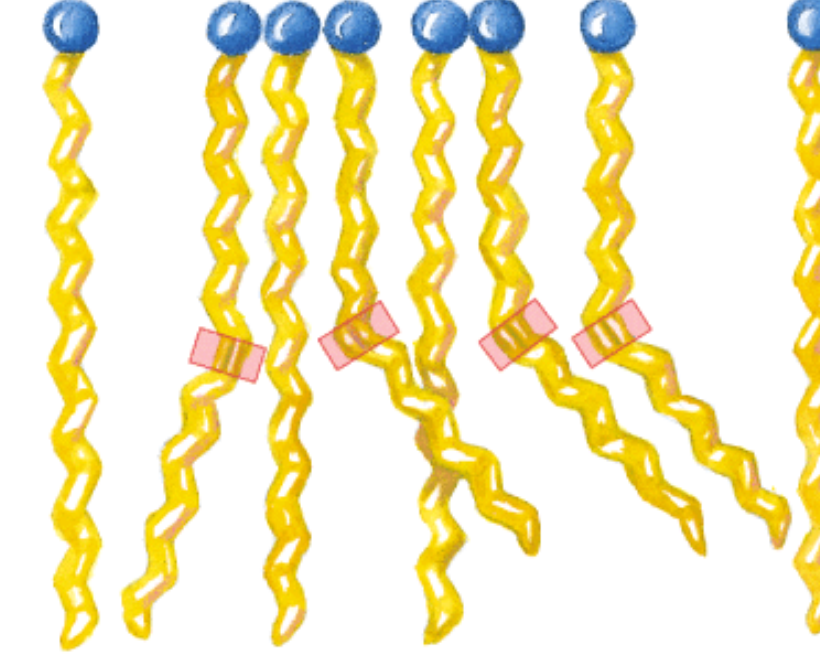


Hydrocarbon chain



Saturated fatty acids

(c)



Mixture of saturated and unsaturated fatty acids

(d)

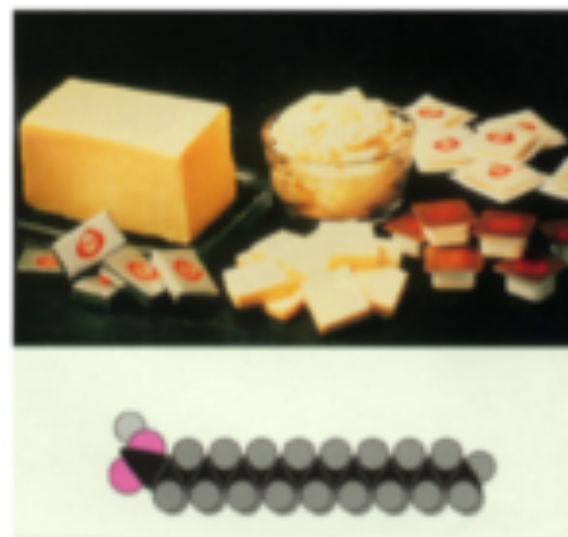
TWO TYPES OF FATS

SATURATED

Solid at room temp.

No double bonds

Most animal fats

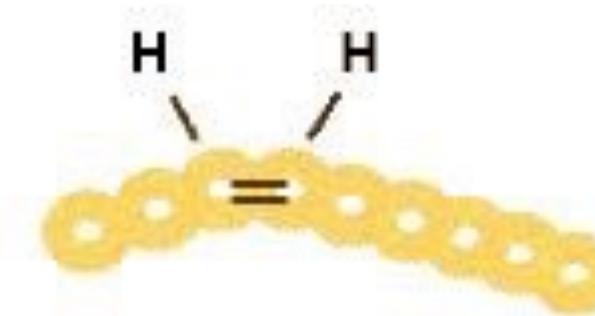


UNSATURATED

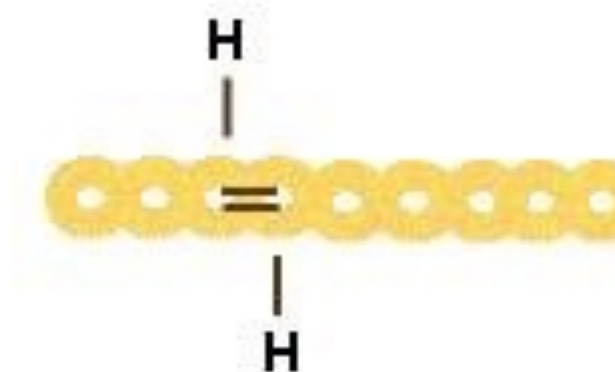
Liquid at room temp.

Double bonds

Most plant fats (oils)

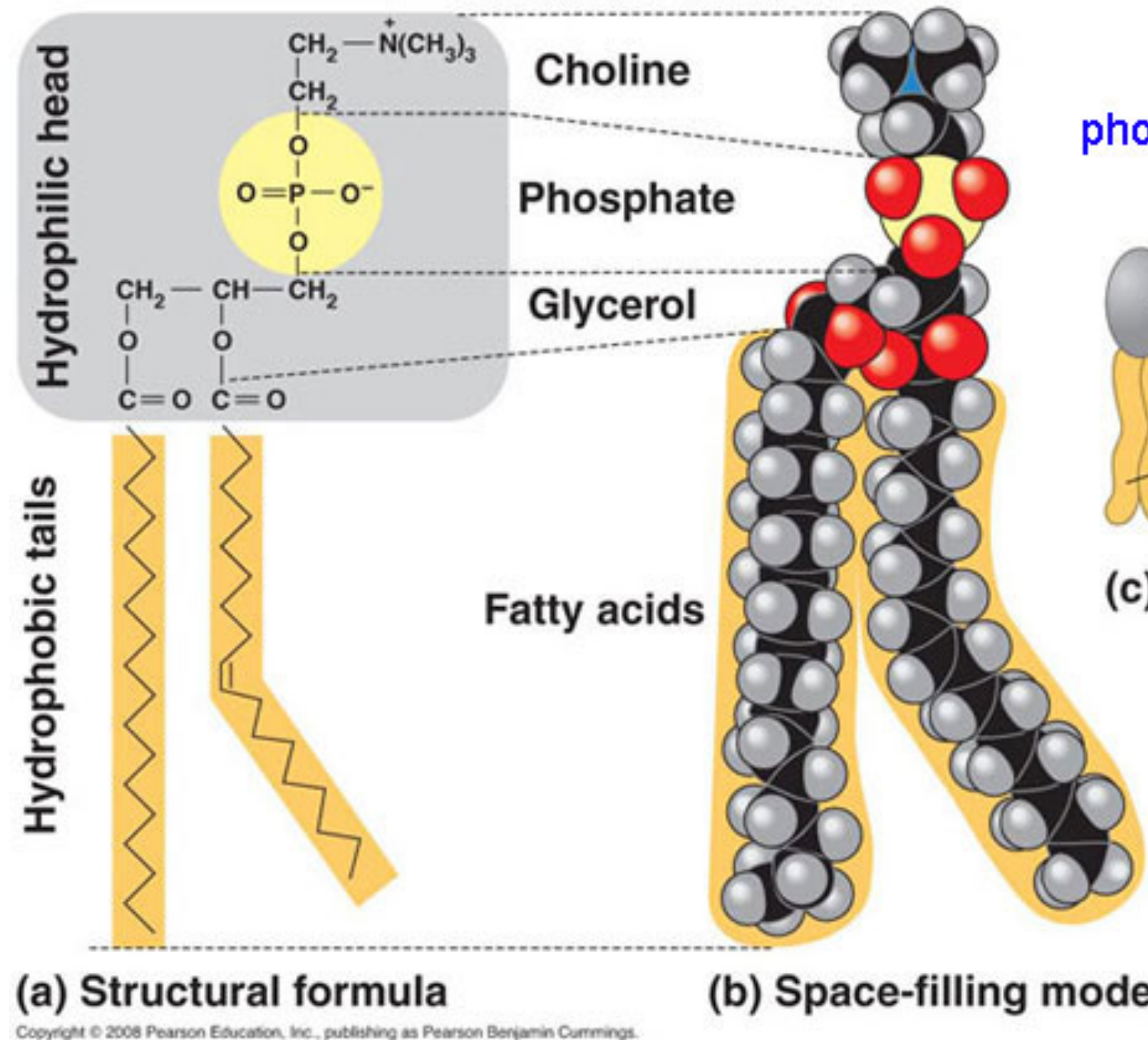


cis-double bond

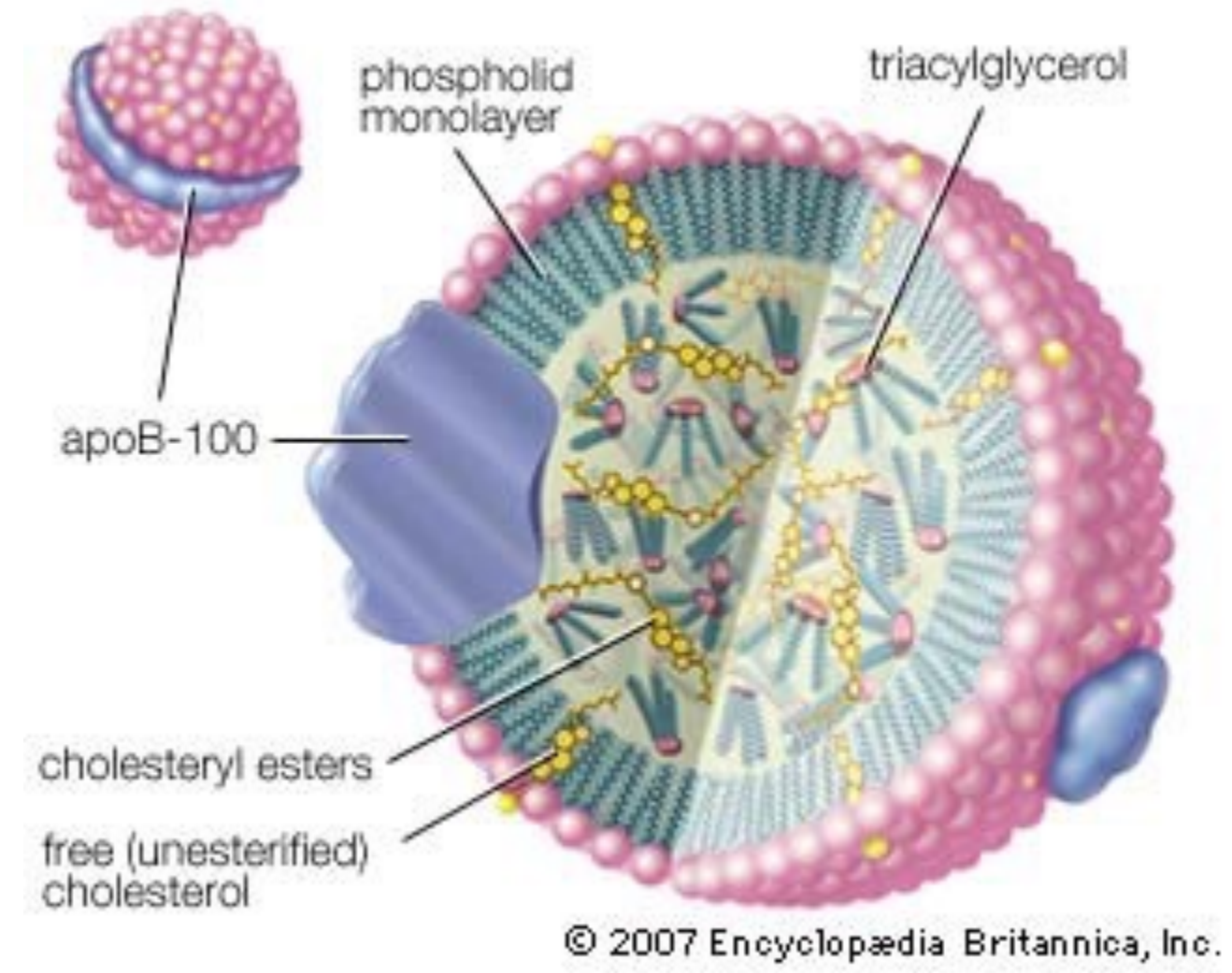
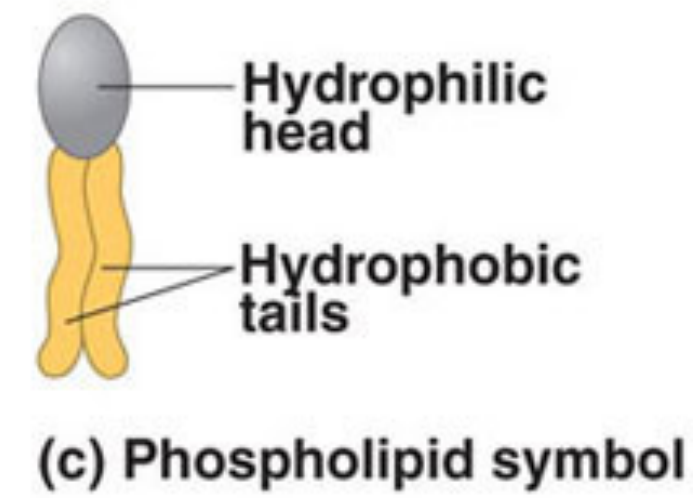


Trans-double bond

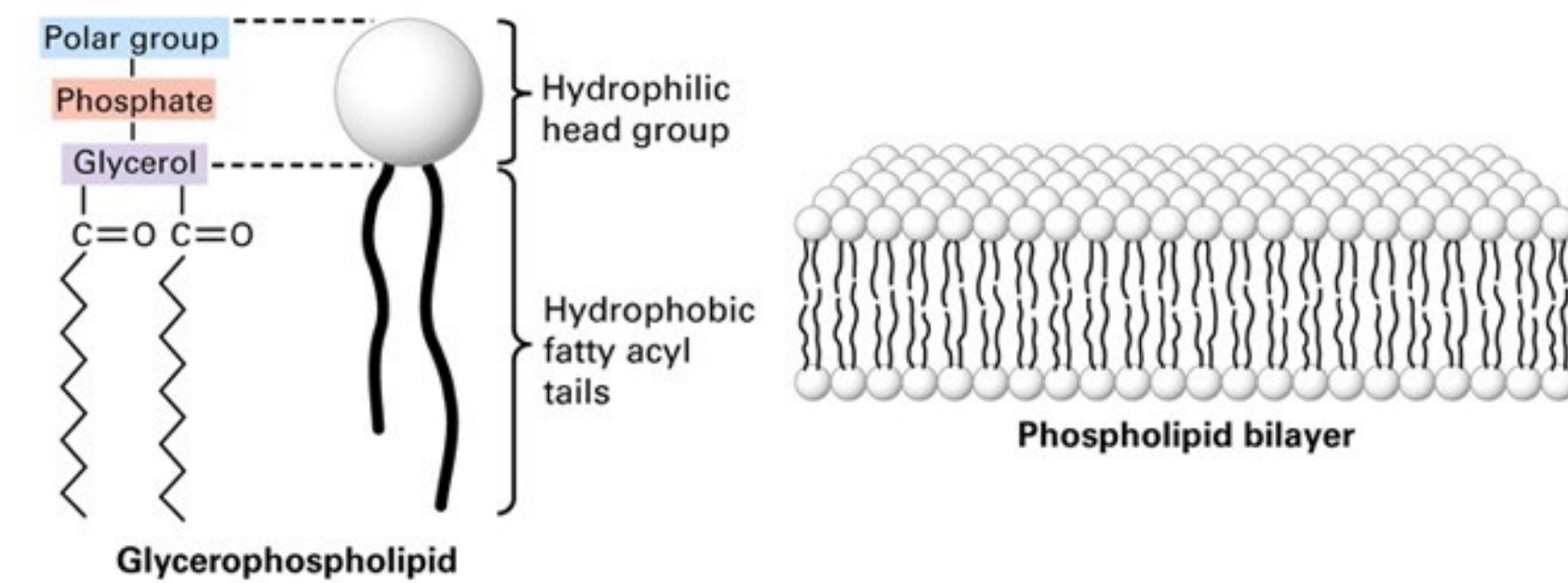
인지질



phosphatidylcholine

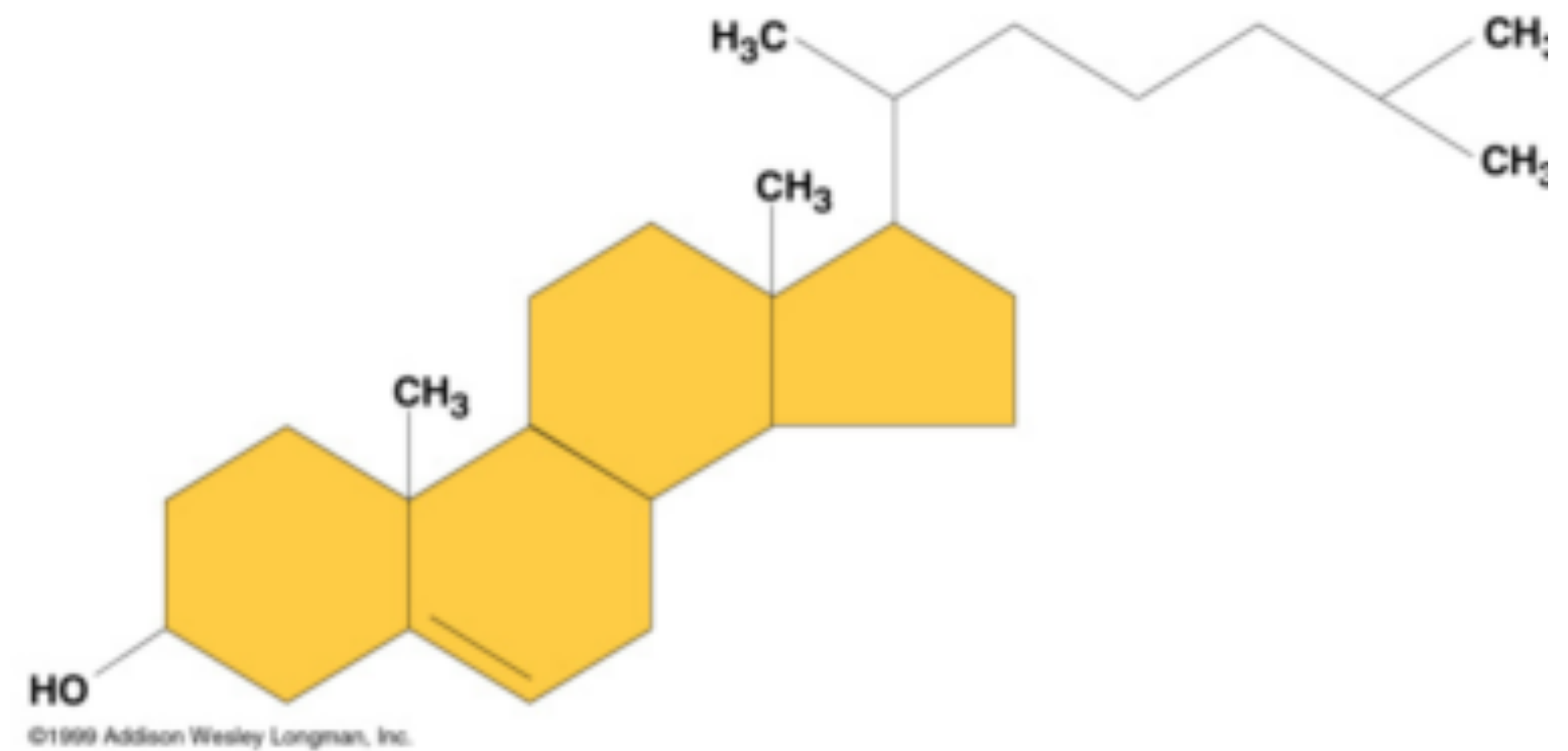


amphipathic



GROUP 3: THE STEROIDS

- Structurally different from fats and phospholipids
- **Characteristic structure: 4 Fused Rings**
Found in all steroid compounds
- Variation in steroids: variation in functional groups attached to ring group



Cholesterol:

Precursor in living organisms for:

- sex hormones (testosterone in male, estrogen and progesterone in female)
- Corticosteroids from adrenals
- Vitamin D
- Bile salts
- Important part of cell membranes

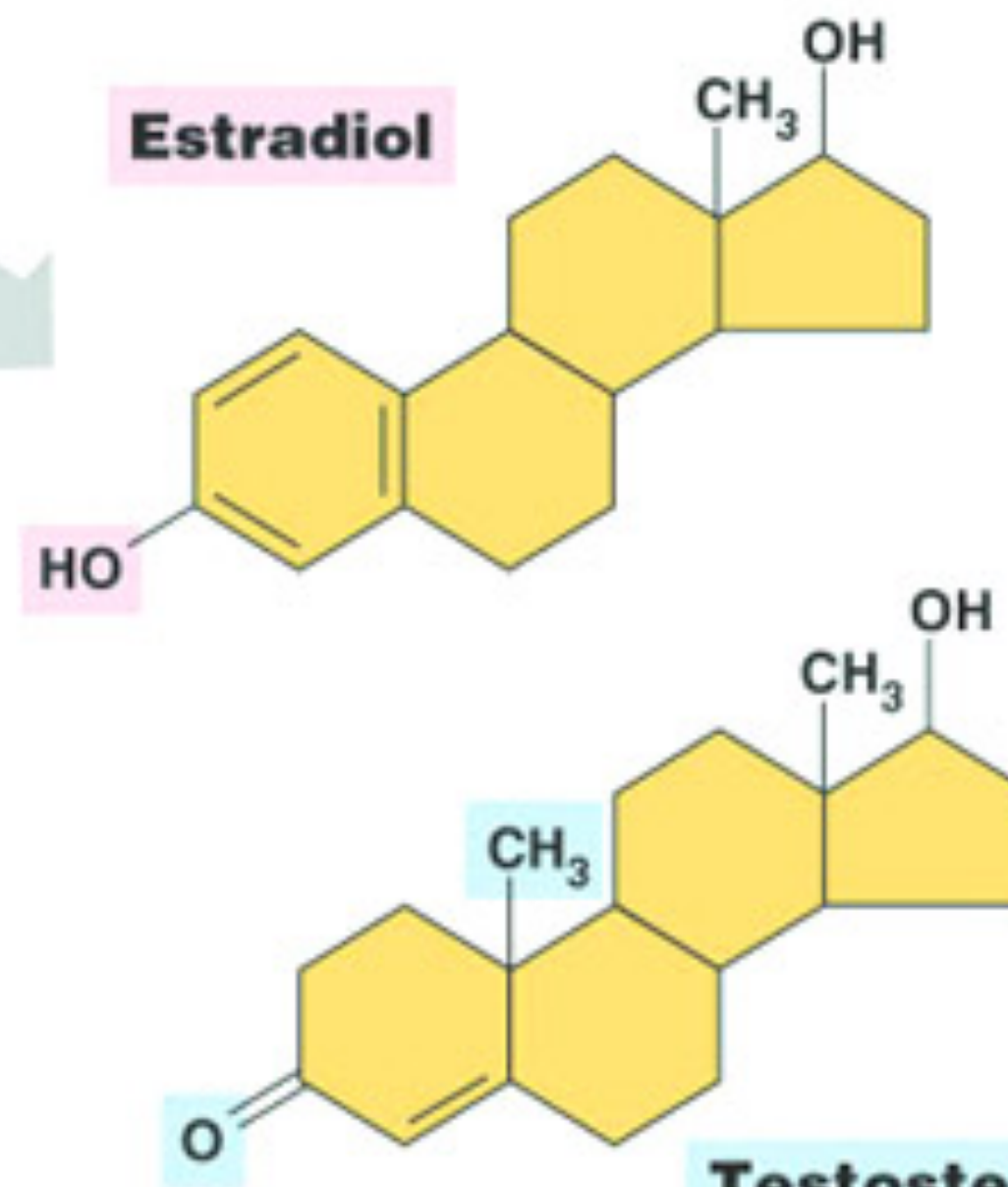
Obtain in diet and make it in the liver.

Anabolic steroids: Testosterone mimics (body thinks its is testosterone)



Female lion

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Male lion

단백질

PROTEINS

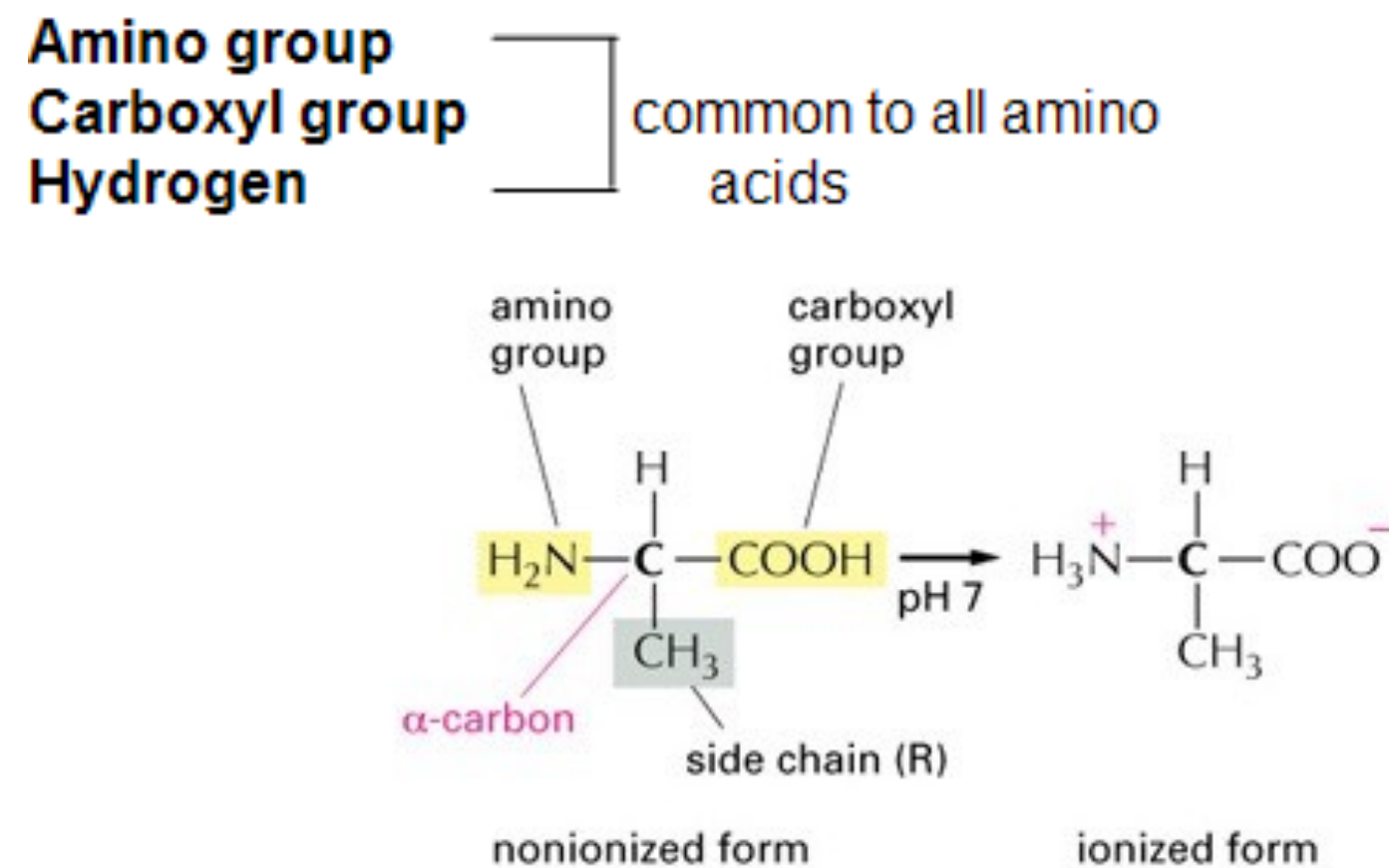
Some of the most important molecules in your body:

Major constituent of cells
Hold the body together
Direct all the metabolic functions

The list at right is by no means complete
But it does give you an idea of the tremendous diversity of proteins.
Proteins are polymers. **MONOMER: AMINO ACID**

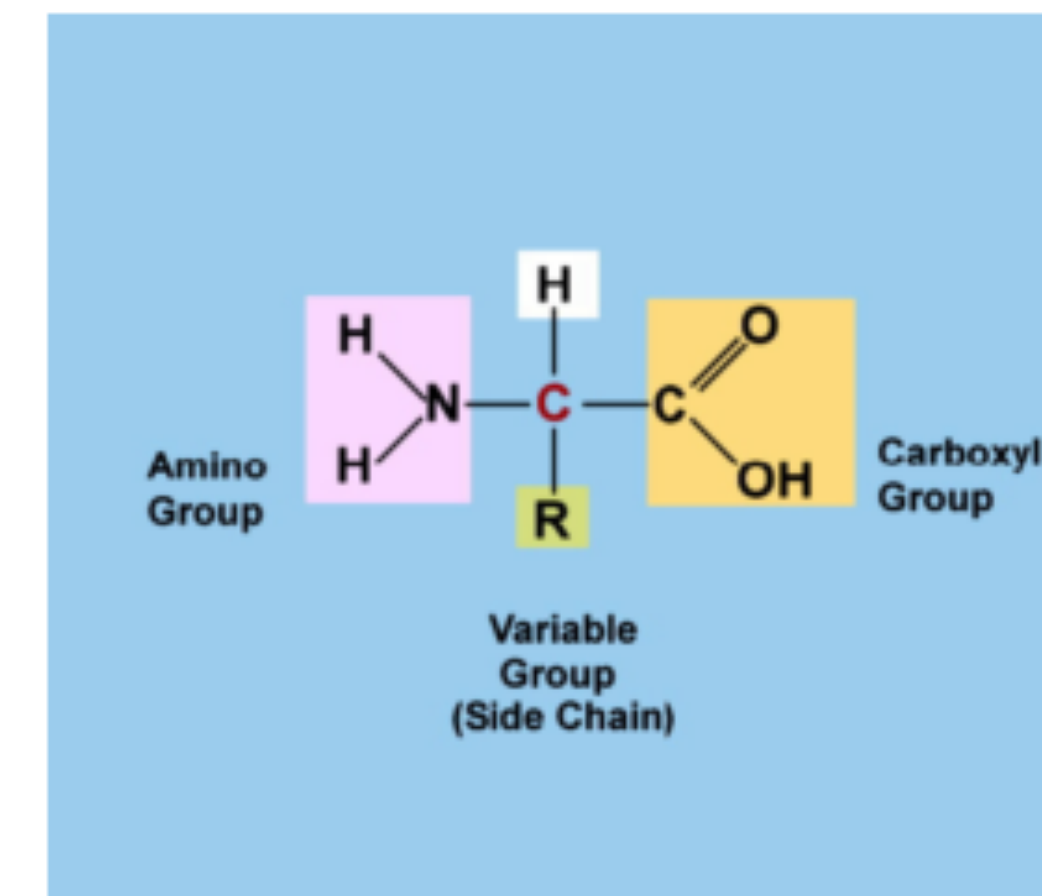
All proteins in living organisms are made from the same set of 20 amino acids!
BASIC STRUCTURE OF AMINO ACID:

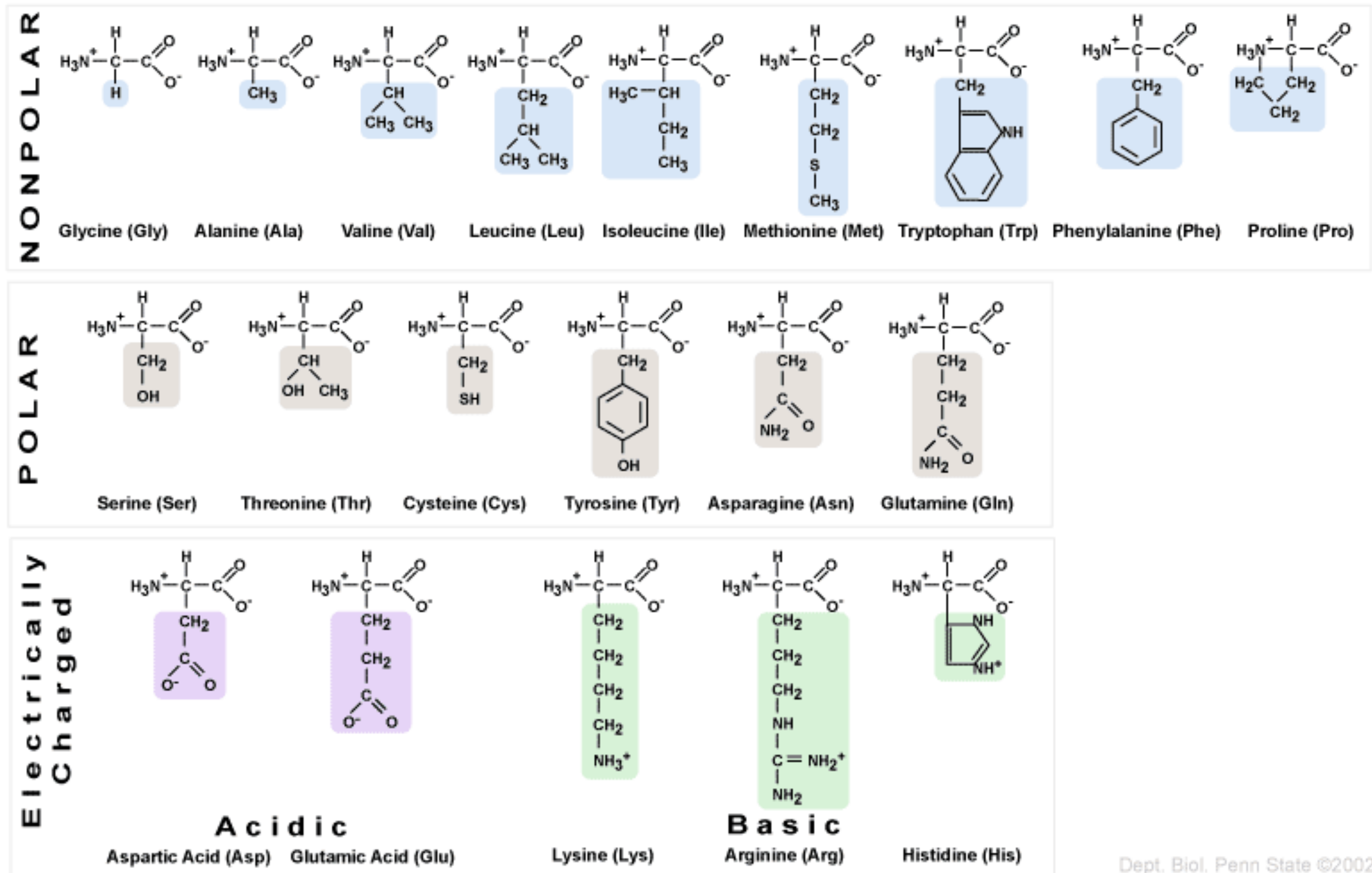
Central carbon with four functional groups:



SOME FUNCTIONS OF PROTEINS

1. STRUCTURAL PROTEINS
2. ENZYMES
3. HORMONES
4. CELL MOVEMENT
5. TOXINS
6. TRANSPORT
7. DEFENSE



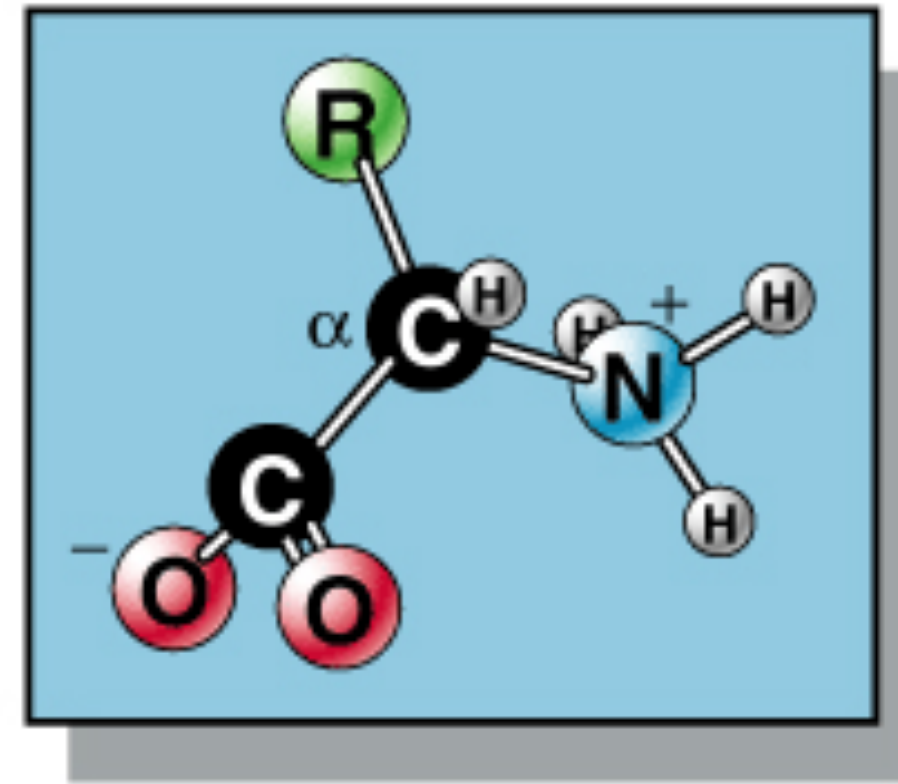


Dept. Biol. Penn State ©2002

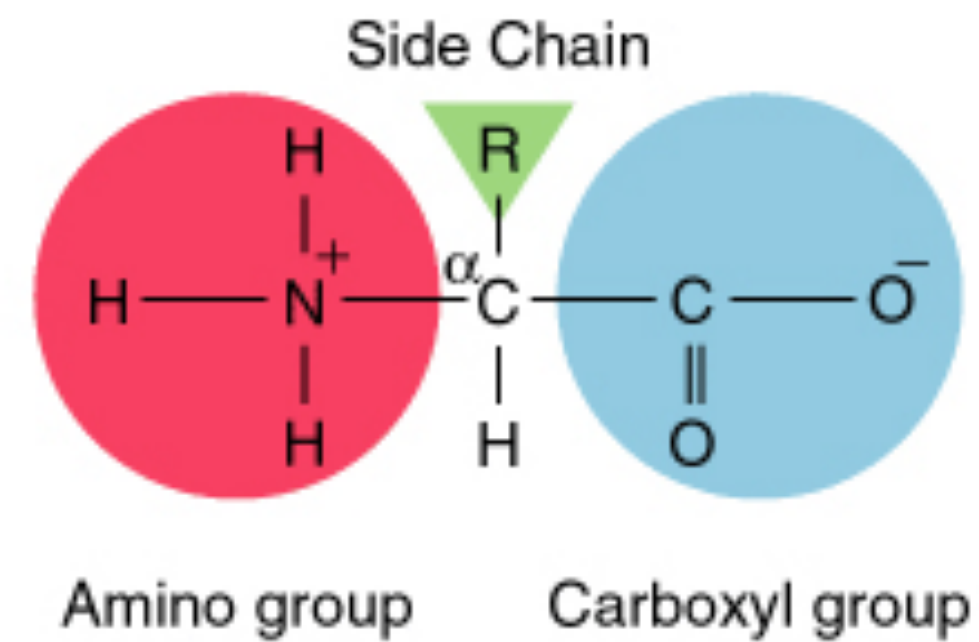
R Group determines:

- 1) **Identity** of amino acid
- 2) Physical properties (**size and shape**)
- 3) **Chemical properties** (polar, non-polar, acidic, basic, neutral)

Peptide Bond

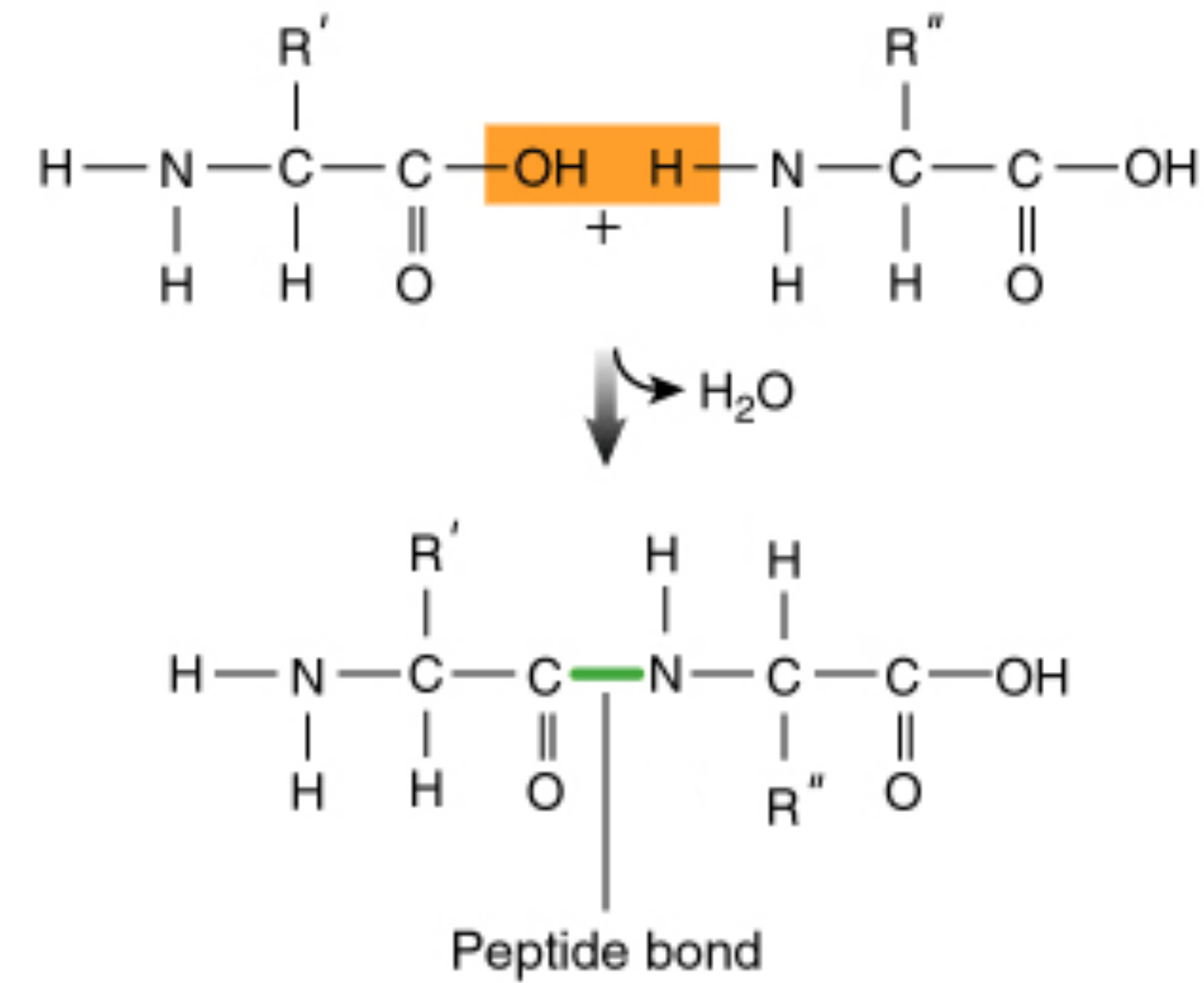


(a)



(b)

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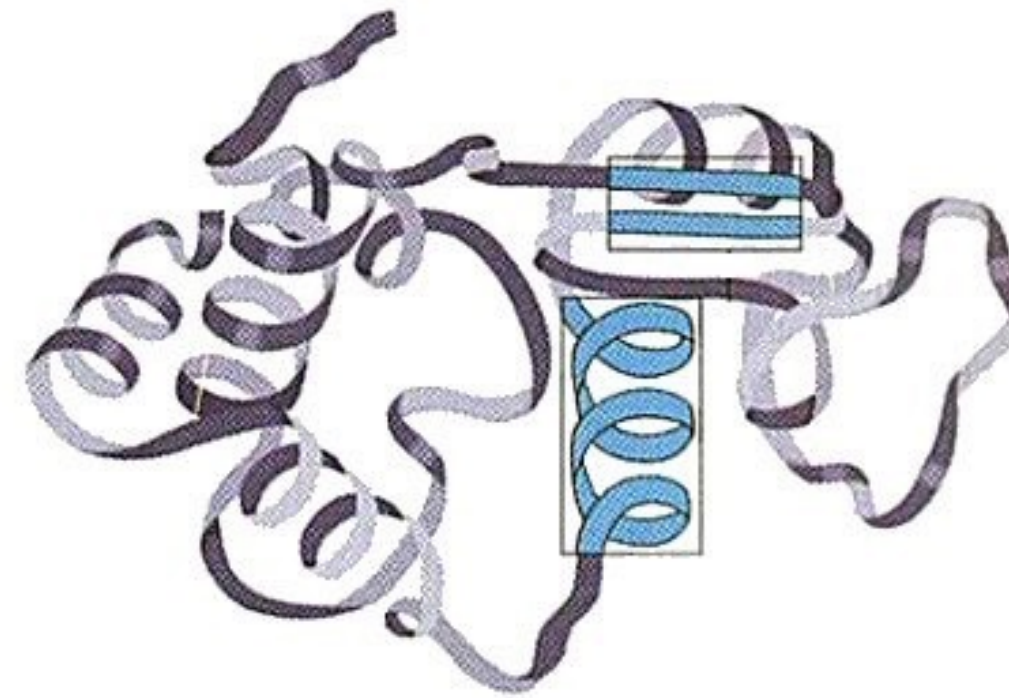


(c)

Primary structure



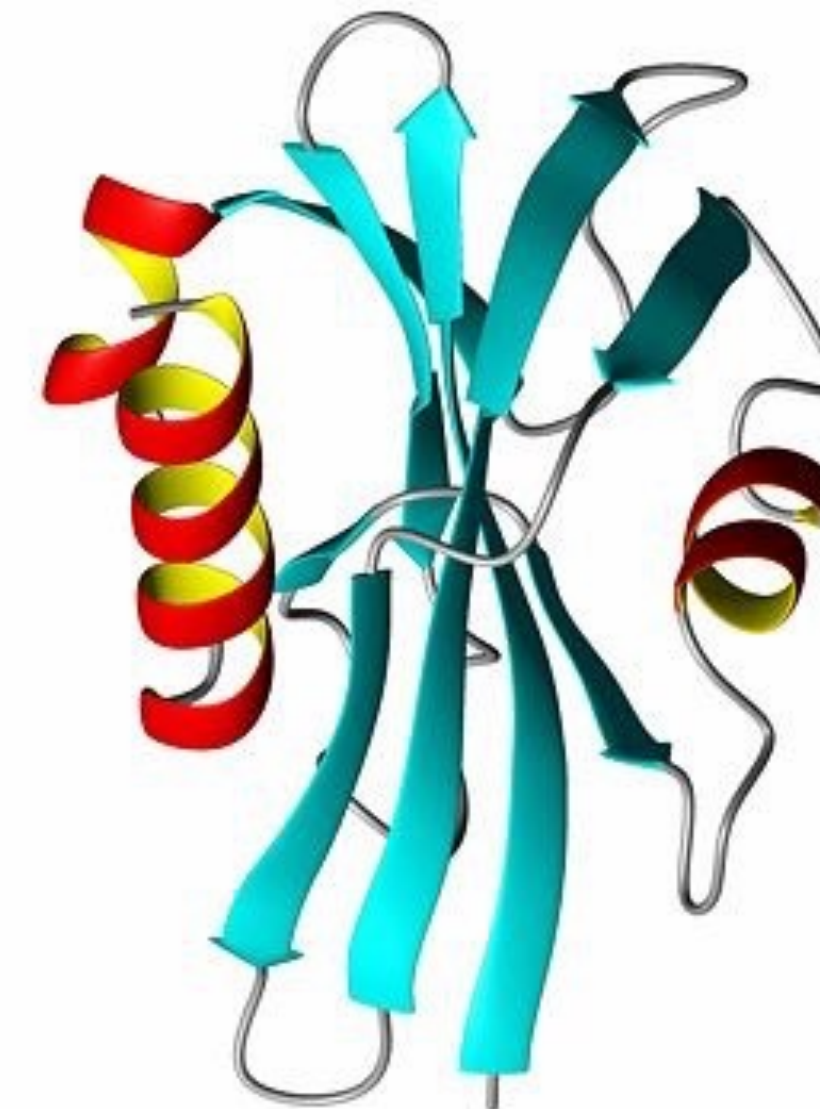
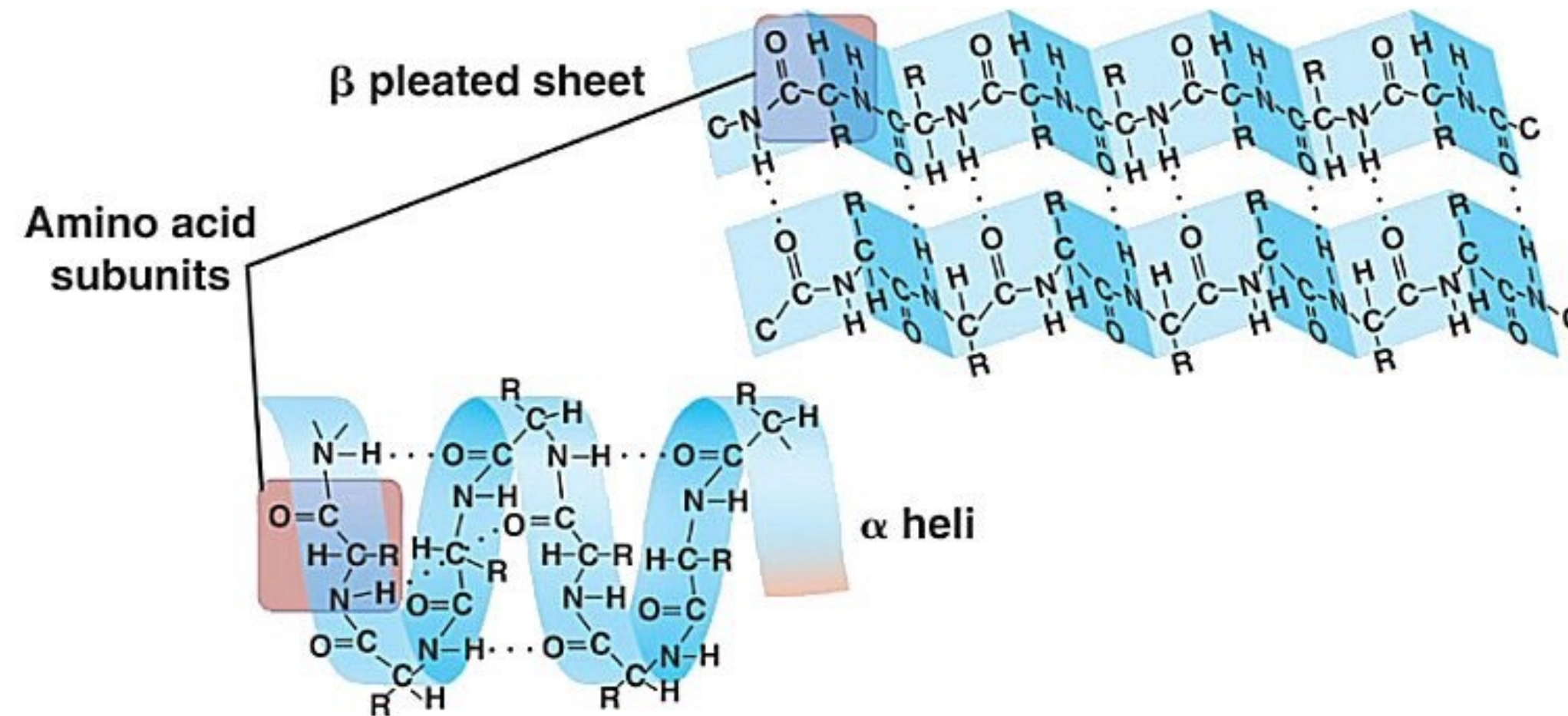
Secondary structure



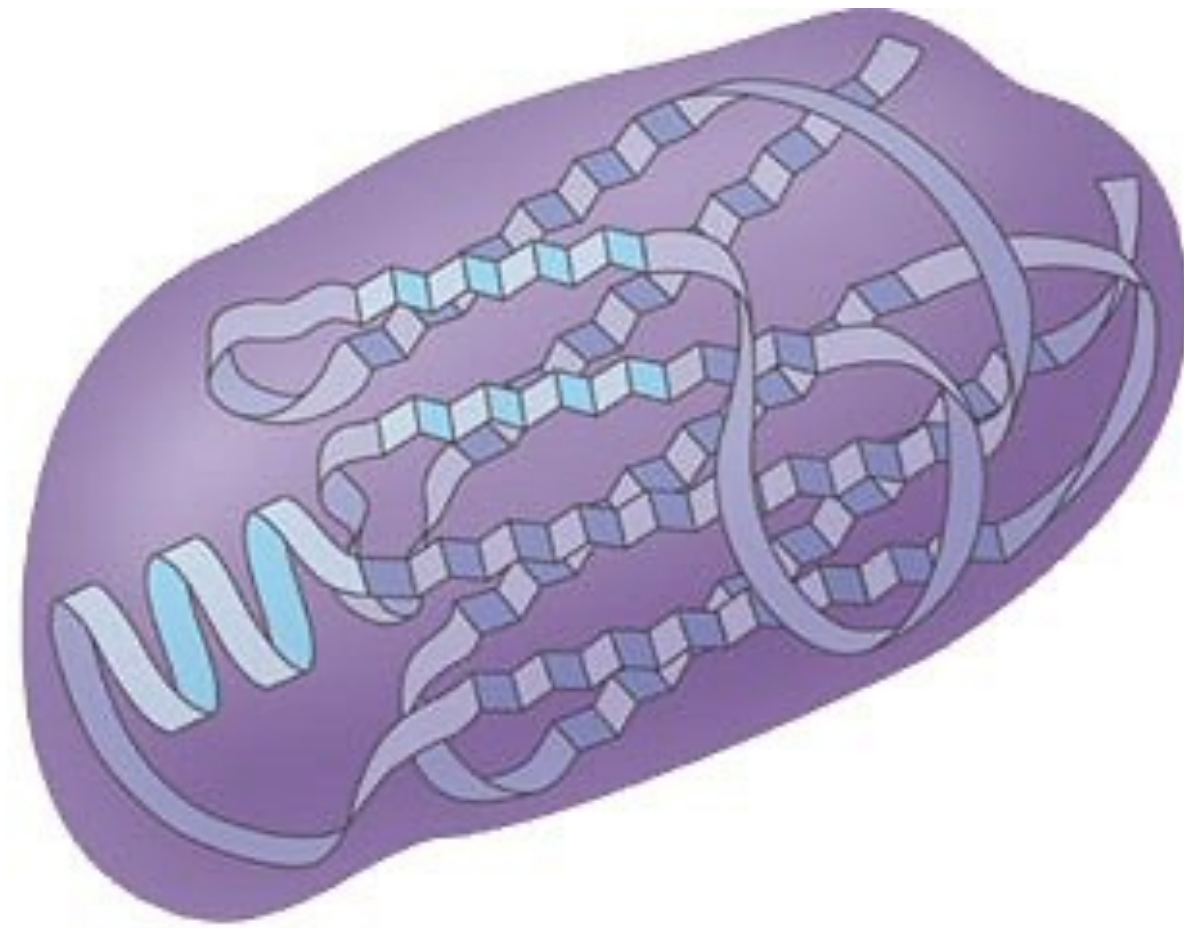
골격간 수소결합.

Alpha helix: 머리카락의 alpha-케라틴과 같은 섬유단백질. 막단백질.

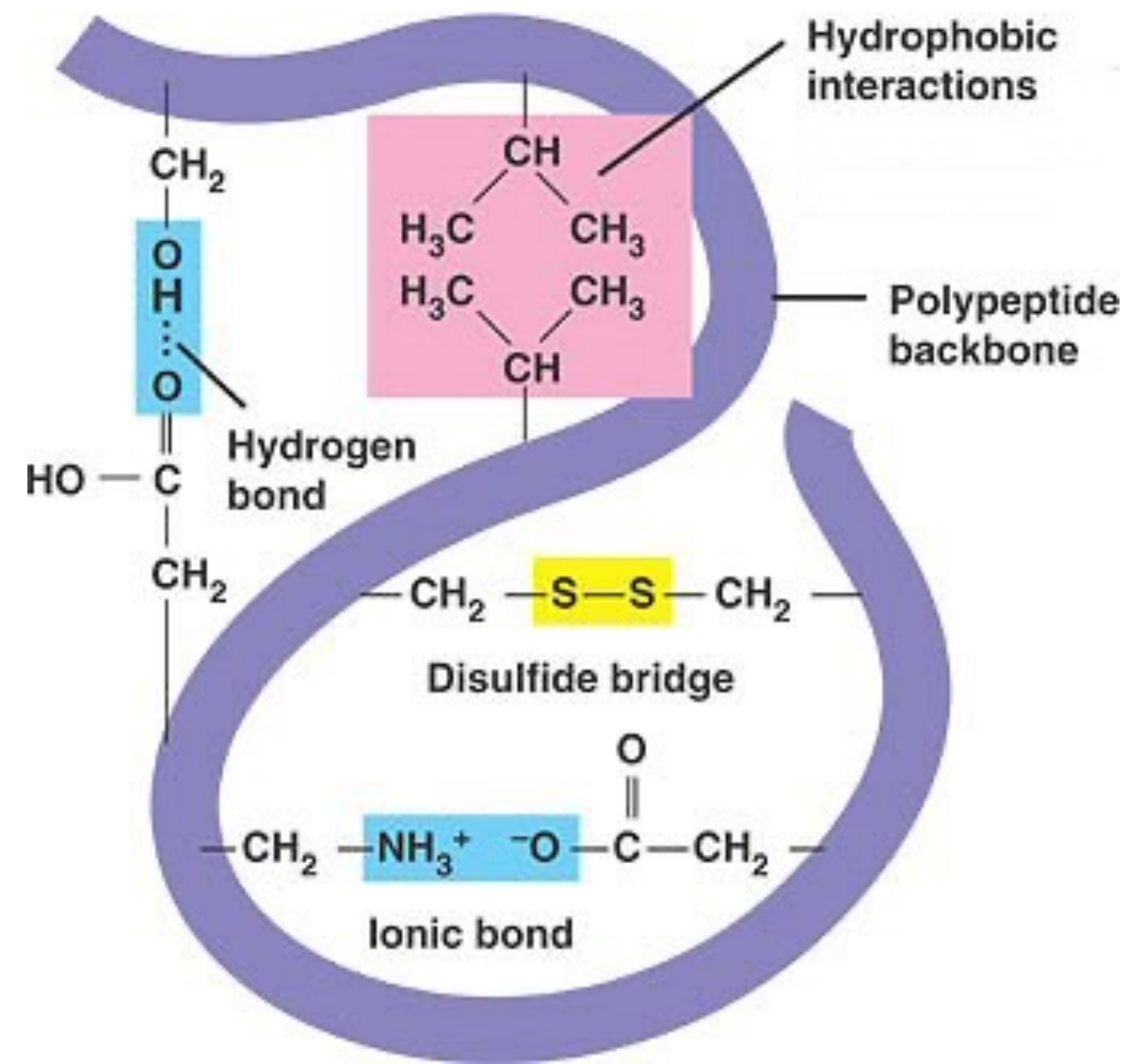
Beta pleated sheet: 거미의 실크 단백질과 같은 섬유단백질.



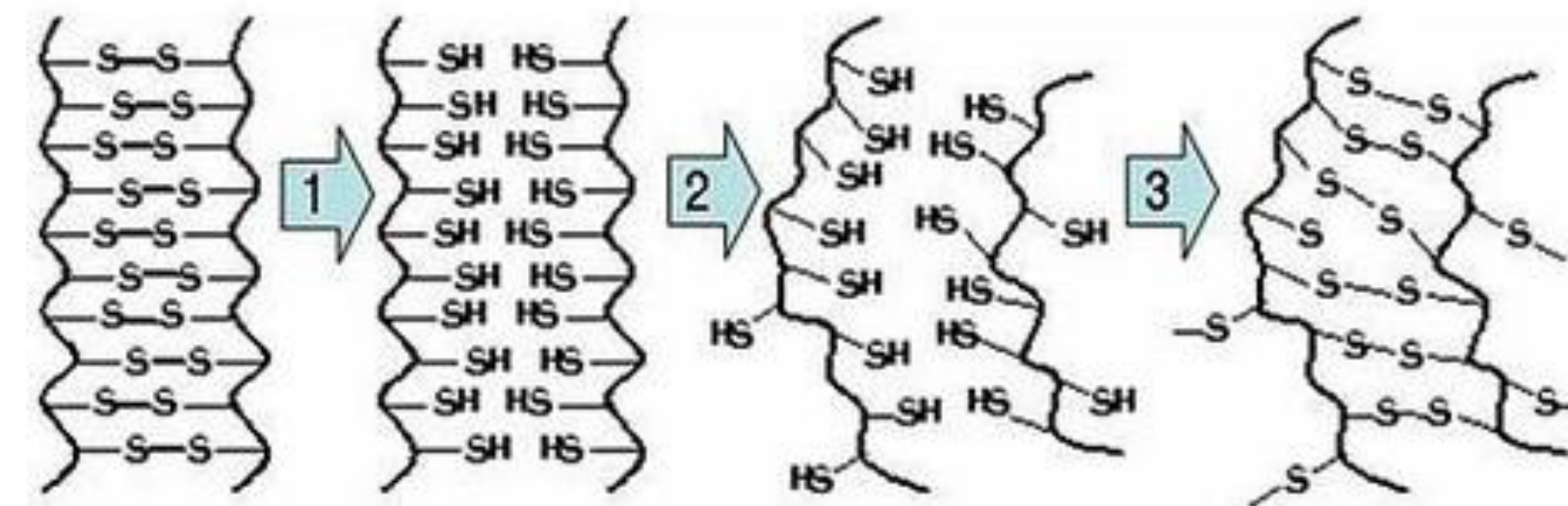
Tertiary structure



R기간의 다양한 상호작용에 의해.



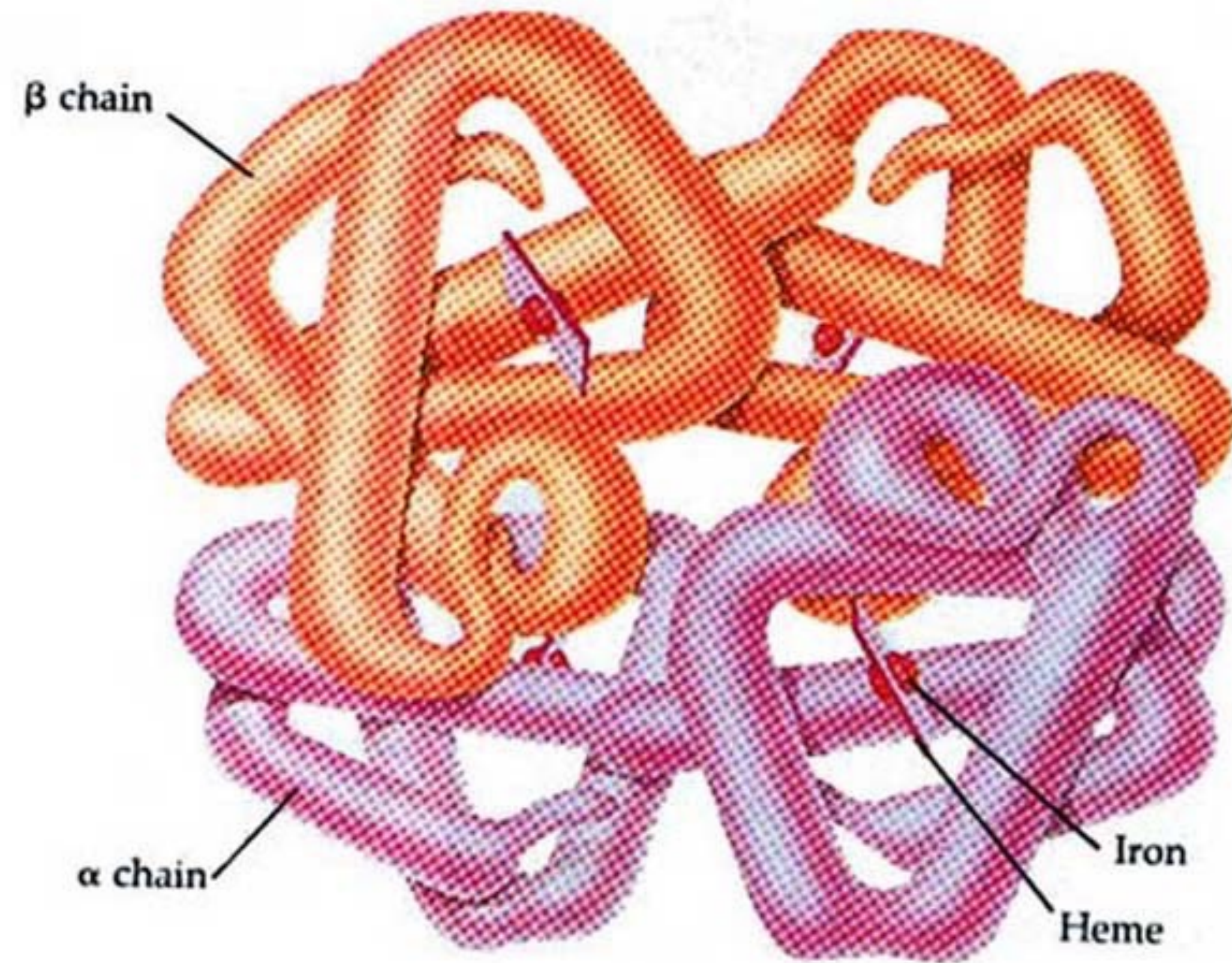
파마의 원리



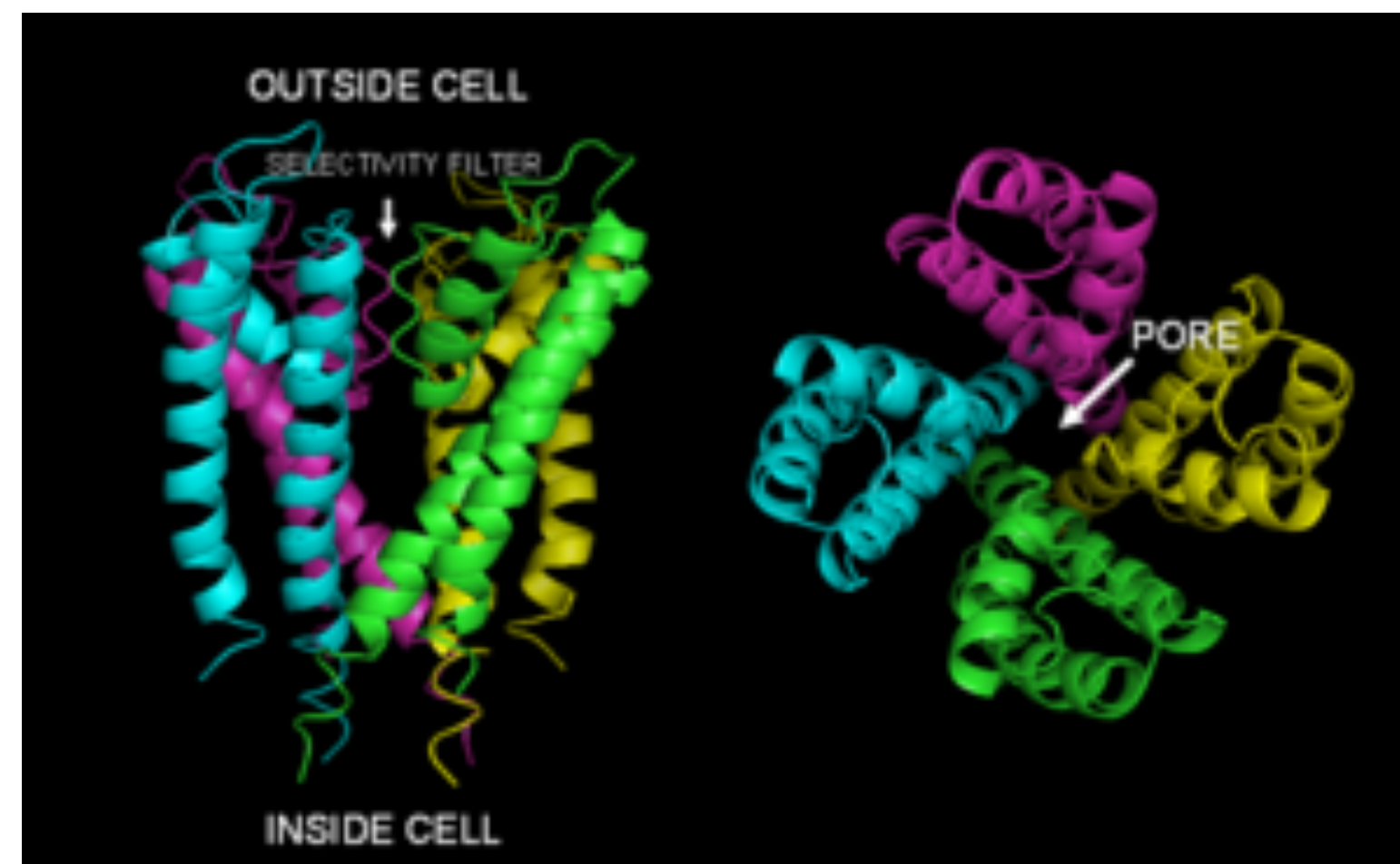
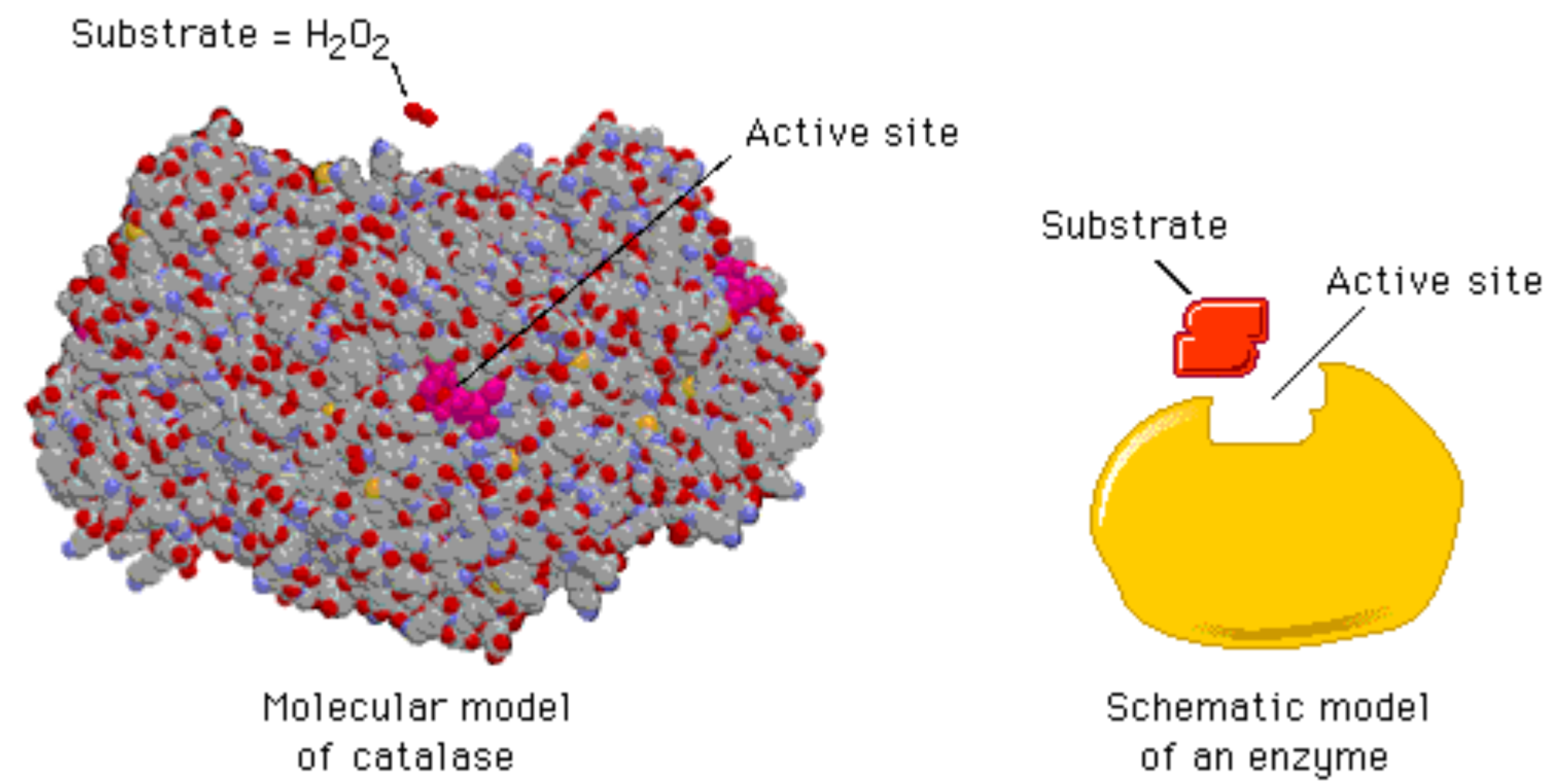
Quaternary structure



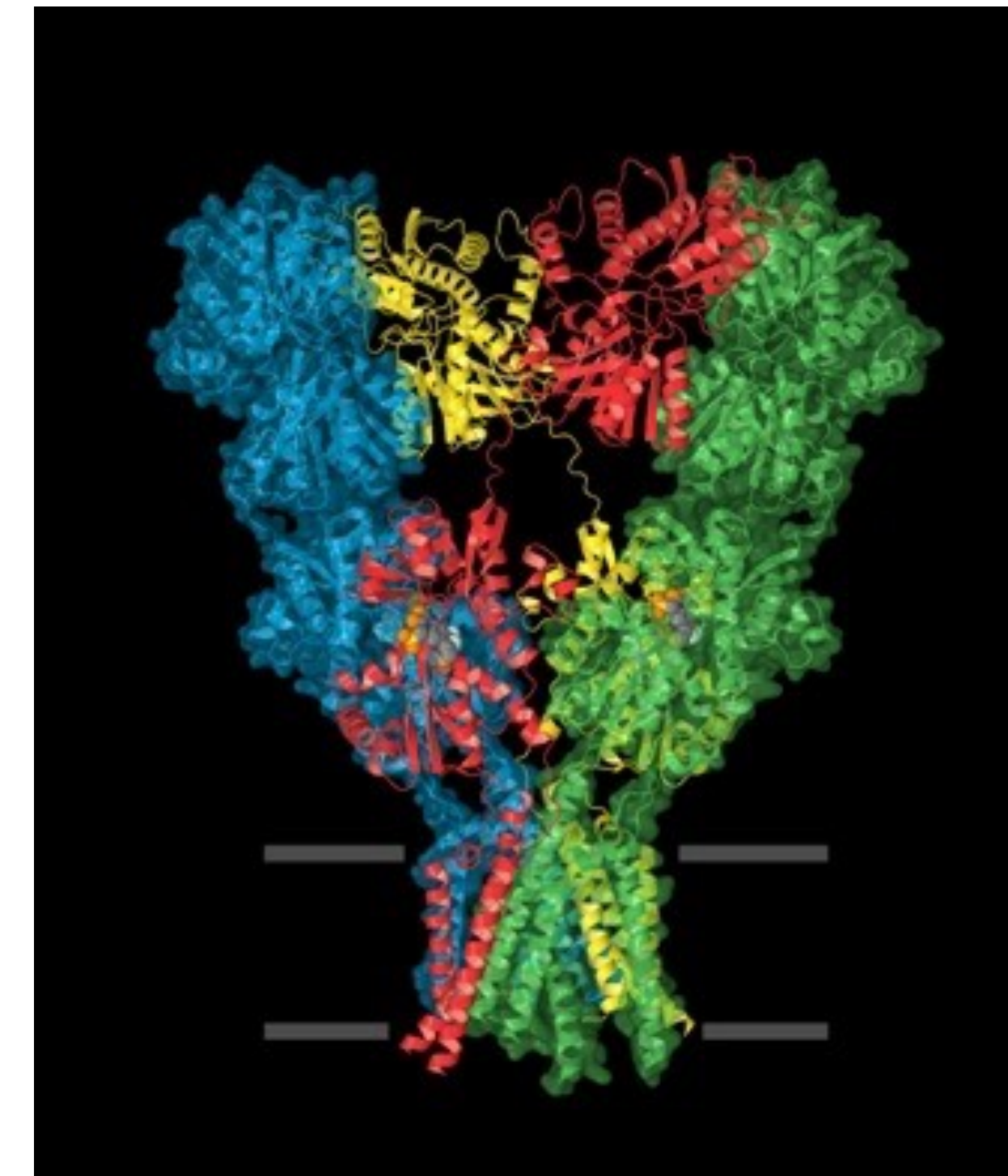
(a) Collagen



(b) Hemoglobin



Structure of an ion channel



Scientists used X-ray crystallography to develop this map of the complete structure of the AMPA-subtype glutamate receptor in the rat brain (courtesy of Dr. Eric Gouaux, OHSU)

소화 및 흡수

탄수화물

Path of absorption

Carbohydrate digestion

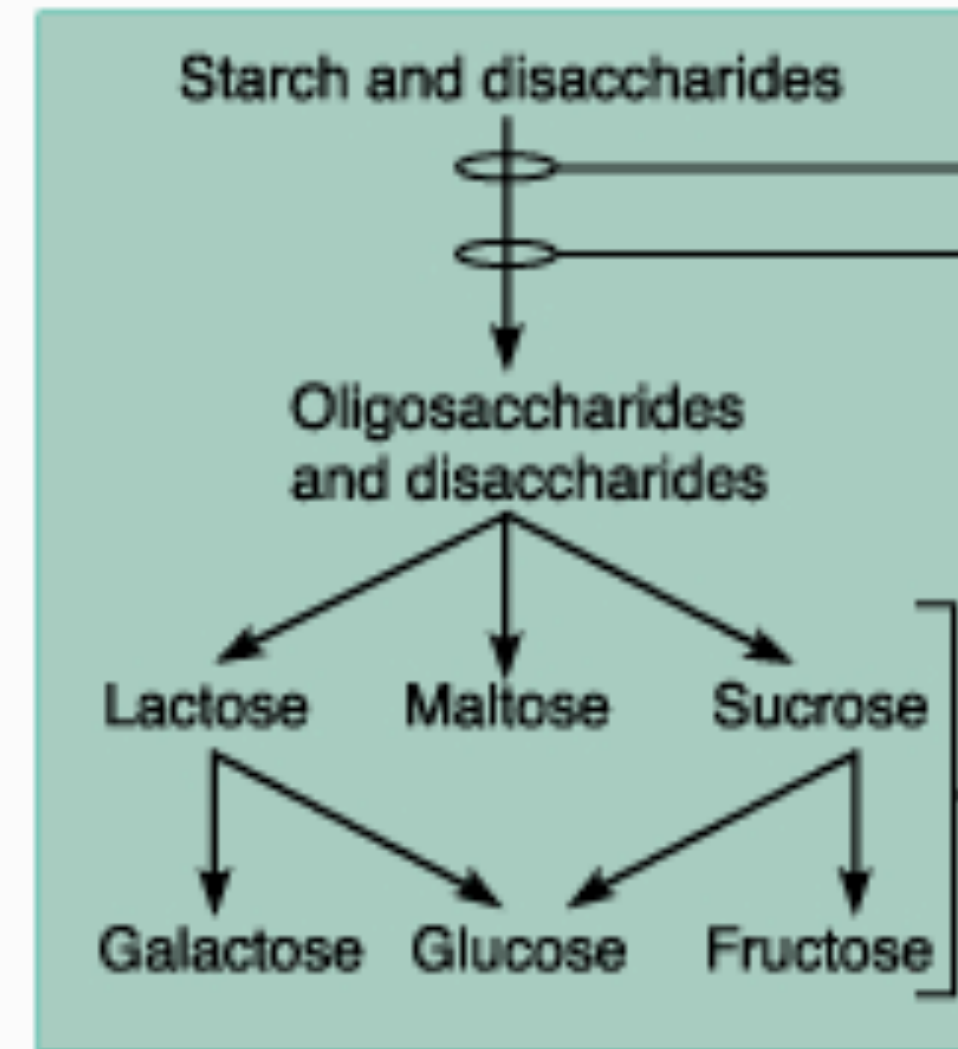
Absorption: The monosaccharides glucose and galactose are absorbed via cotransport with sodium ions; fructose passes via facilitated diffusion. All monosaccharides enter the capillary blood in the villi and are transported to the liver via the hepatic portal vein.

Glucose + glucose = maltose

Glucose + galactose = lactose

Glucose + fructose = sucrose

Foodstuff



Enzyme(s) and source

Salivary amylase
Pancreatic amylase

Brush border enzymes in small intestine (dextrinase, glucoamylase, lactase, maltase, and sucrase)

Site of action

Mouth
Small intestine

Small intestine

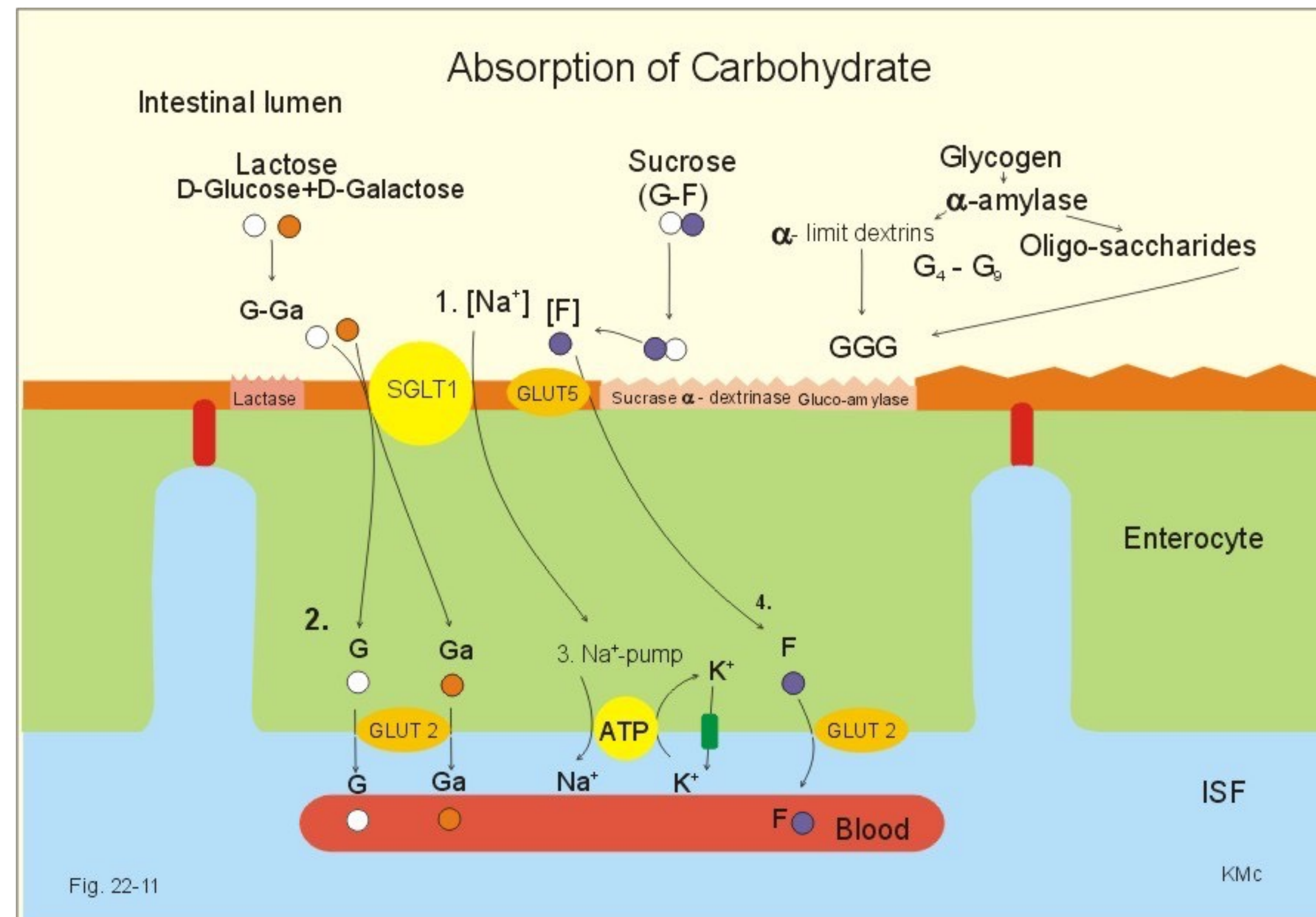


Fig. 22-11

지질

Path of absorption

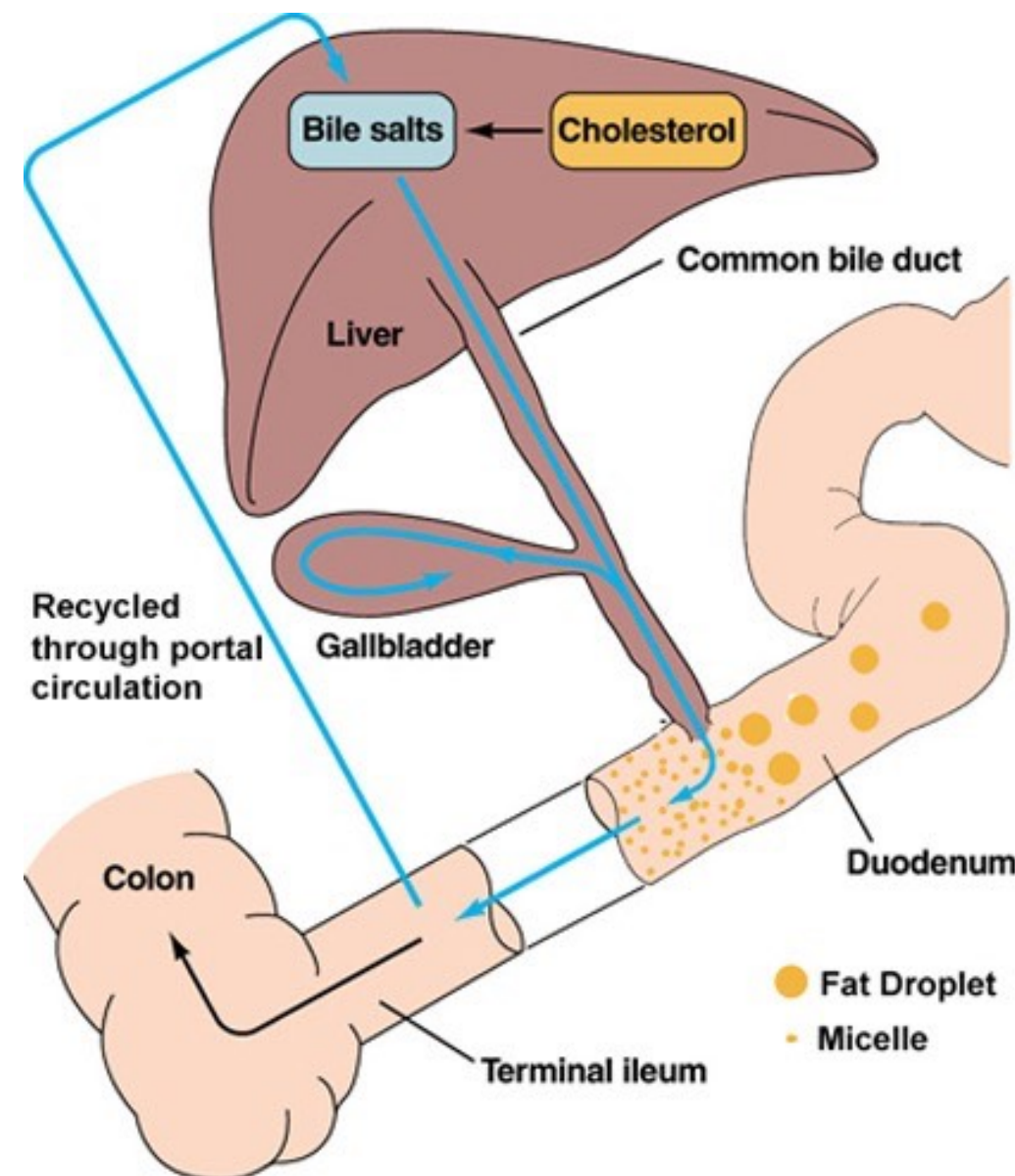
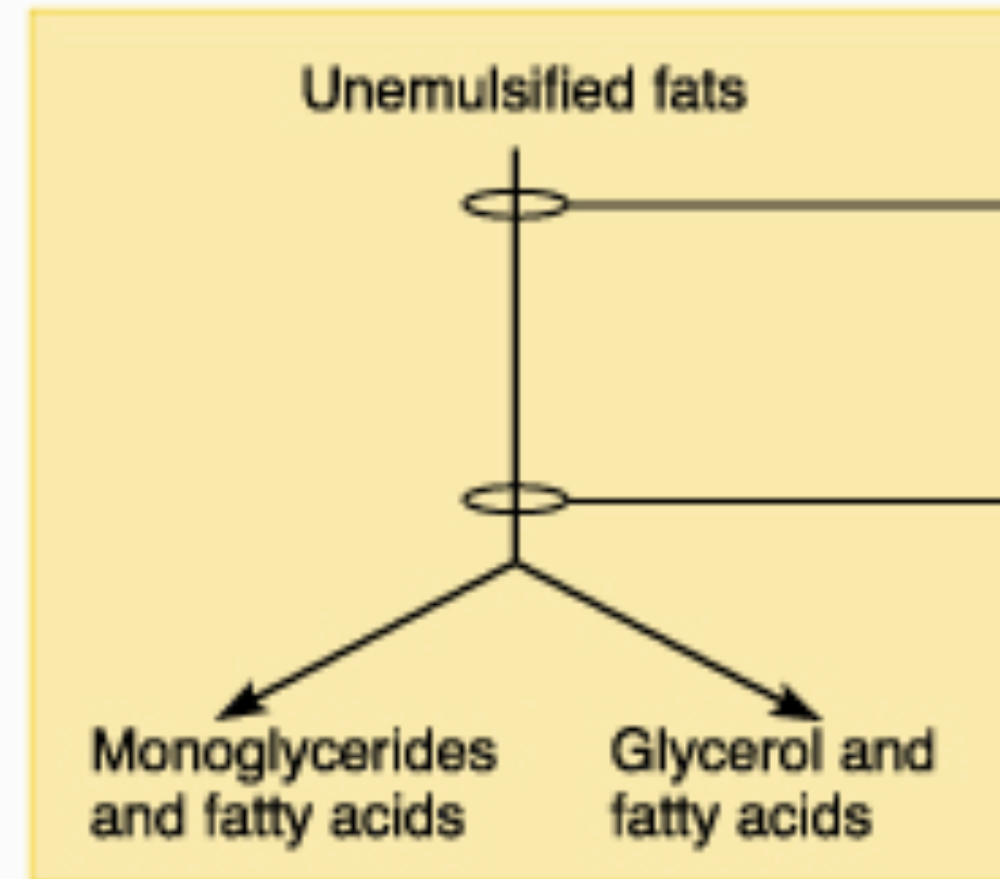
Fat digestion

Absorption: Fatty acids and monoglycerides enter the intestinal cells via diffusion. They are combined with proteins within the cells, and the resulting chylomicrons are extruded. They enter the lacteals of the villi and are transported to the systemic circulation via the lymph in the thoracic duct. (Glycerol and short-chain fatty acids are absorbed into the capillary blood in the villi and transported to the liver via the hepatic portal vein.)

Foodstuff

Enzyme(s) and source

Site of action

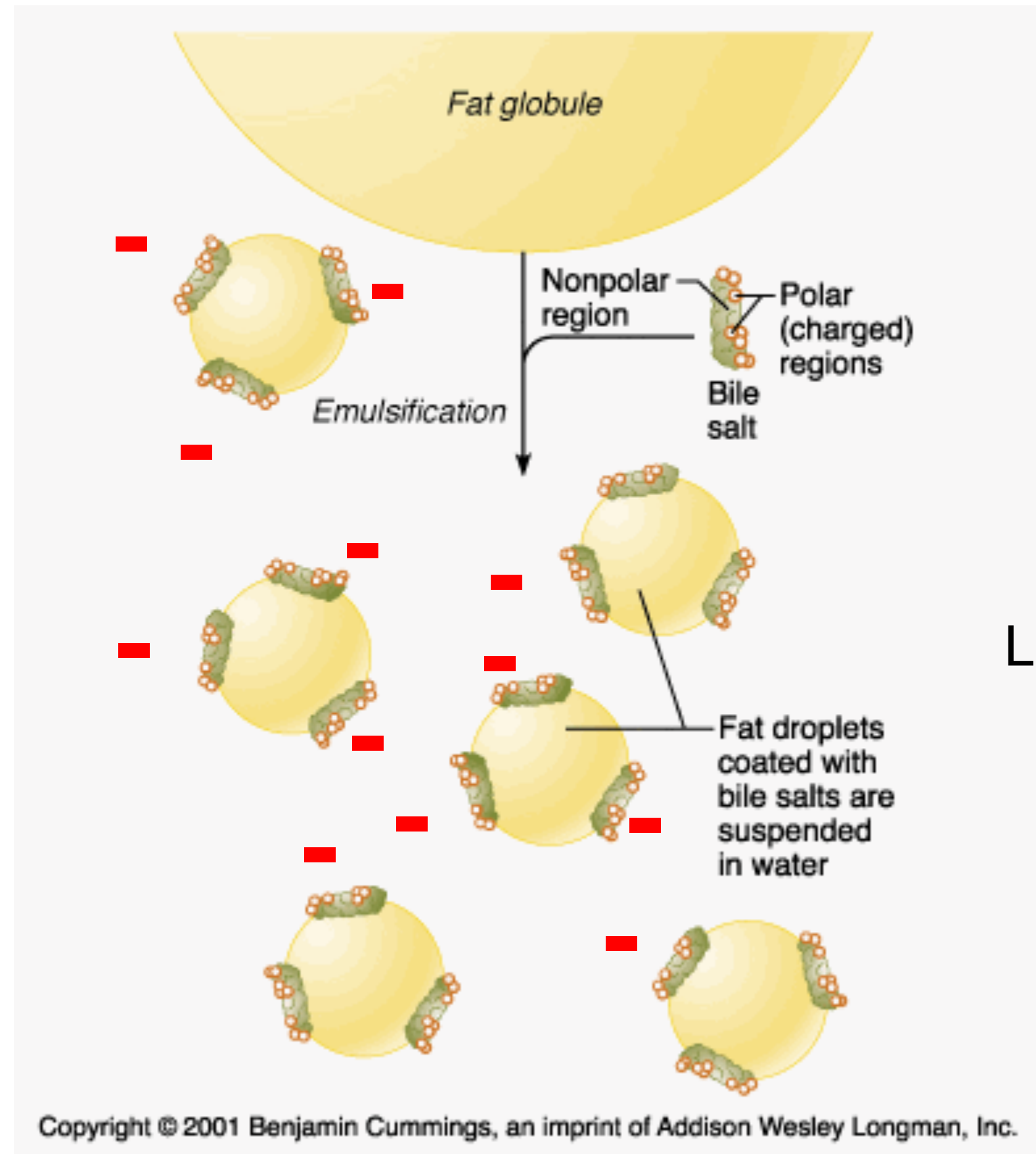


담즙염의 Enterohepatic circulation

- 지방의 소화를 돕는다.(소화 효소X)

1. Detergent action: 유화 작용 (emulsification)
2. Micelle 형성

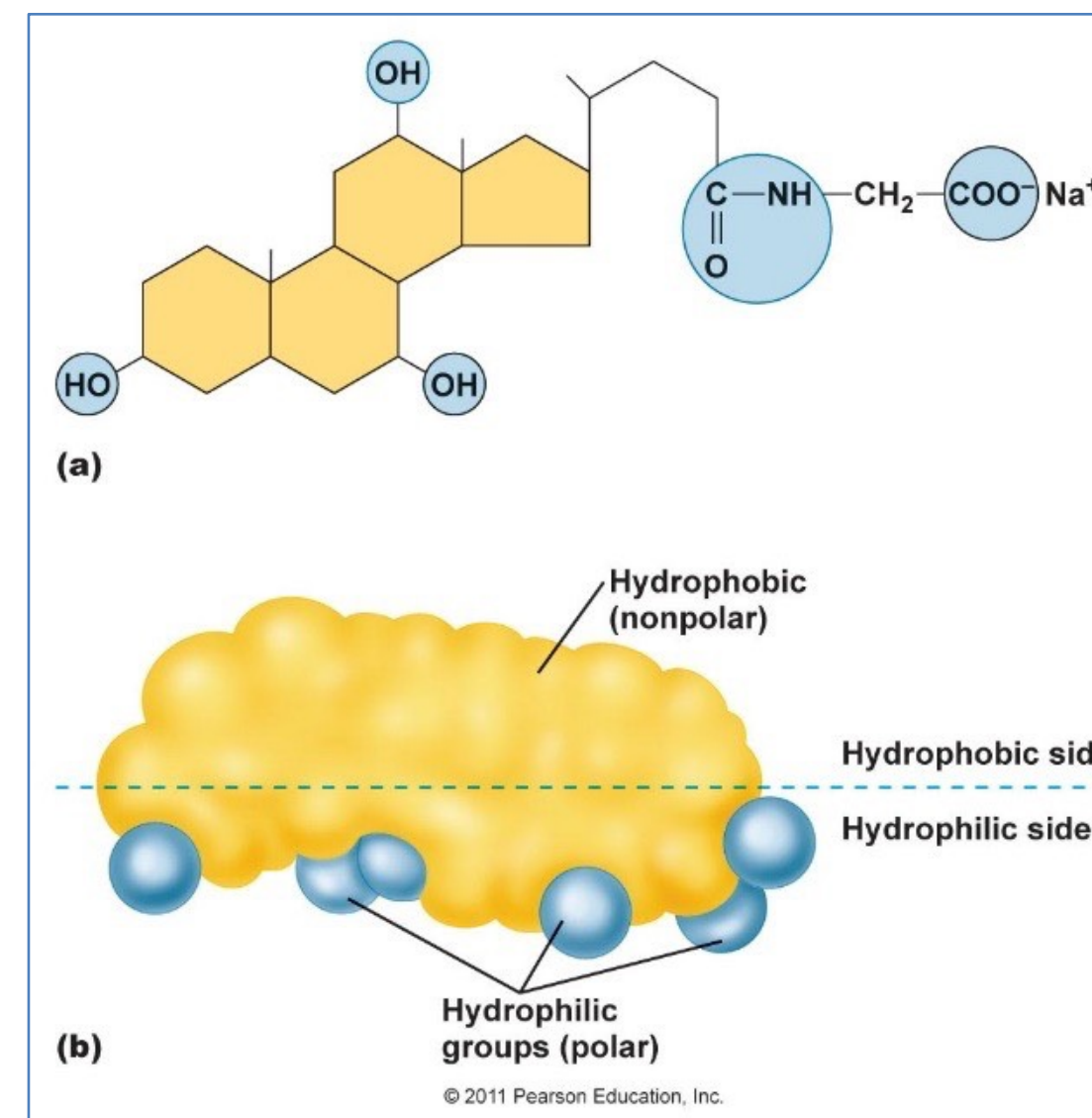
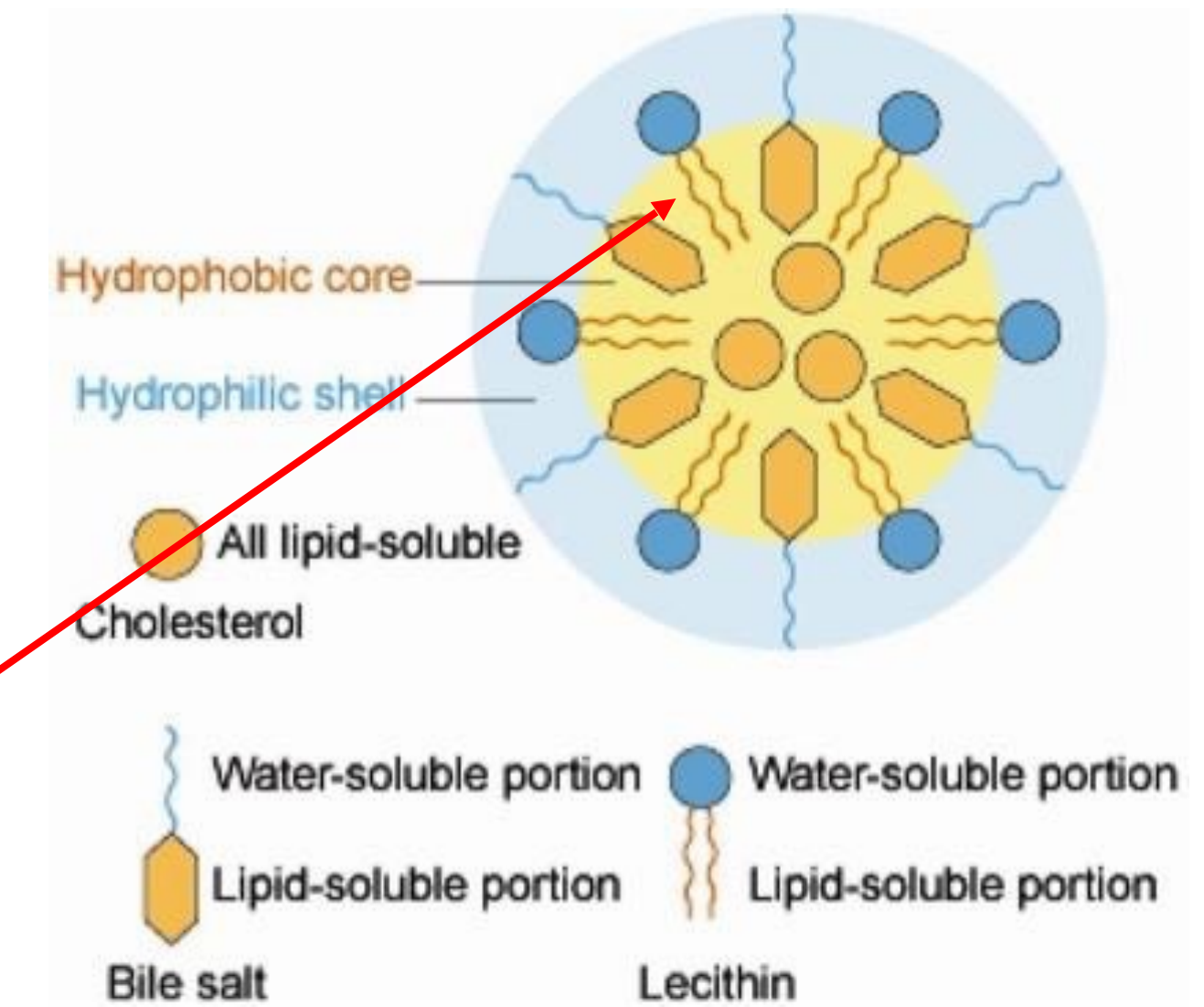
Emulsification(유화) & micelle formation



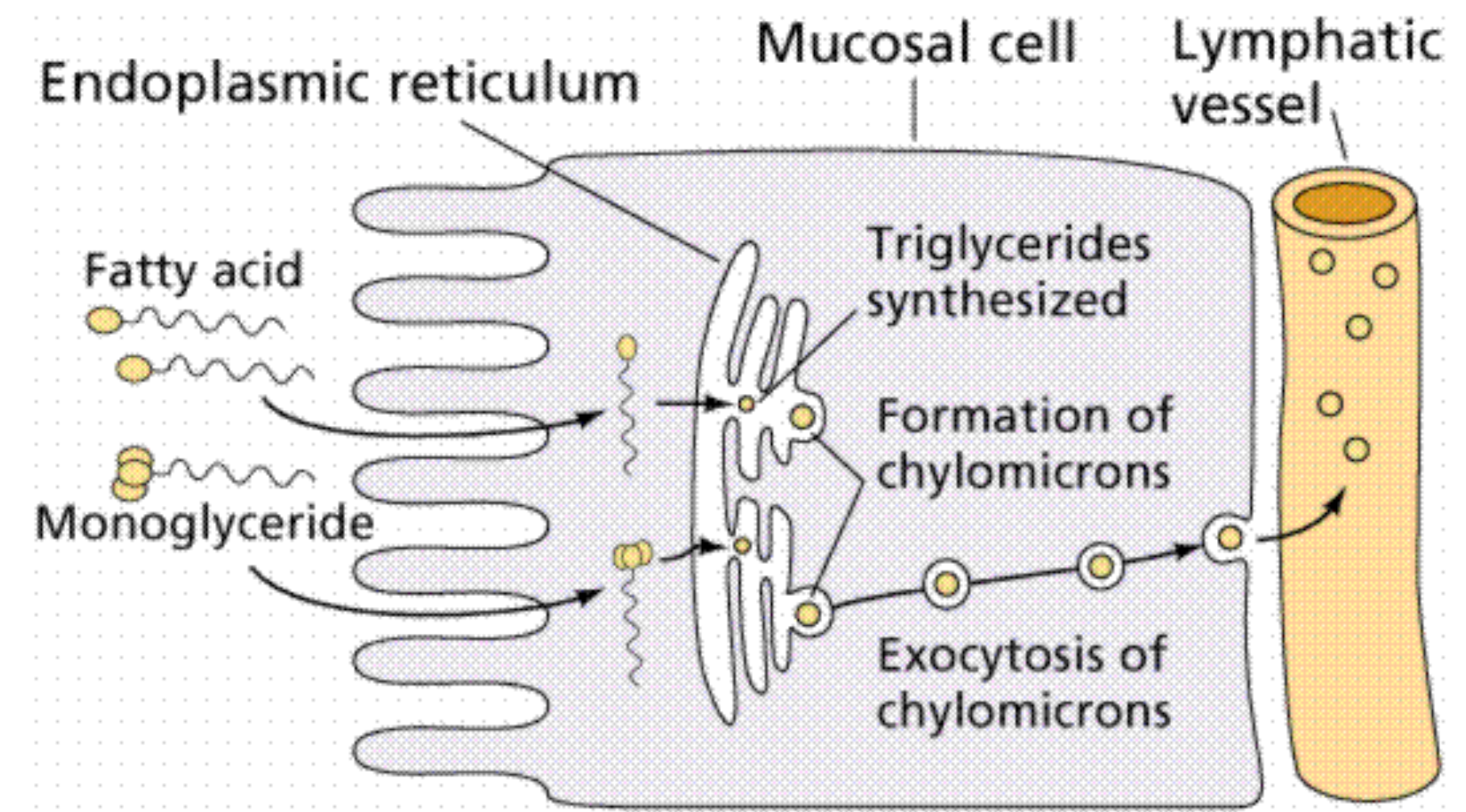
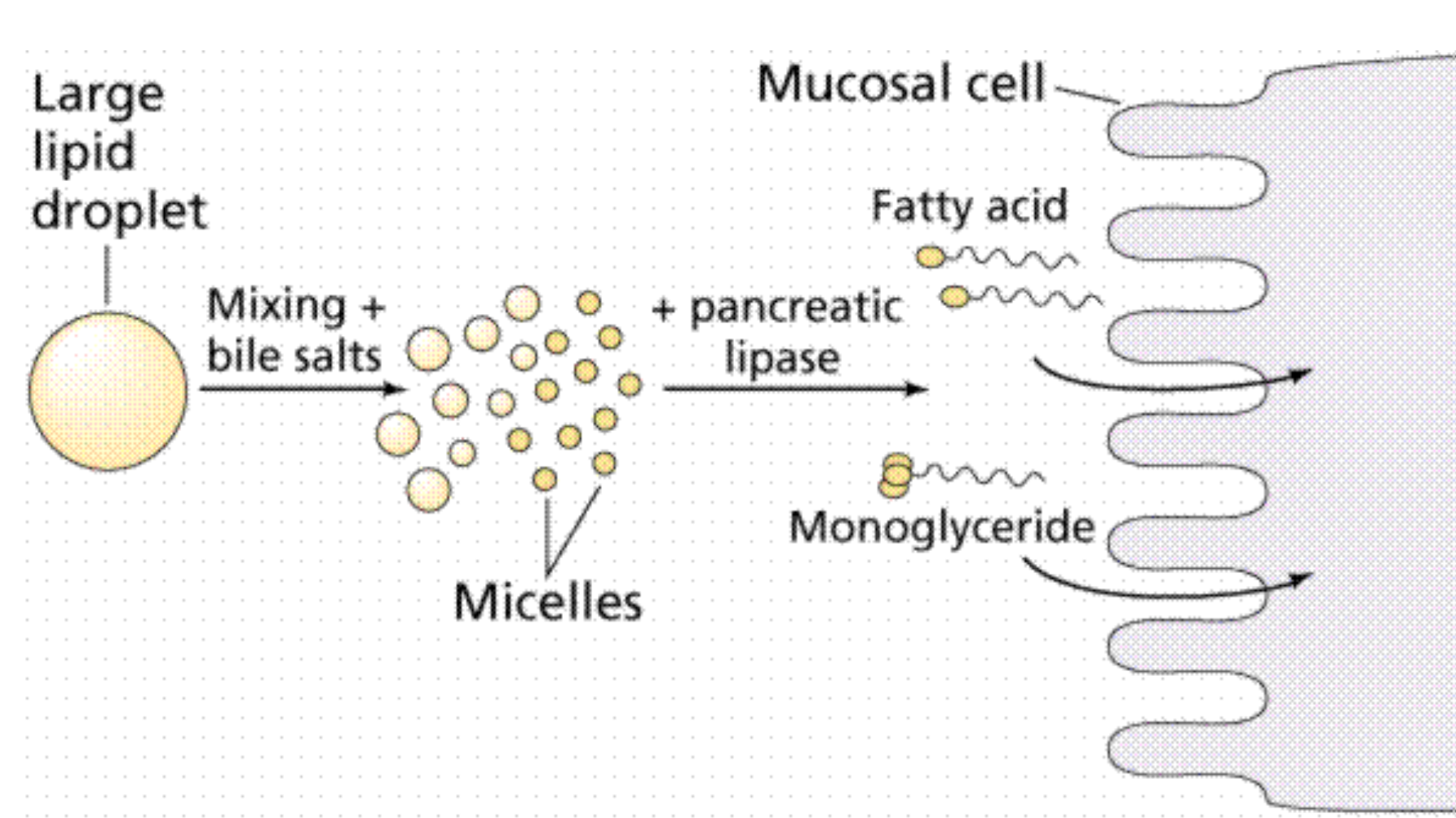
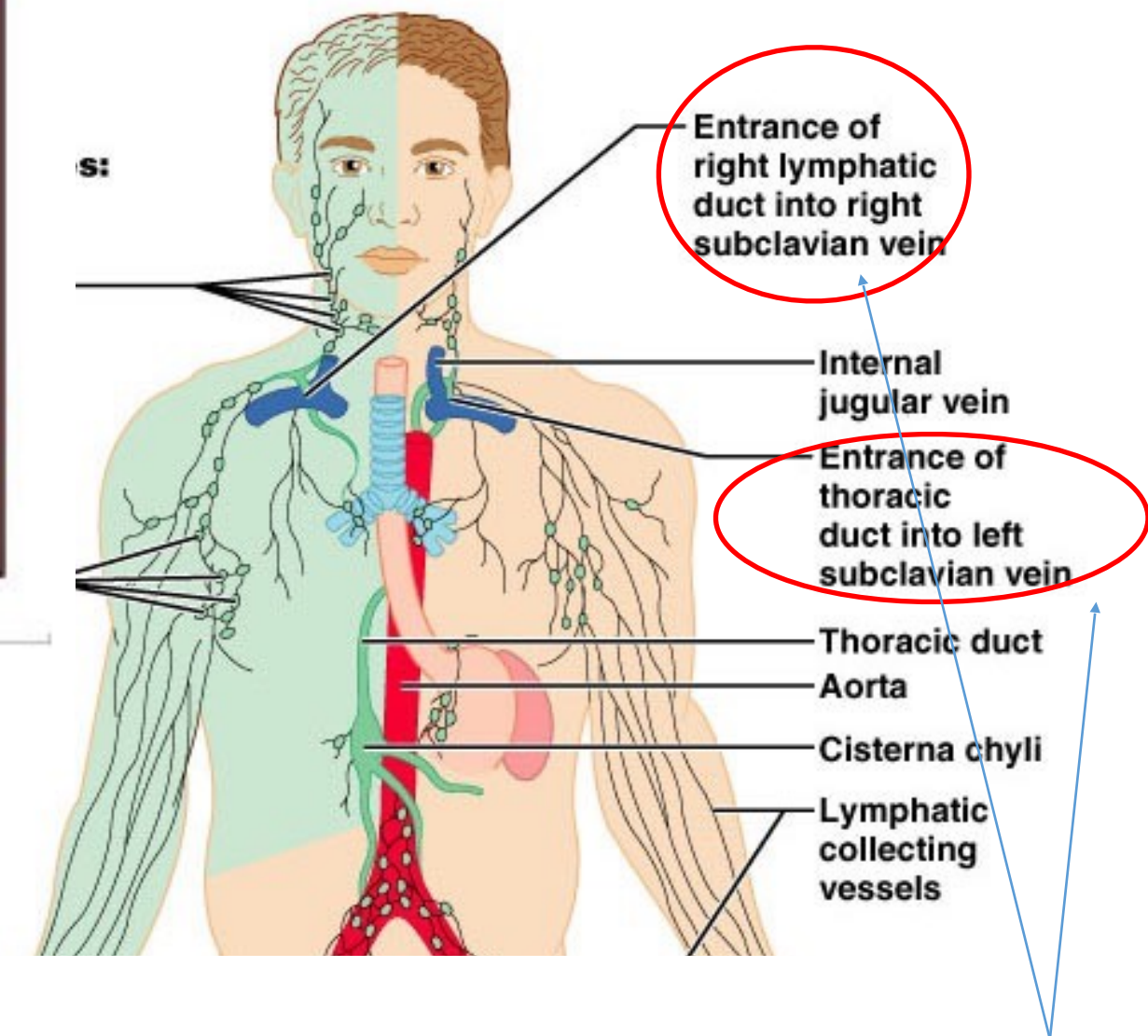
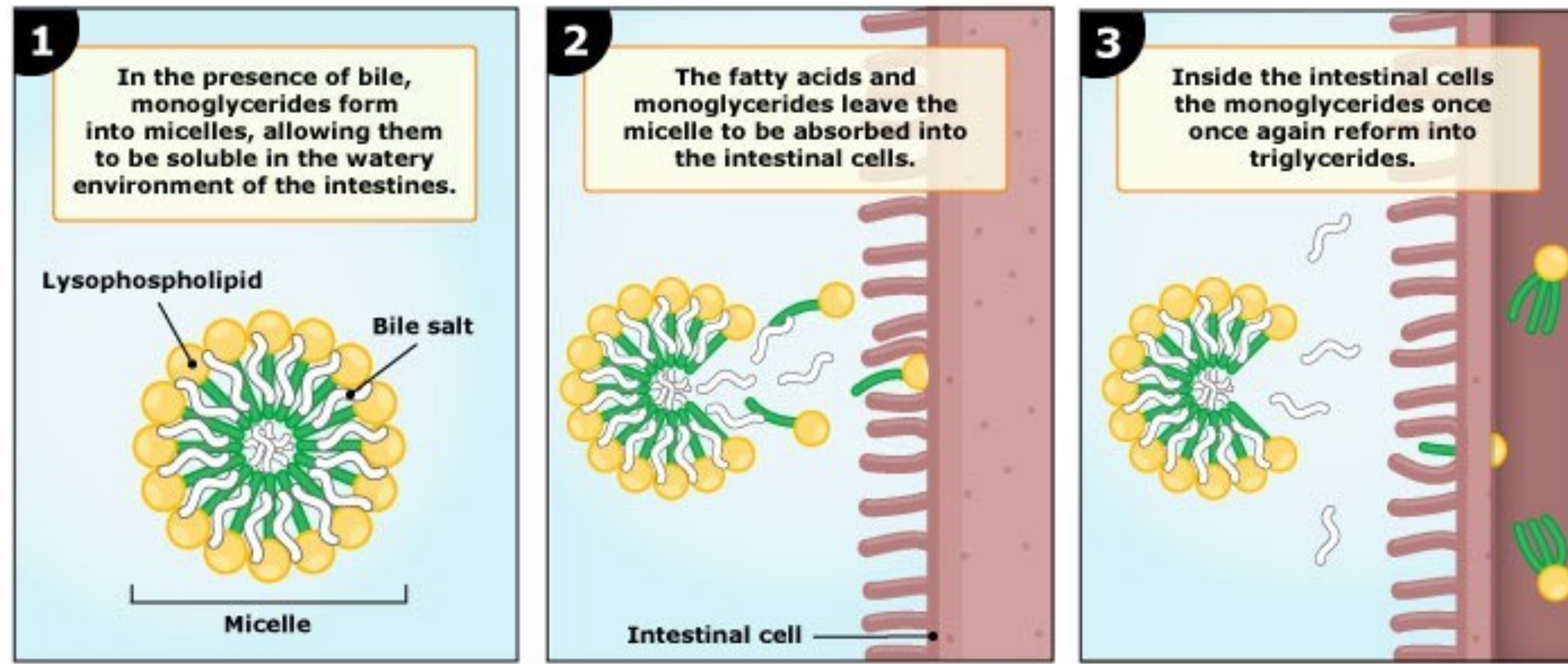
Lipase

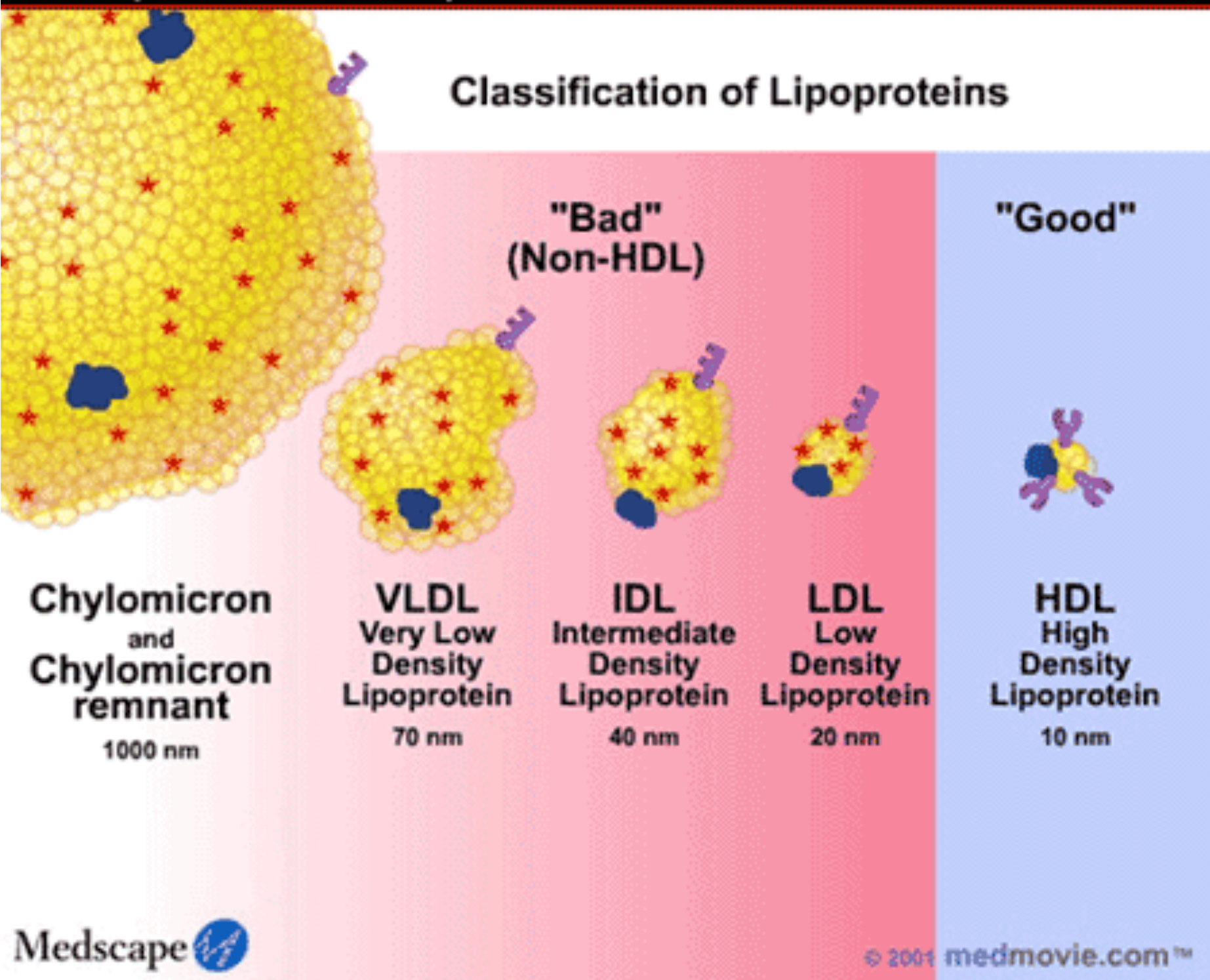
**Fatty acid
&
Monoglyceride
&
지용성 비타민**

Micelle

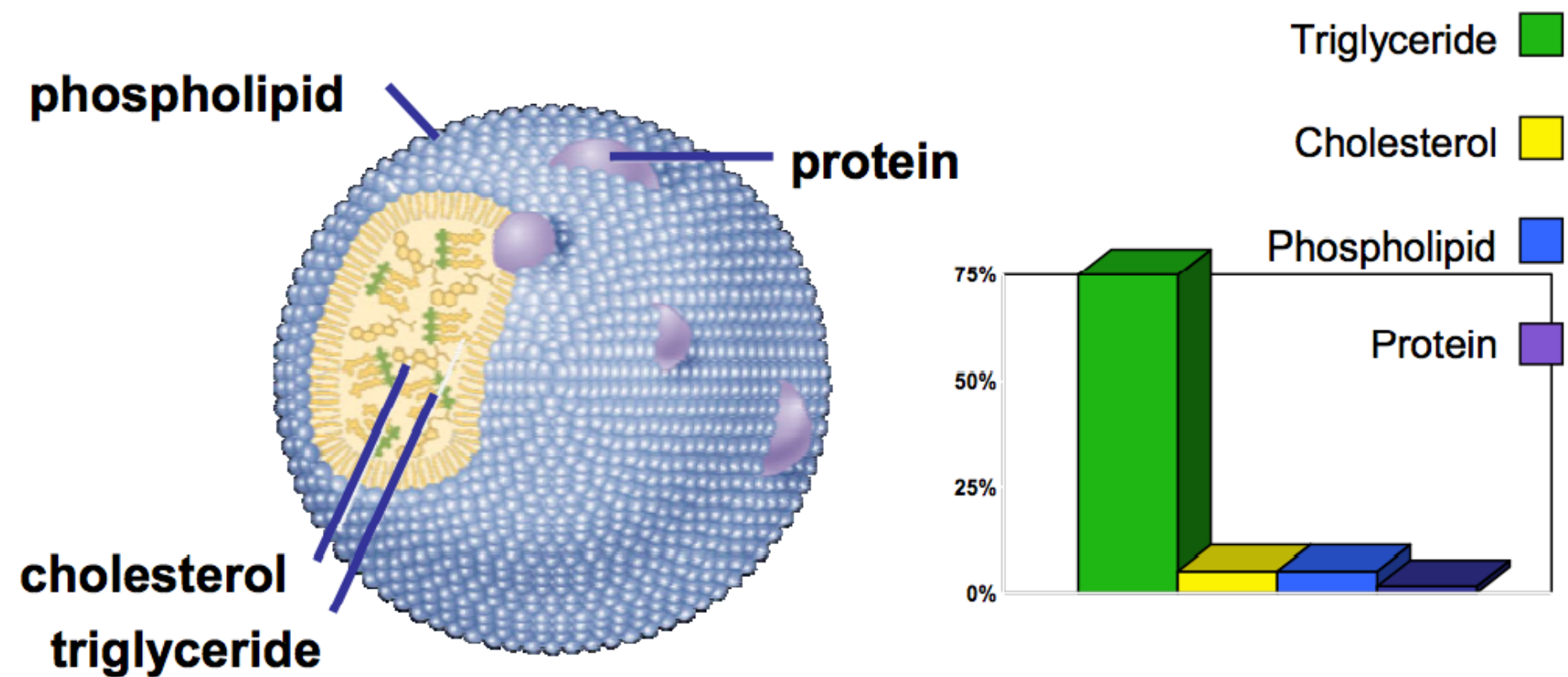


Micelle: 직경 3-10nm. 담즙의 다른 구성성분인 콜레스테롤, 레시틴과 함께 만드는 것. 지용성 물질이 장 내강을 통과할 수 있는 유일한 수단.

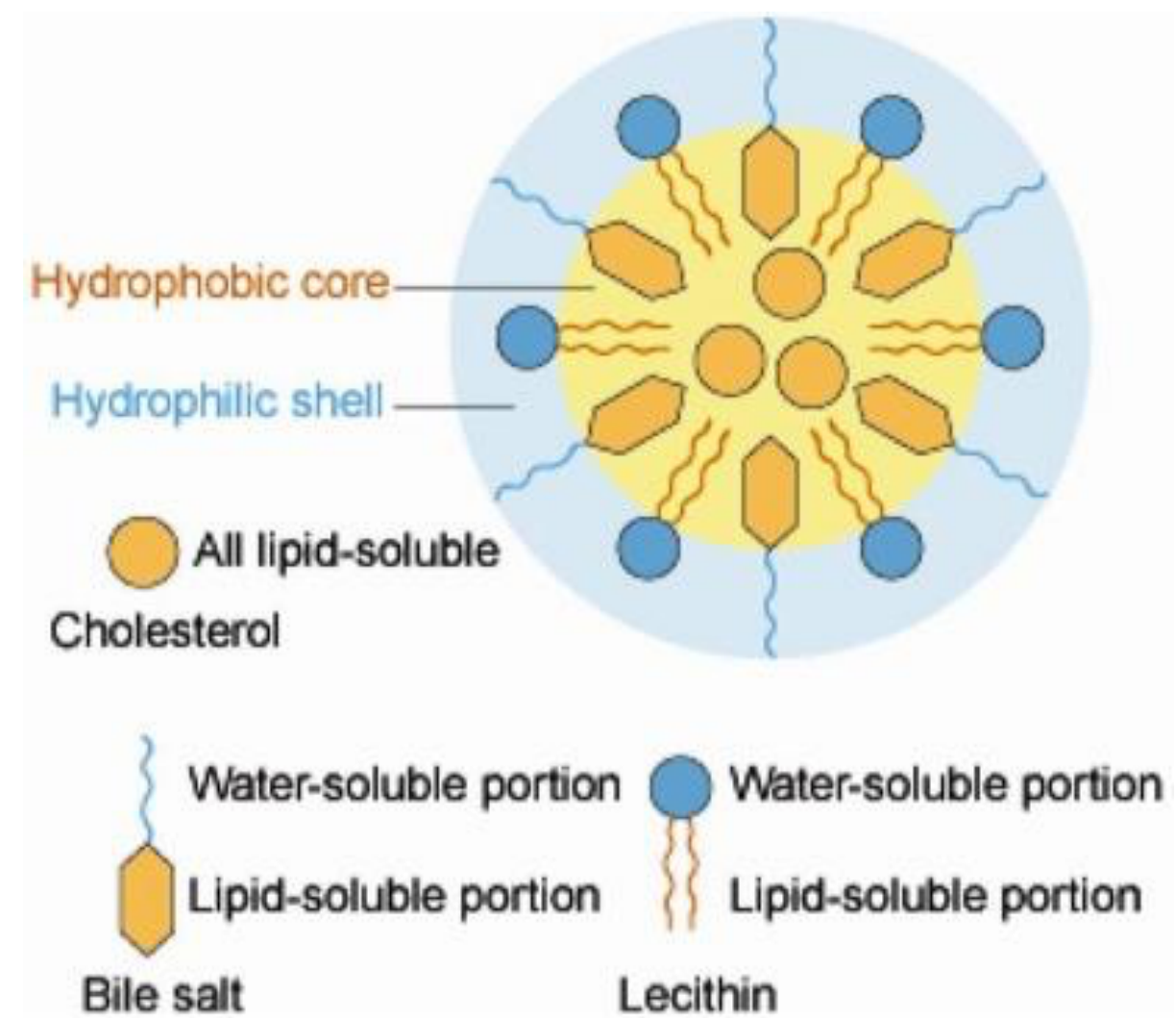




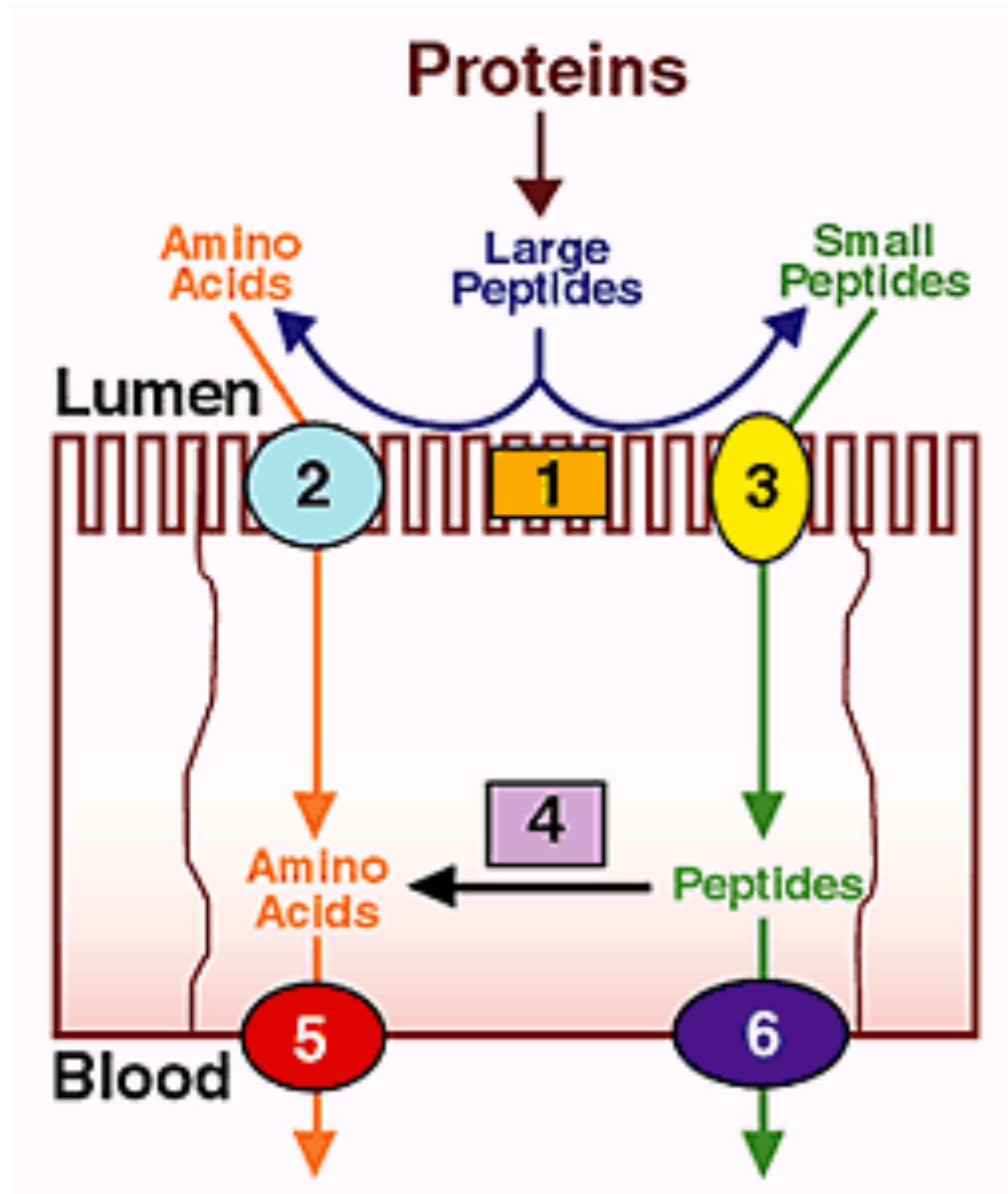
Chylomicrons



Micelle

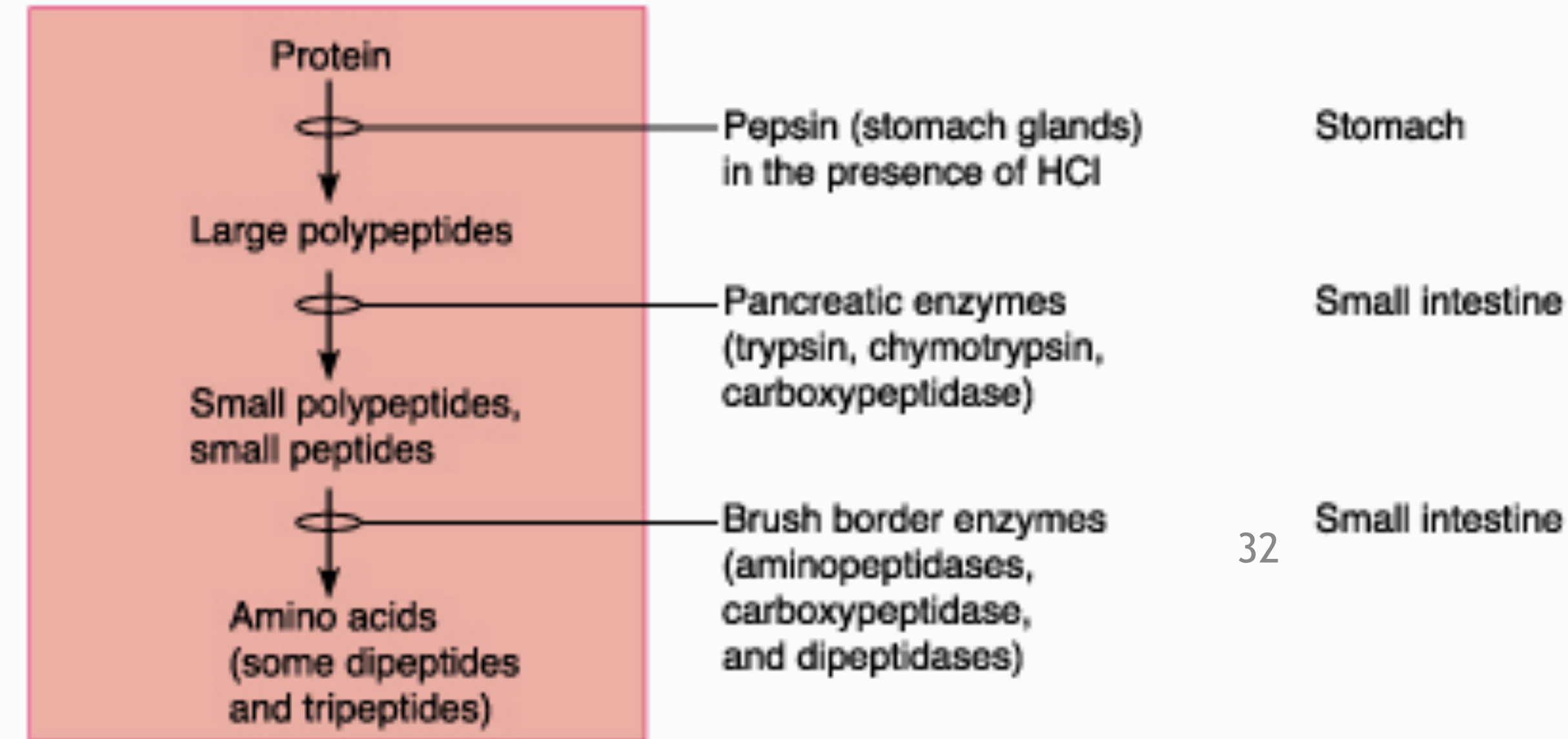


단백질

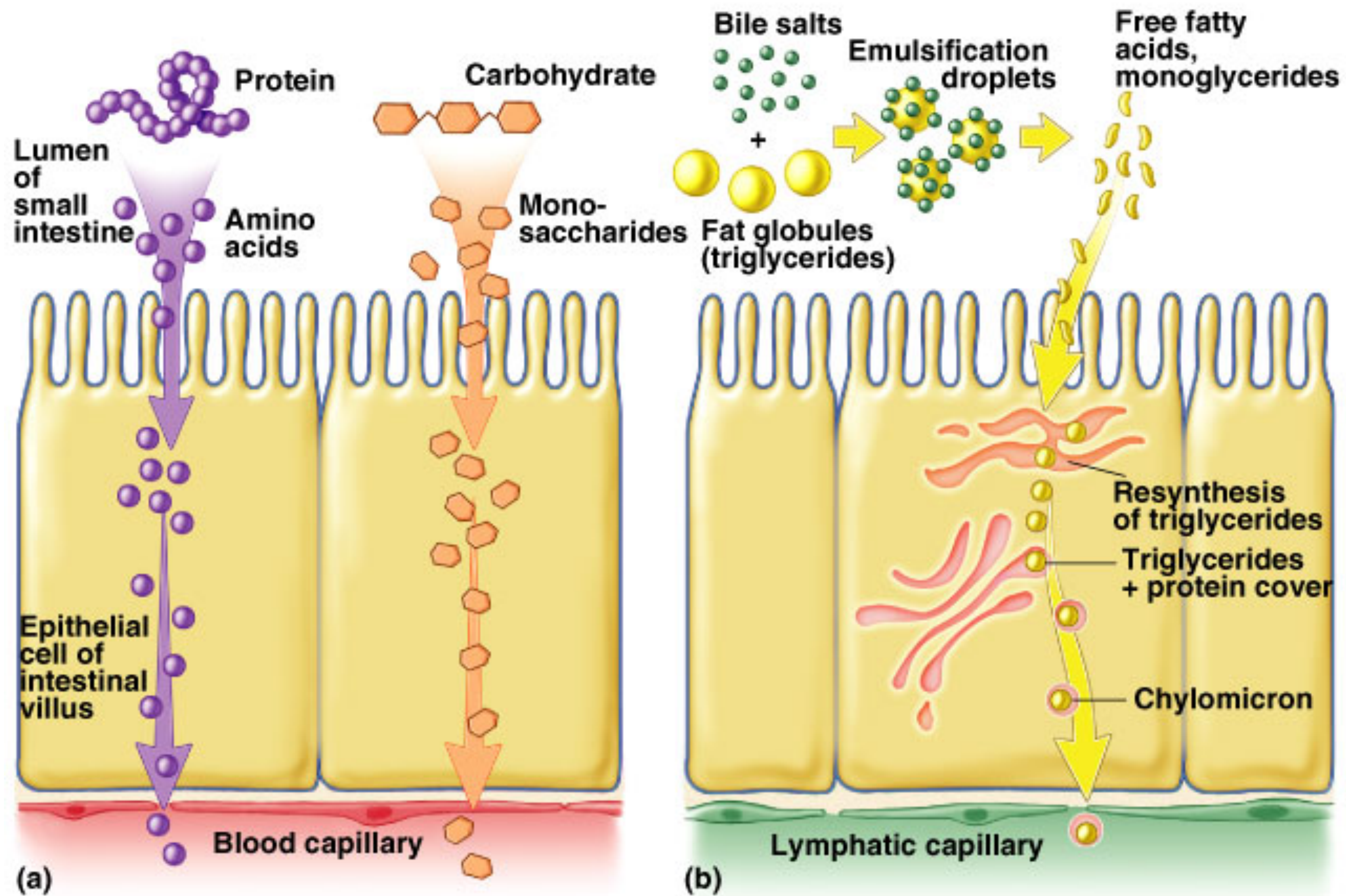


Protein digestion

Absorption: Amino acids are absorbed via cotransport with sodium ions; they enter the capillary blood in the villi and are transported to the liver via the hepatic portal vein.



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세포호흡

Cell Respiration

인산화(phosphorylation) →

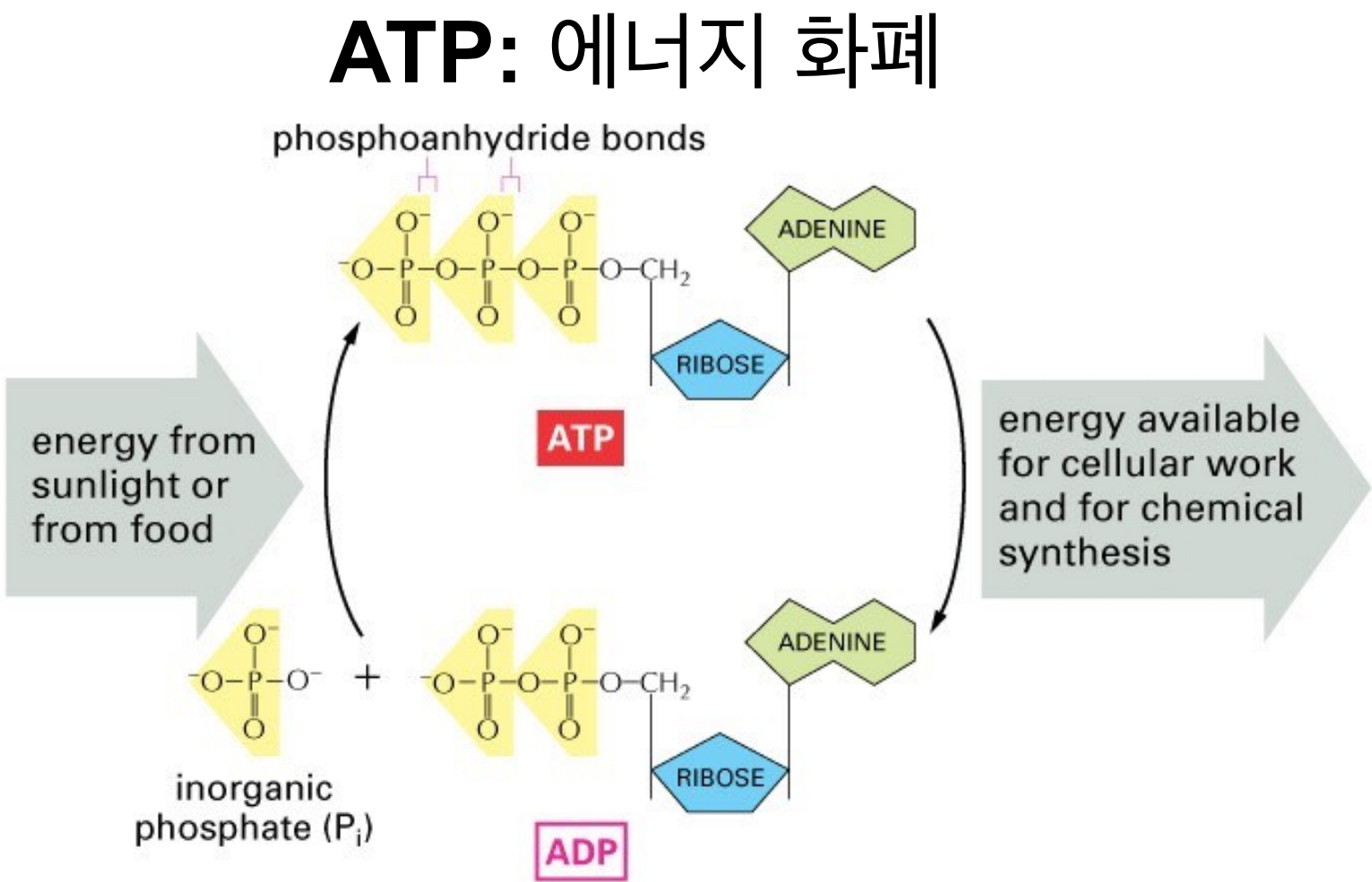
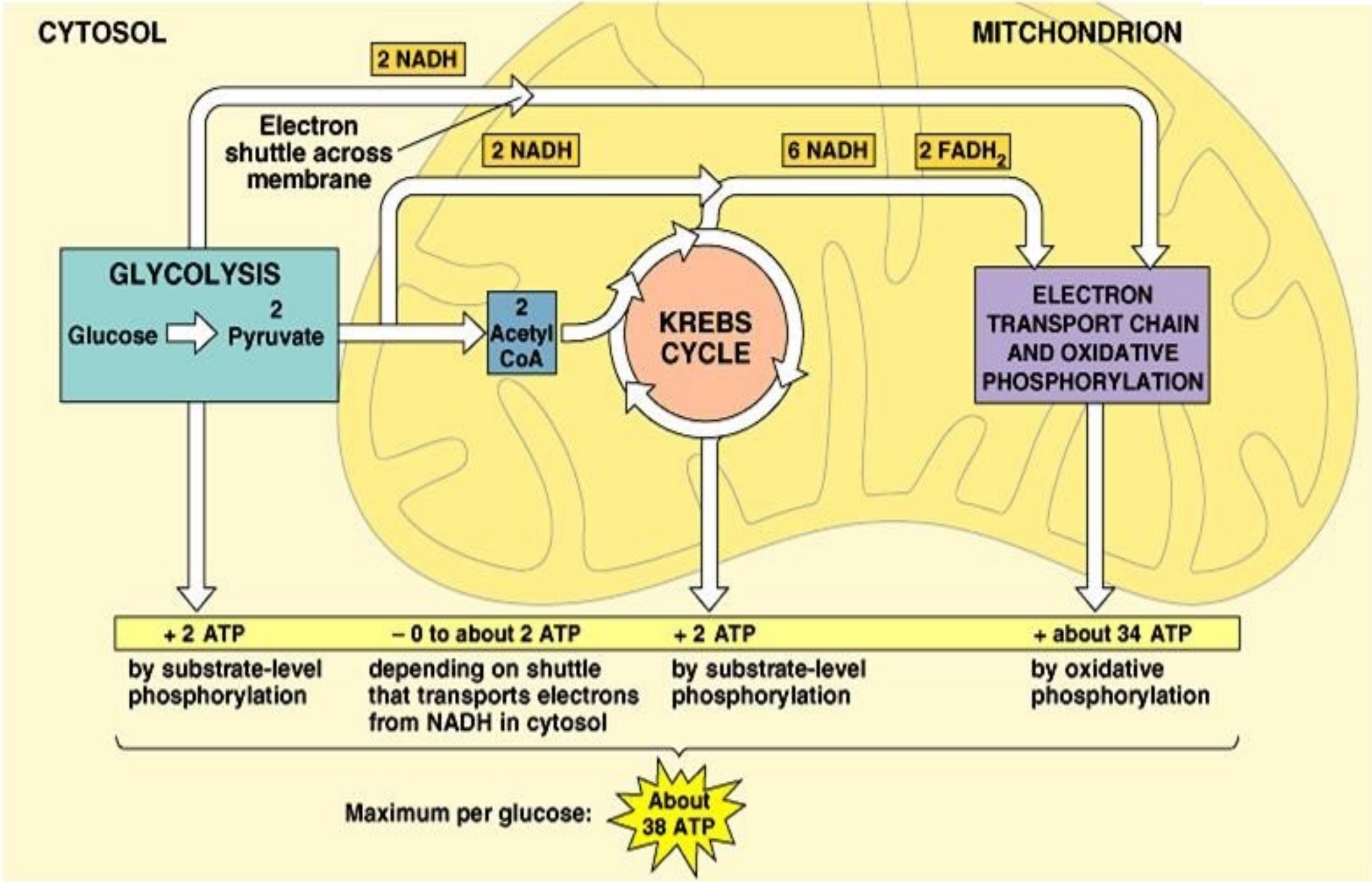
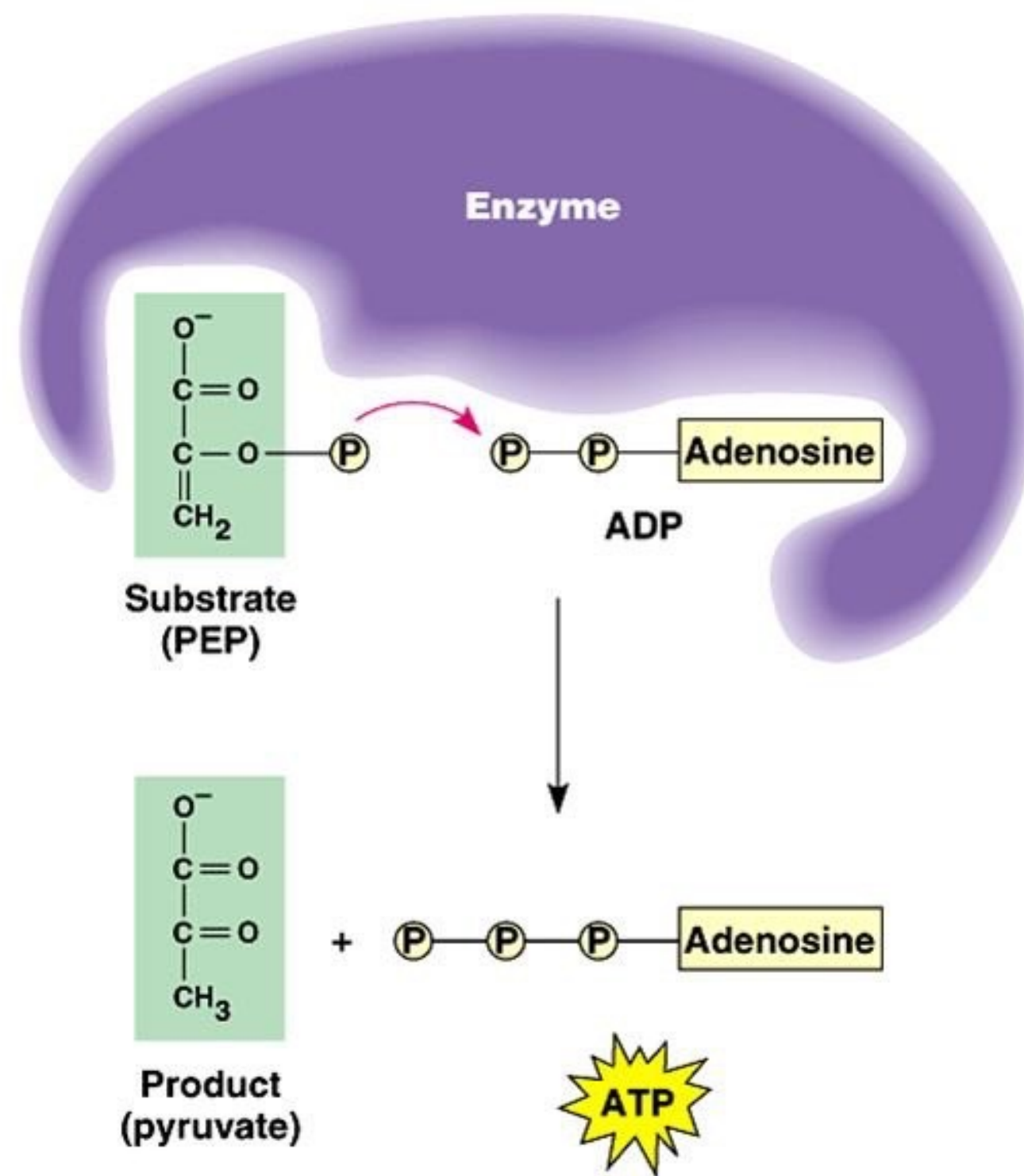


Figure 3-32 Essential Cell Biology, 2/e. (© 2004 Garland Science)



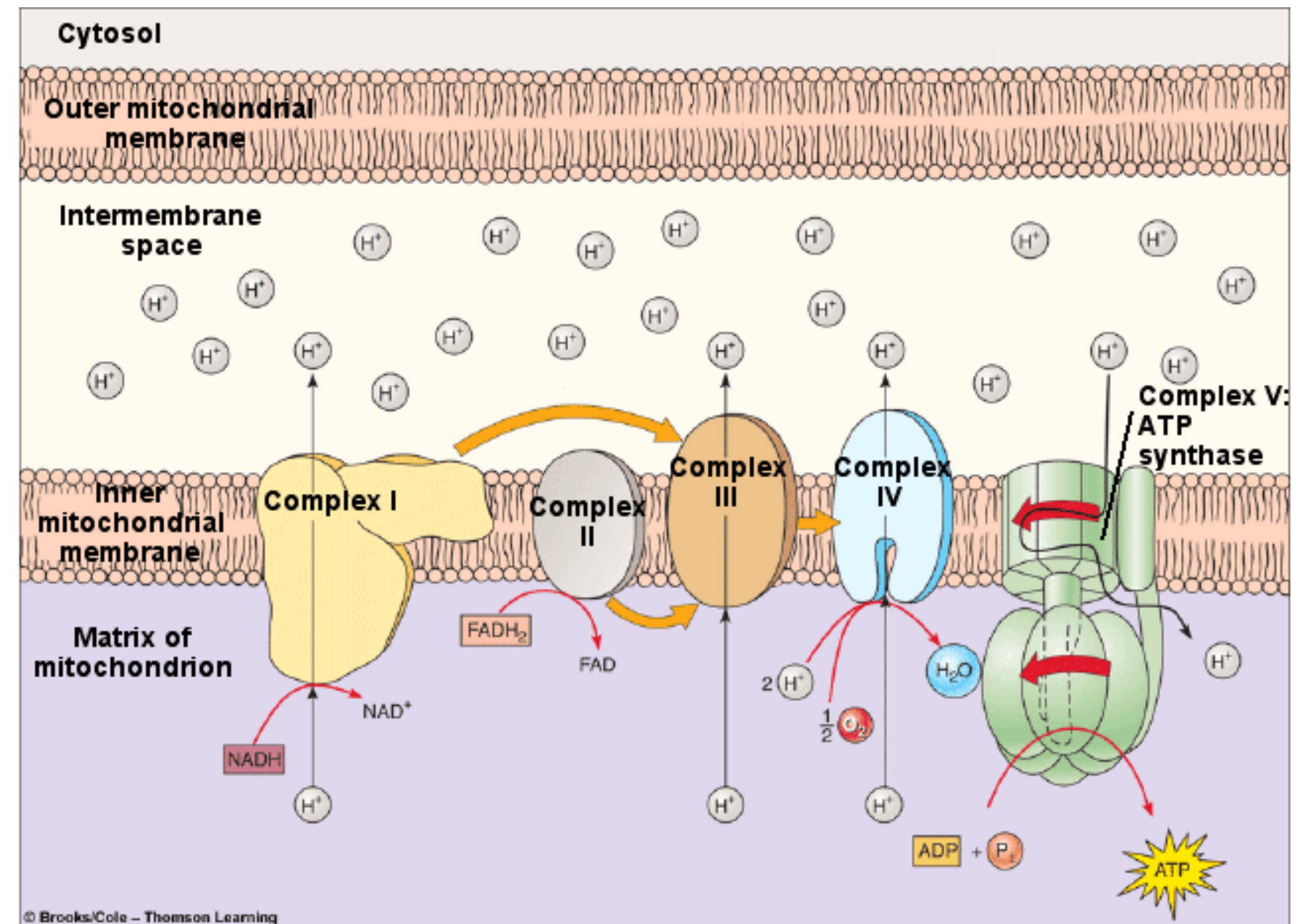
Substrate level phosphorylation & Oxidative phosphorylation

기질 수준 인산화



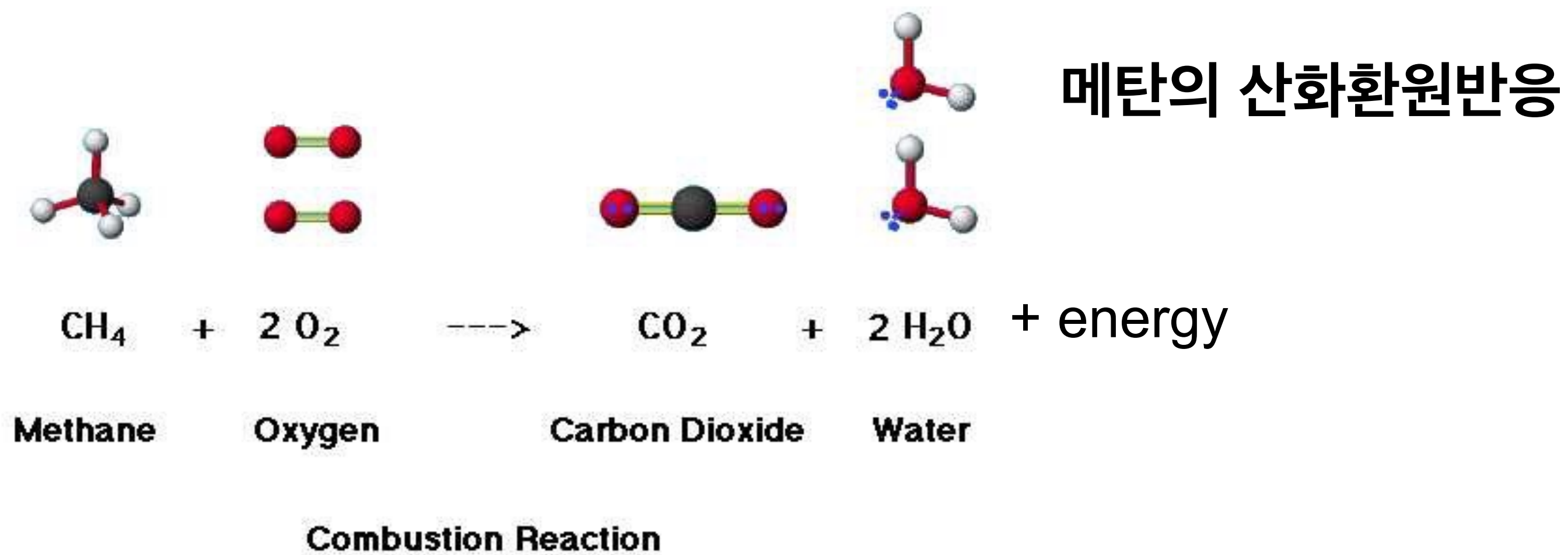
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산화적 인산화



(a)

Fig. 7-10a(2)
Page 149



최종적으로 전자는 위치 에너지를 잃게 됨

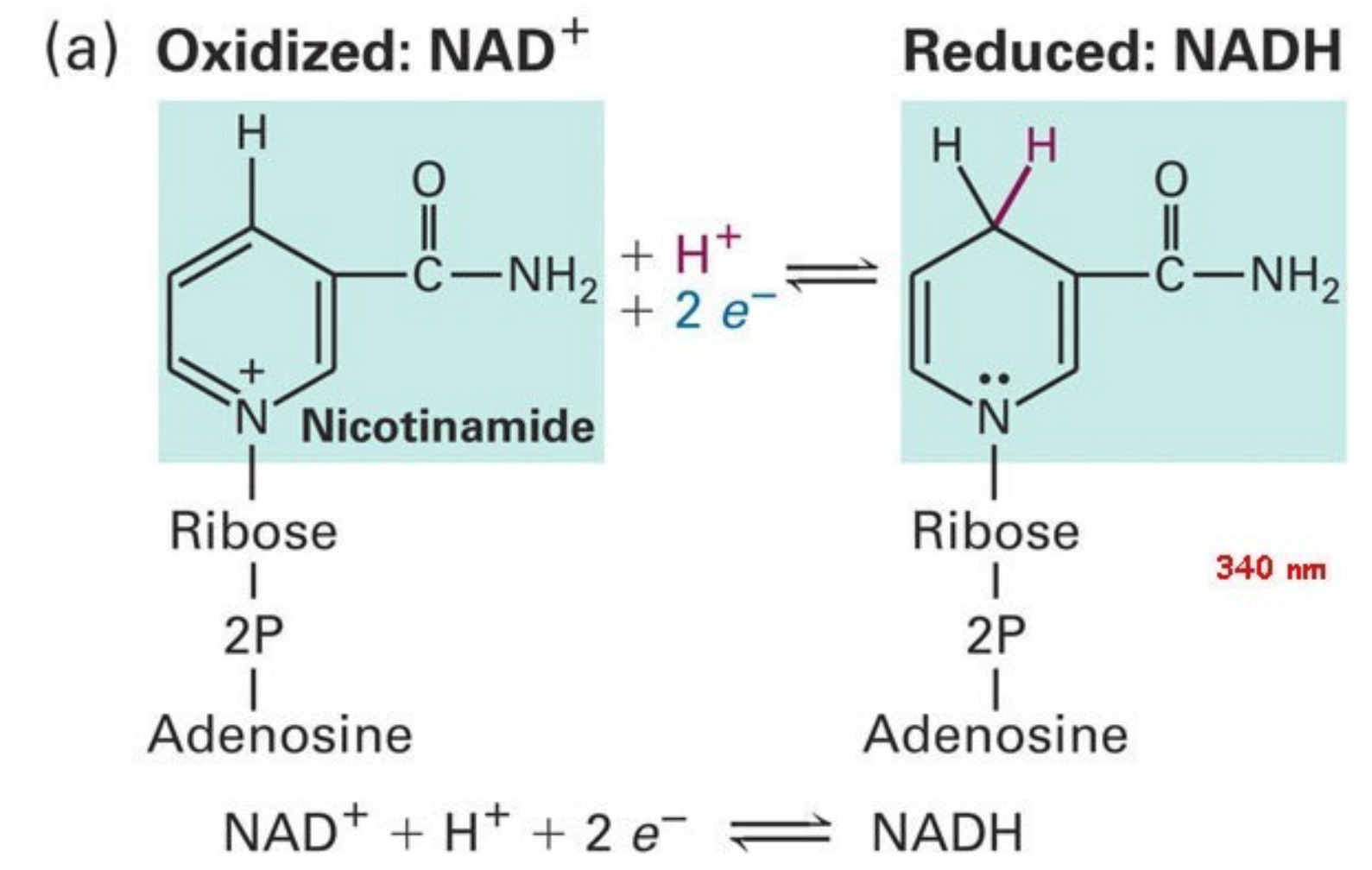
→ 에너지 방출!!

포도당의 산화환원반응



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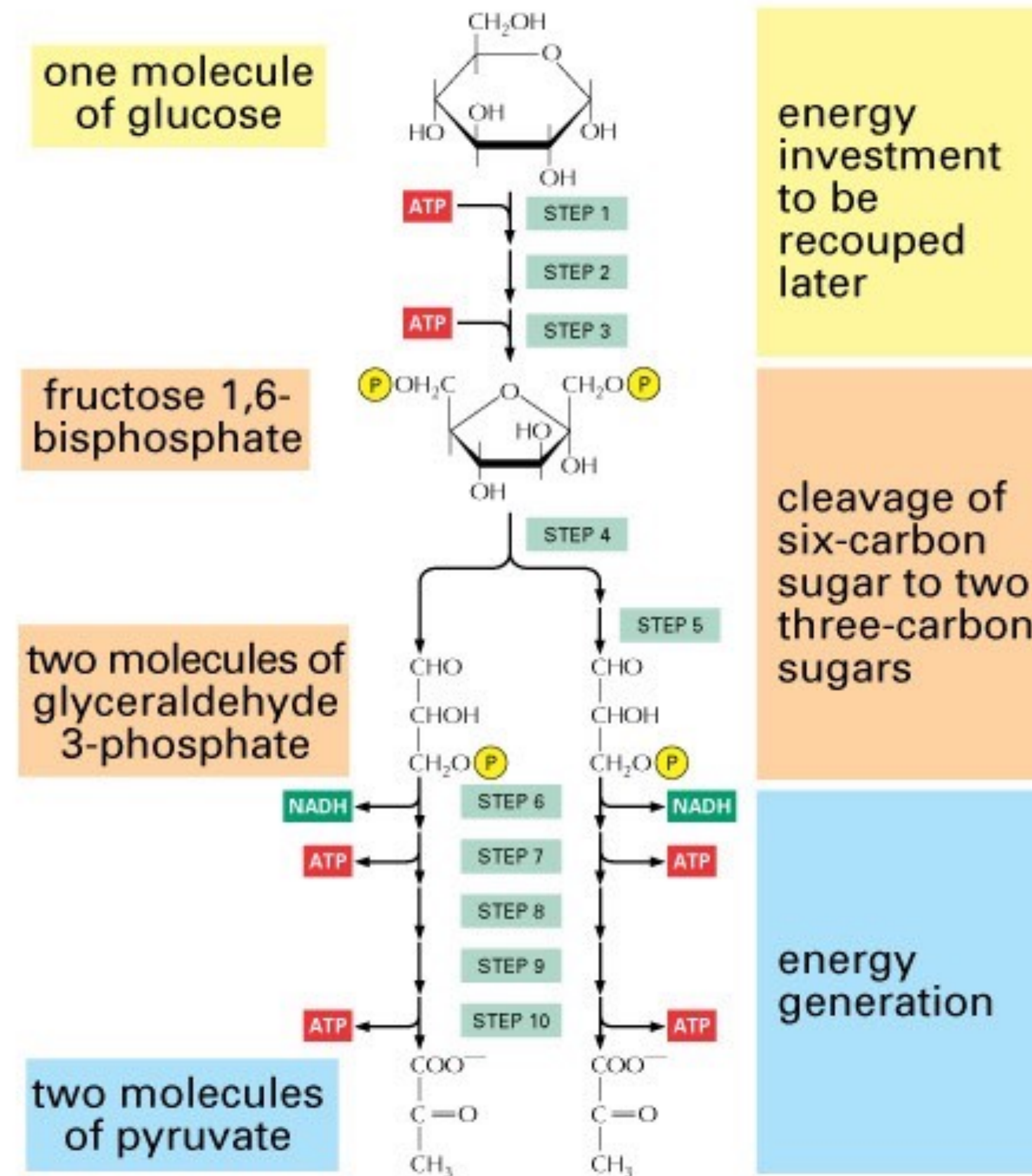
전자왕복기구로서의 NAD⁺ 조효소



Dehydrogenase는 기질 (ex: glucose)로부터 두개의 전자, 두개의 양성자를 제거시키고 이중 두개의 전자, 한 개의 양성자를 NAD⁺에 전달.

음식에서 NAD⁺로 전자들이 전달될 때 전자들은 위치 에너지를 거의 잃지 않는다.

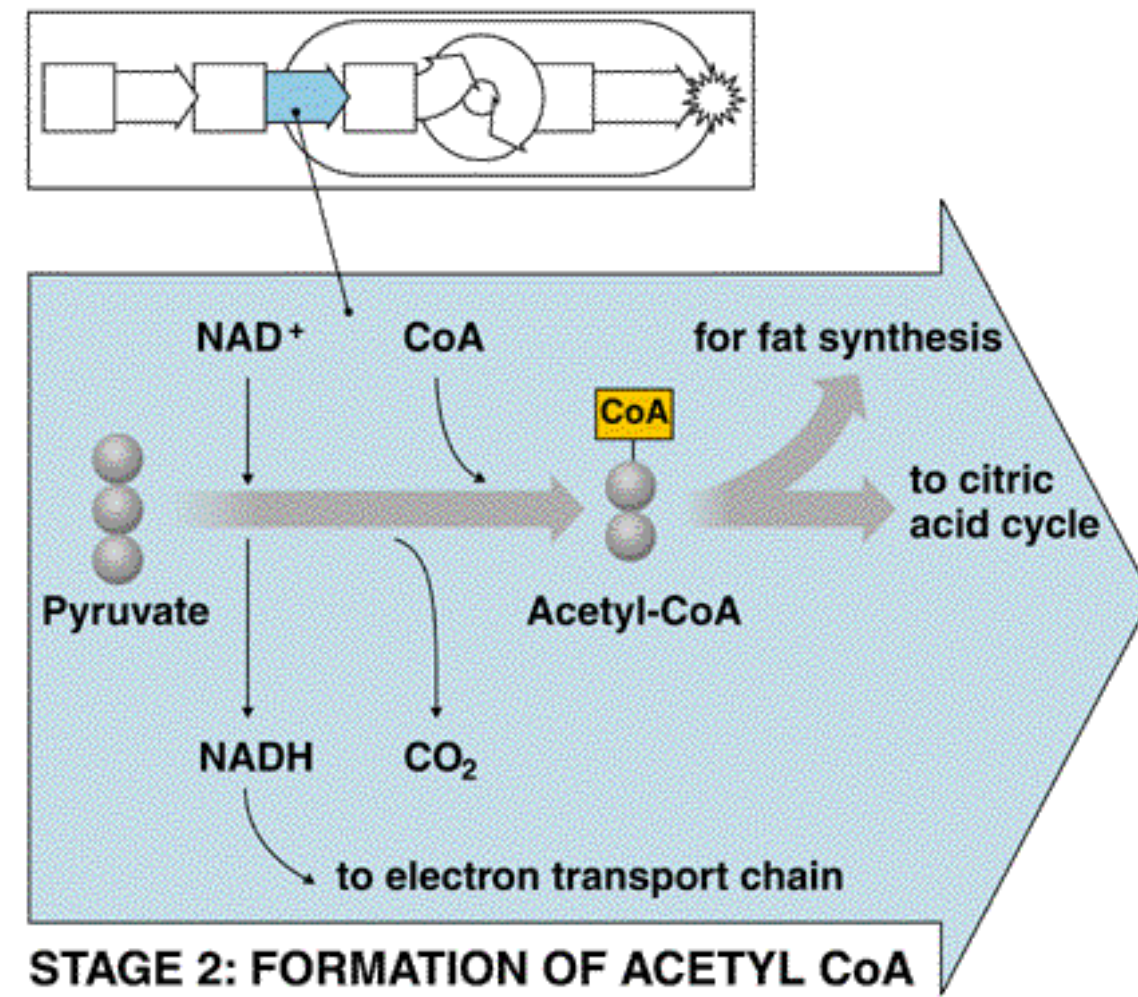
Glycolysis



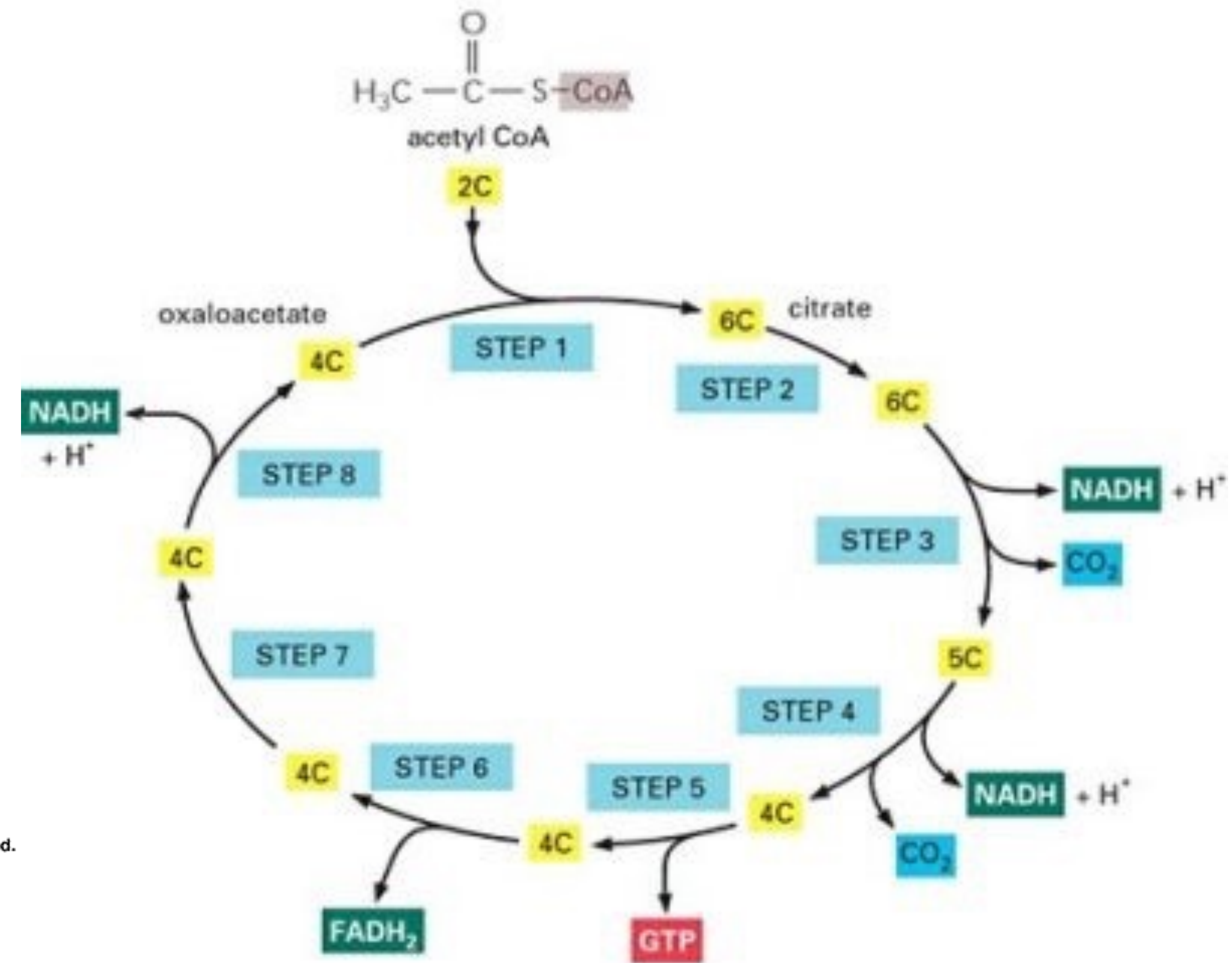
2 NADH
2ATP

TCA Cycle

Tobin/Dusheck, Asking About Life, 2/e
Figure 6.8



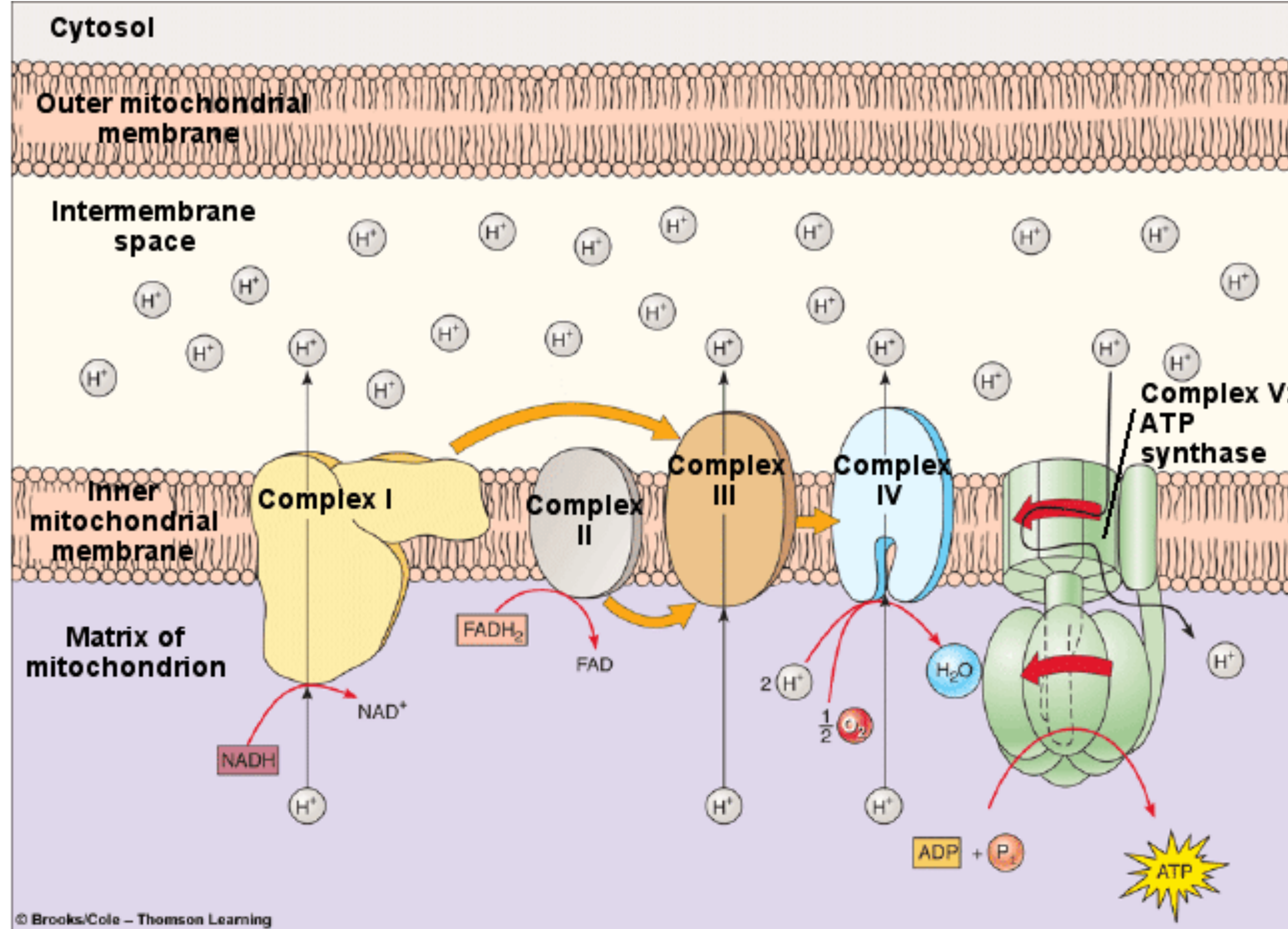
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NET RESULT: ONE TURN OF THE CYCLE PRODUCES THREE NADH, ONE GTP, AND ONE FADH₂, AND RELEASES TWO MOLECULES OF CO₂

한분자의 포도당에서 두분자의
pyruvate 생성.

Electron Transport Chain

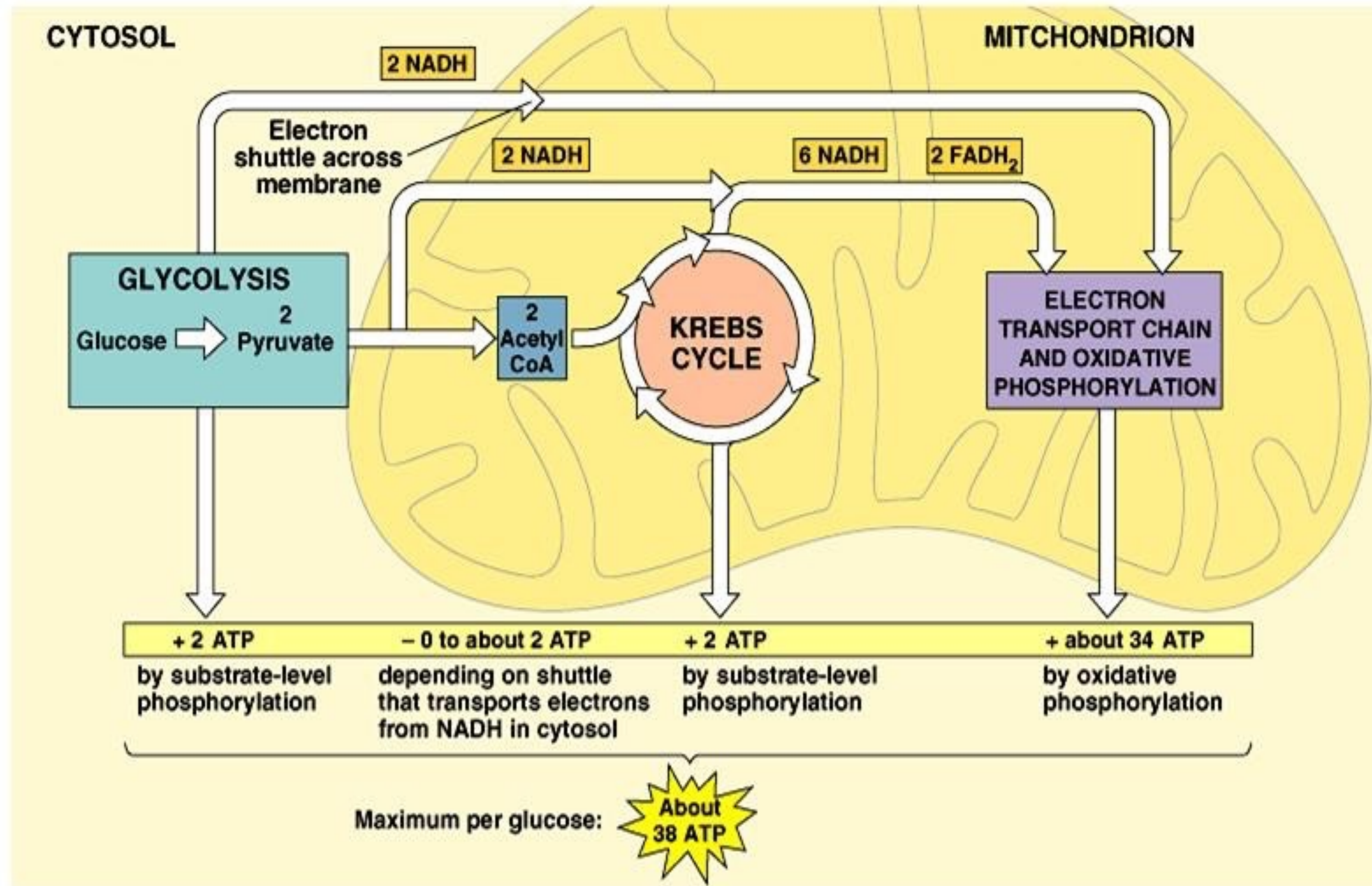


Electronegativity가 높은 O_2 로 전자가 단계적으로 이동하면서 에너지적으로 안정되며 자유E 감소.

(a)

Fig. 7-10a(2)
Page 149

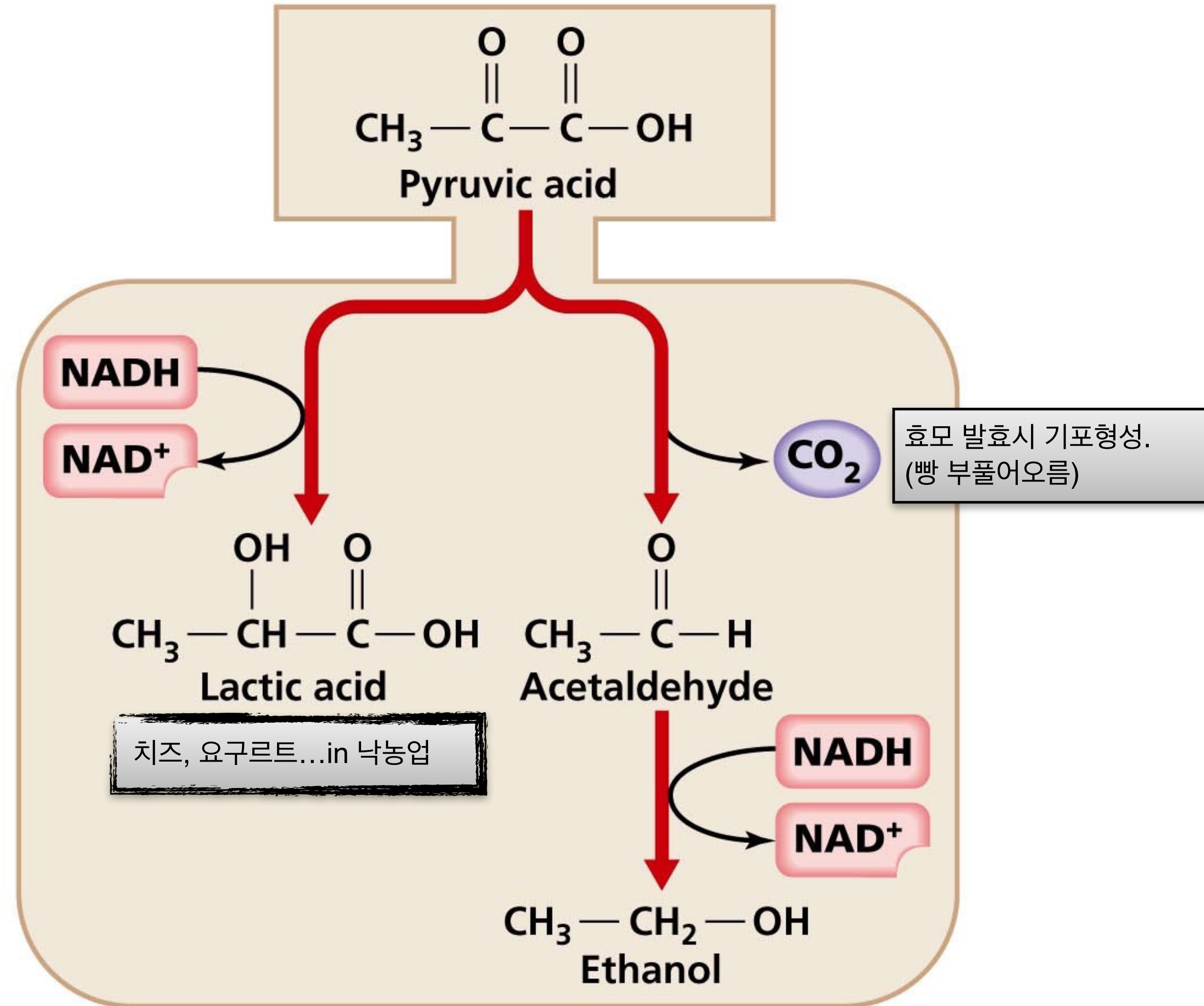
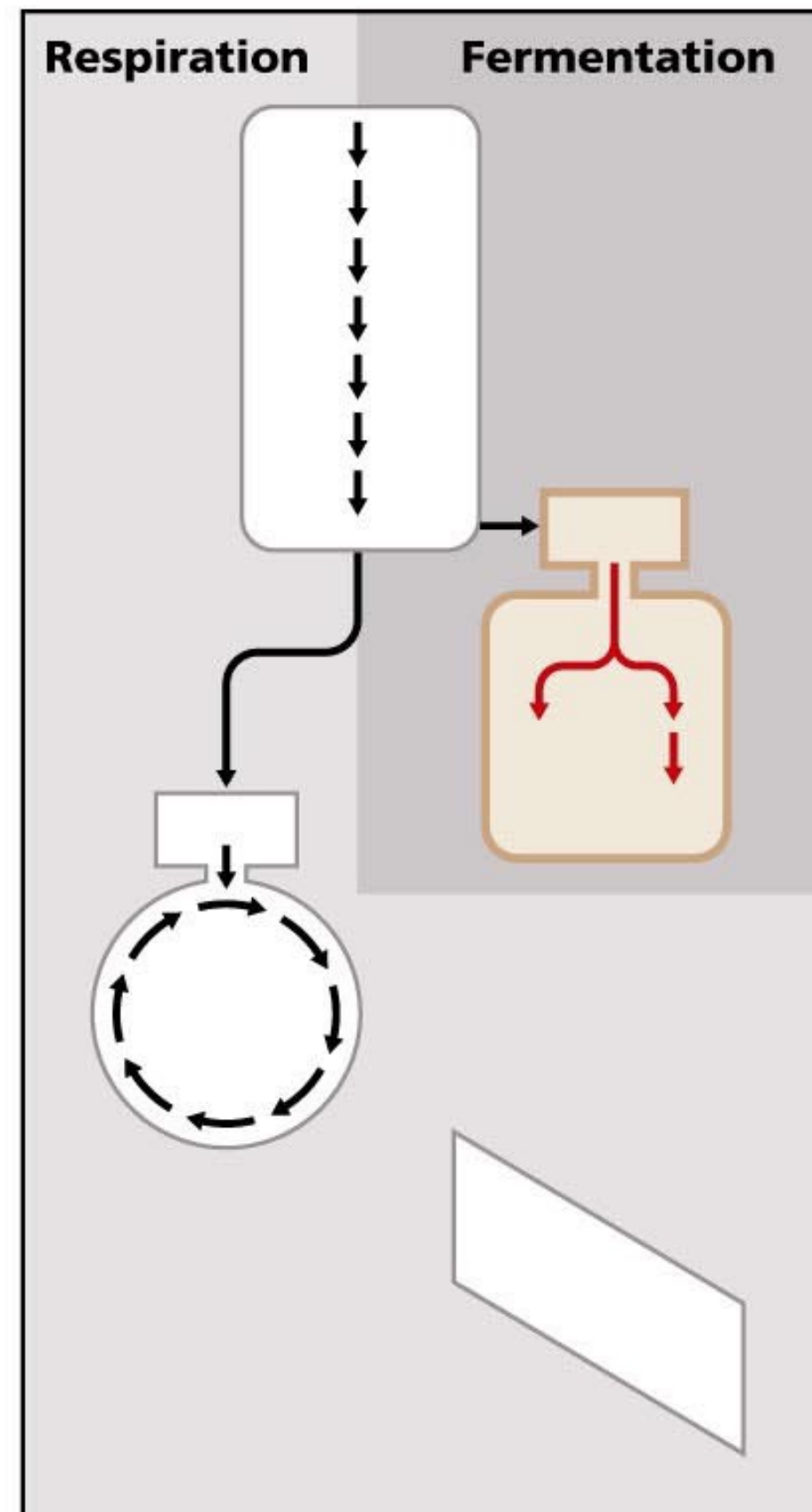
NADH 1개가 수소이온 10개 이동시키고, 3,4개의 수소이온이 한분자의 ATP 생성.
즉 한분자의 NADH가 약 세분자의 ATP 생성. $FADH_2$ 는 1.5~2분자 ATP 생성.



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포도당의 40%가 ATP로. 나머진 열. (효율적인 자동차의 가솔린 효율이 25% 미만)

Fermentation (산소 없이 ATP 만들기)



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- NAD⁺를 재생성해야만 해당과정이 계속될 수 있다.(해당과정에서 NAD⁺가 산화제로 기능하고 있으므로)
- 에너지 효율 2%밖에 안됨(호기성 호흡은 40%).

당신생

Gluconeogenesis (당신생)

- 성인의 경우 glucose는 체액에 약 20 g, glycogen 형태로 약 190 g의 양으로 존재.
- glucose의 하루 소모량은 160 g 정도로서 직접적인 glucose의 방출량은 하루정도의 양으로 충분.
- 그러나 금식이나 과격한 운동 후에는 부족하게 되므로 비탄수화물들로부터 재생성이 되어야만 함.
- 주합성경로: 간이 전체량의 90%를 차지
- 결과적으로 간이나 신장이 혈액 내의 포도당 농도를 유지시켜 뇌와 근육에 제공하는 것.

1. 주요 비탄수화물 전구체들

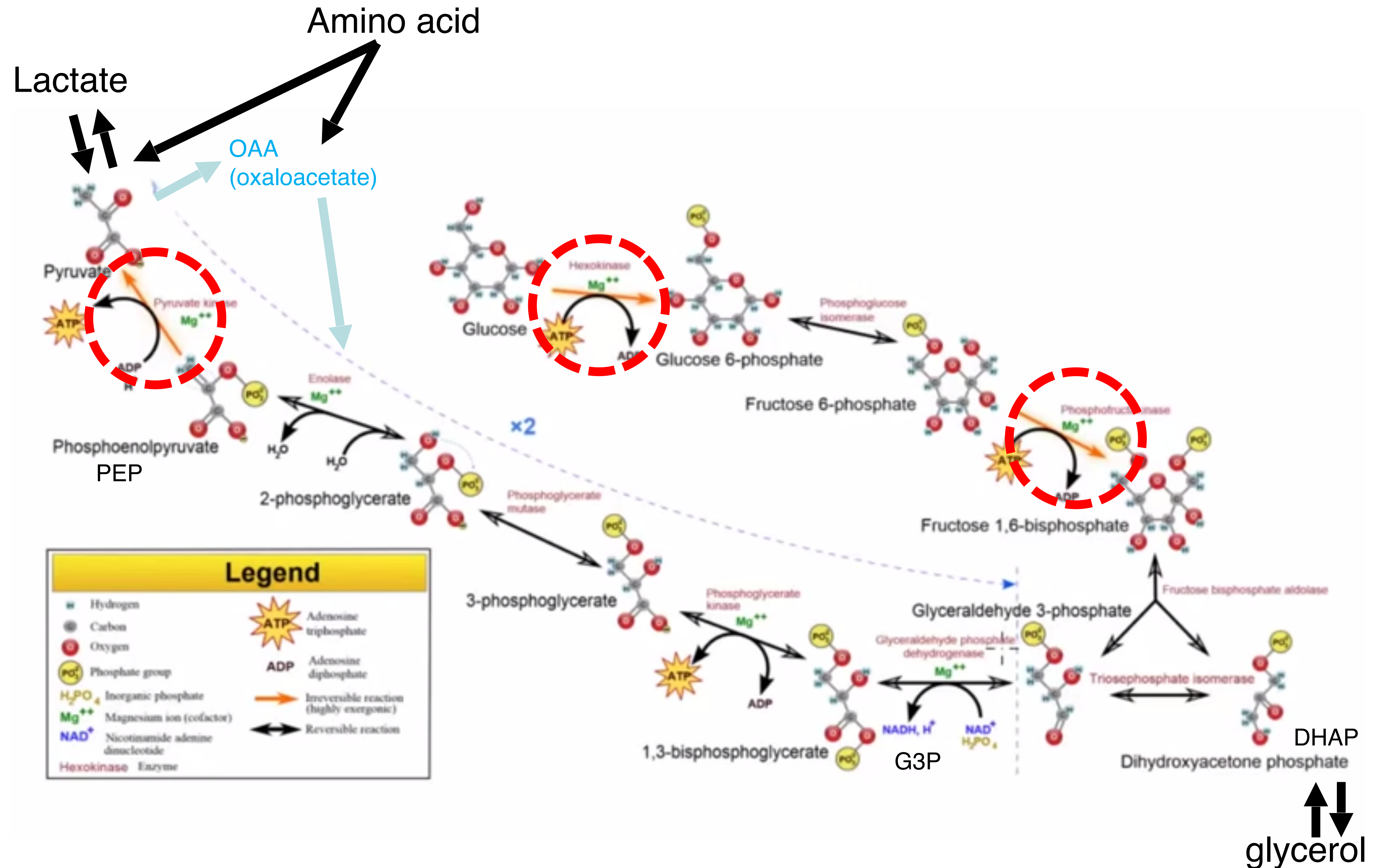
lactate: 활동성인 근육에서 pyruvate로 전환된다.

amino acids: 음식물의 단백질과 근육에서 단백질의 분해에서 나오는 아미노산 (Leu와 Lys는 제외)은 **pyruvate**나 **oxaloacetate**로 전환된다.

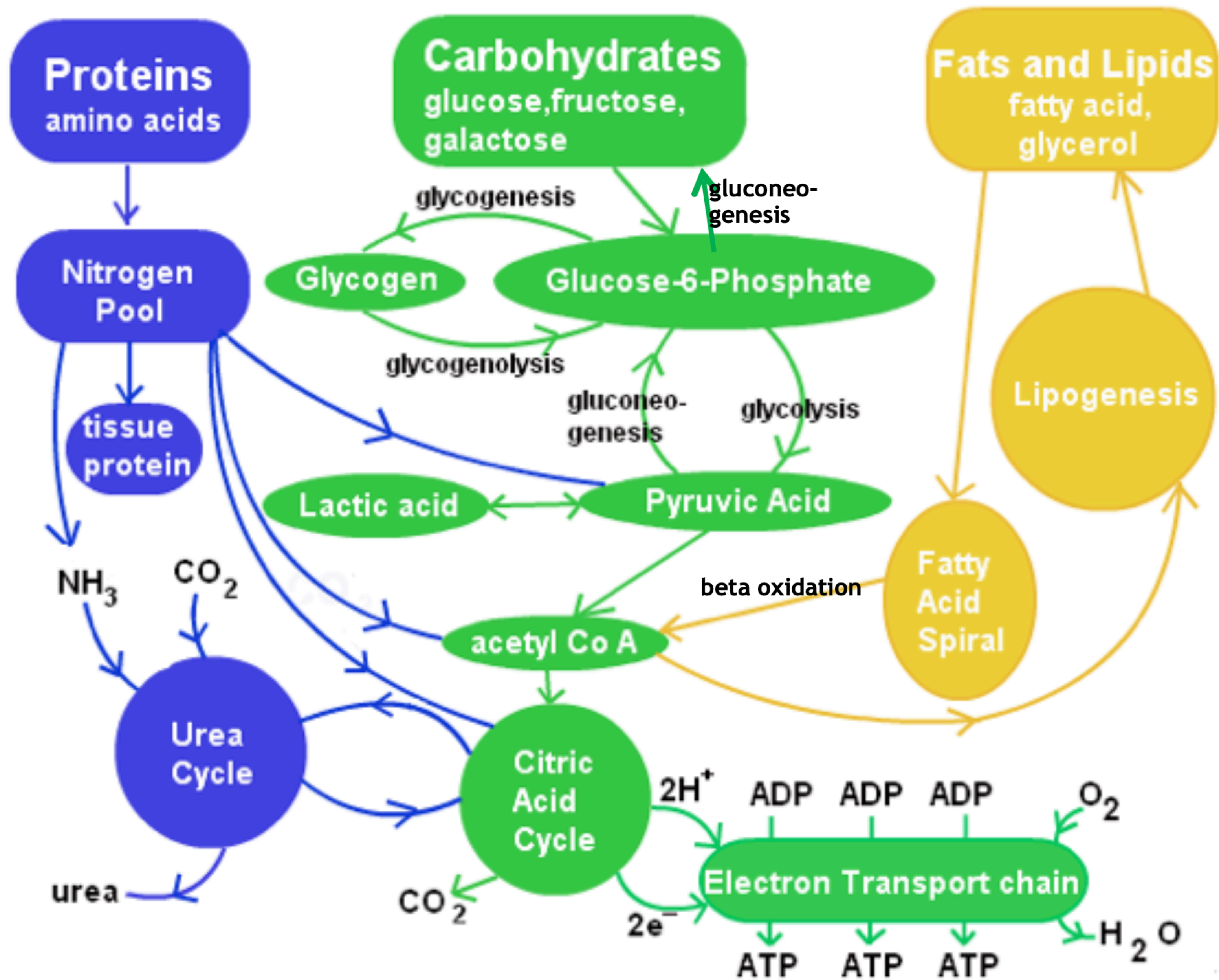
glycerol: 지방세포에서 triacylglycerol의 가수분해에서 나오는 glycerol은 dihydroxyacetone phosphate (DHAP)로 전환된다. 그러나 **지방산의 경우는 동물에서는 glucose로 전환되지 않는다.**

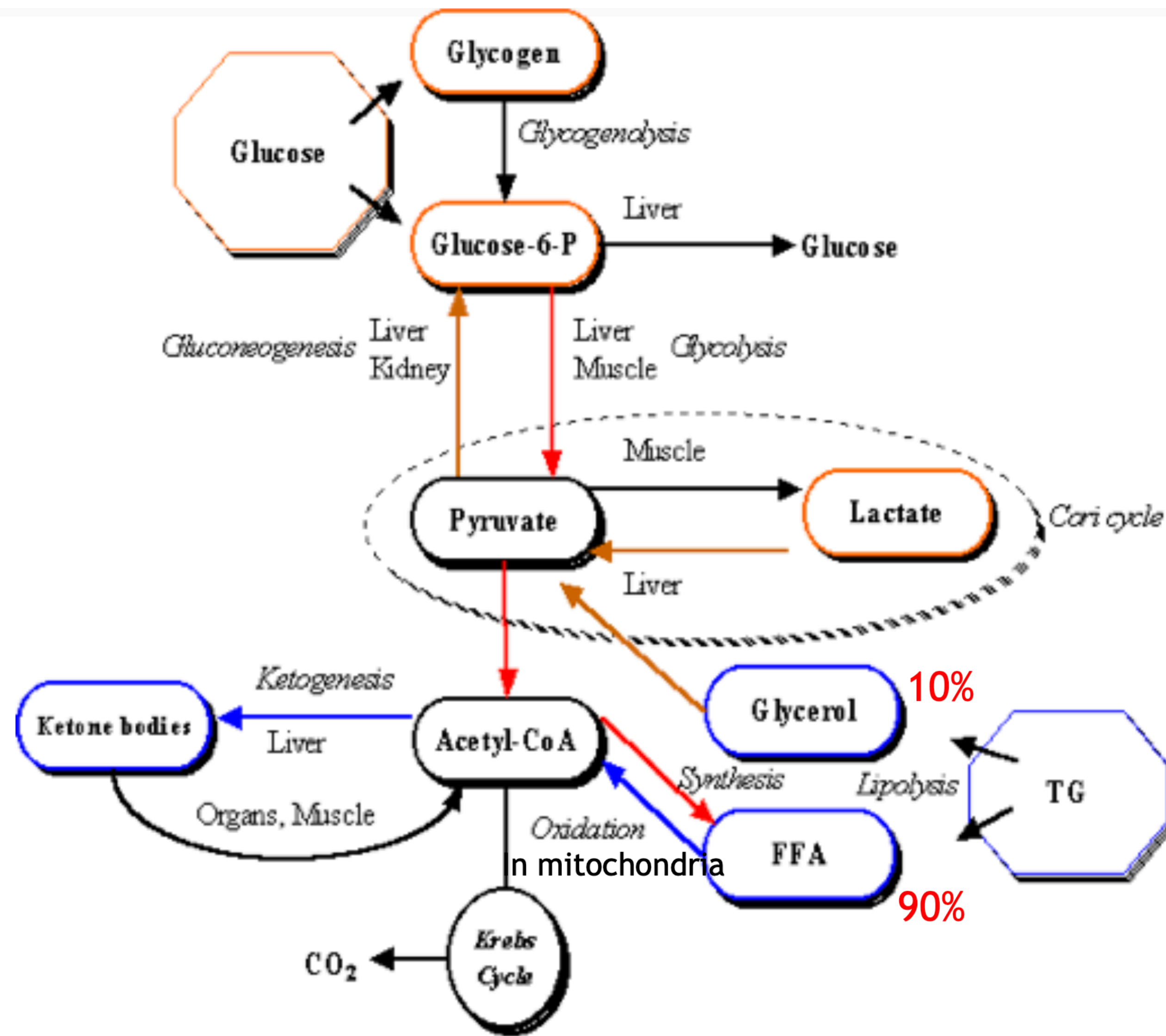
2. gluconeogenesis 과정은 해당과정의 역방향 진행이지만 정확히 역반응은 아니다.

Glycolysis & Gluconeogenesis



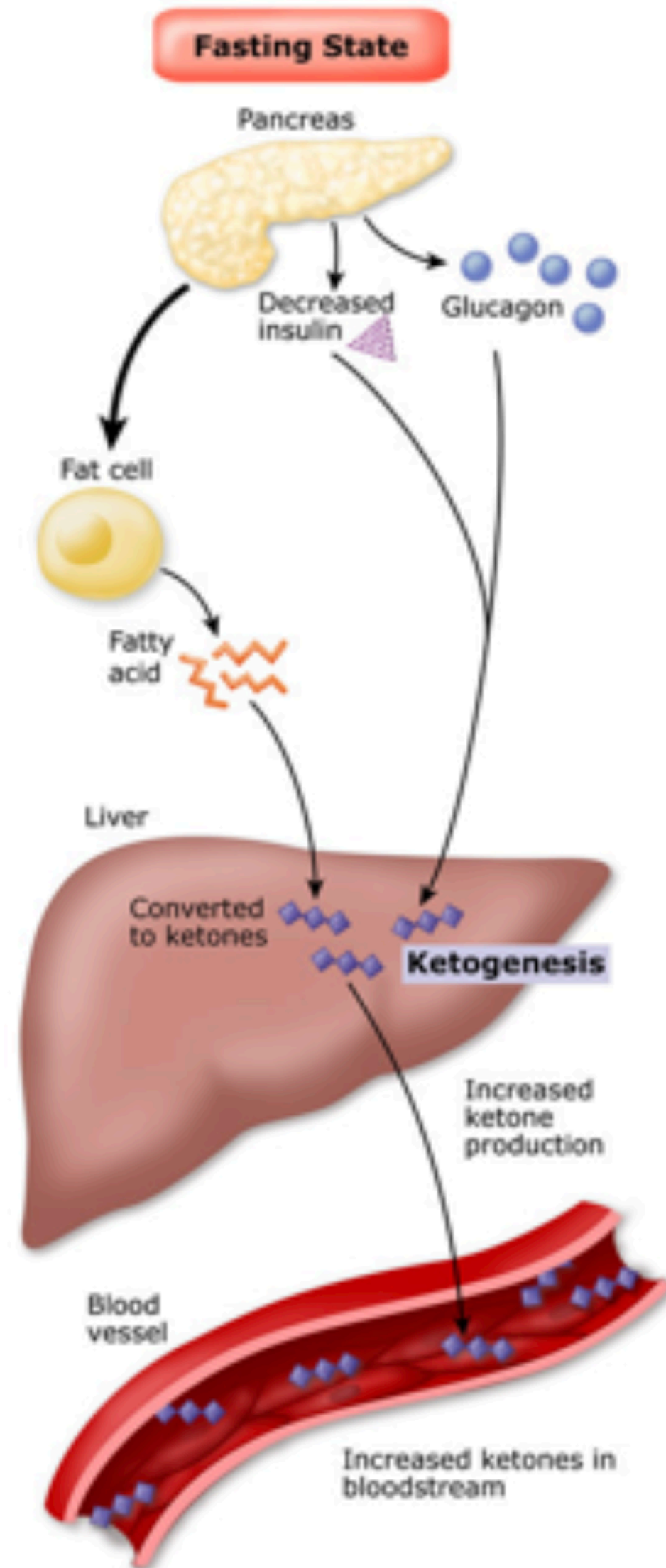
영양소 간 상호 전환 및 작용





OUTLINE OF GLUCOSE AND FAT METABOLISM

Ketone Production by Liver During Fasting Conditions (Ketosis)

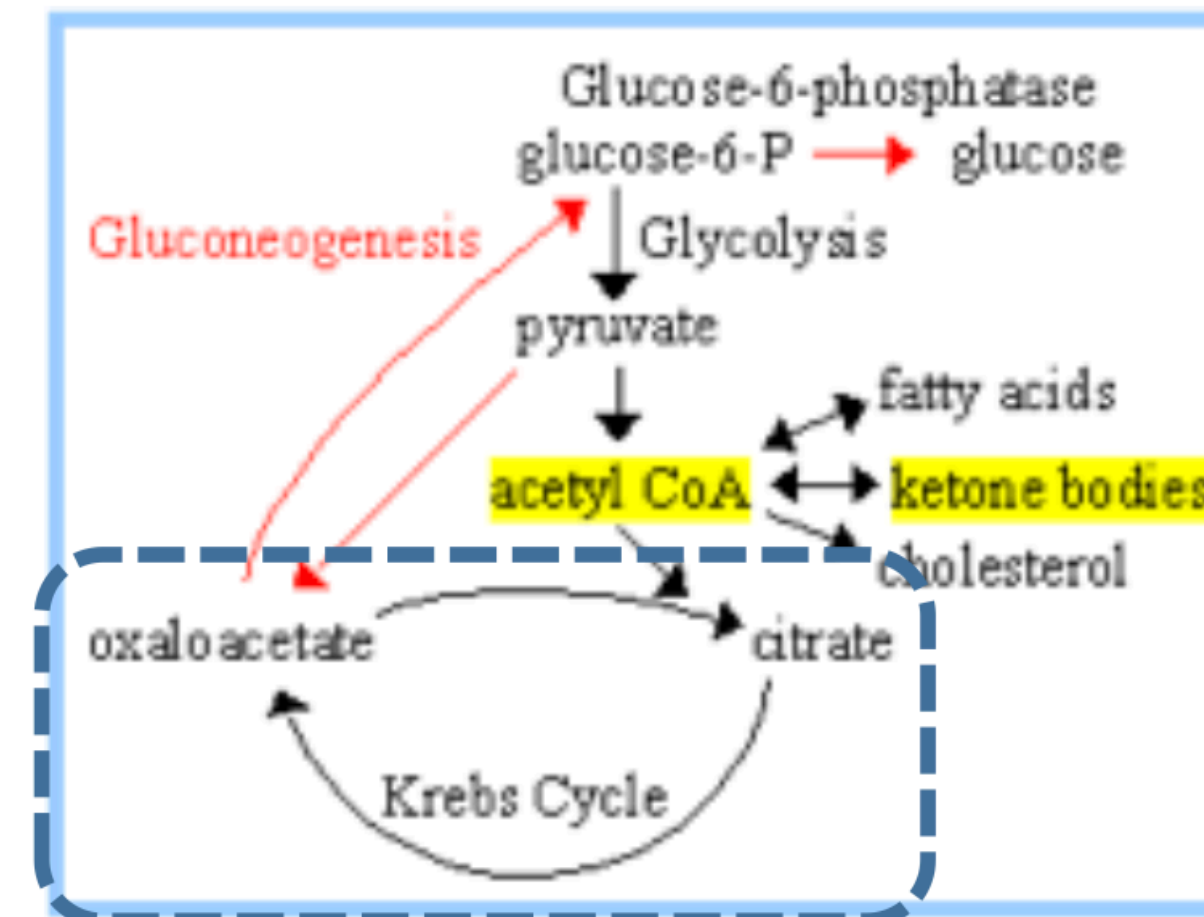


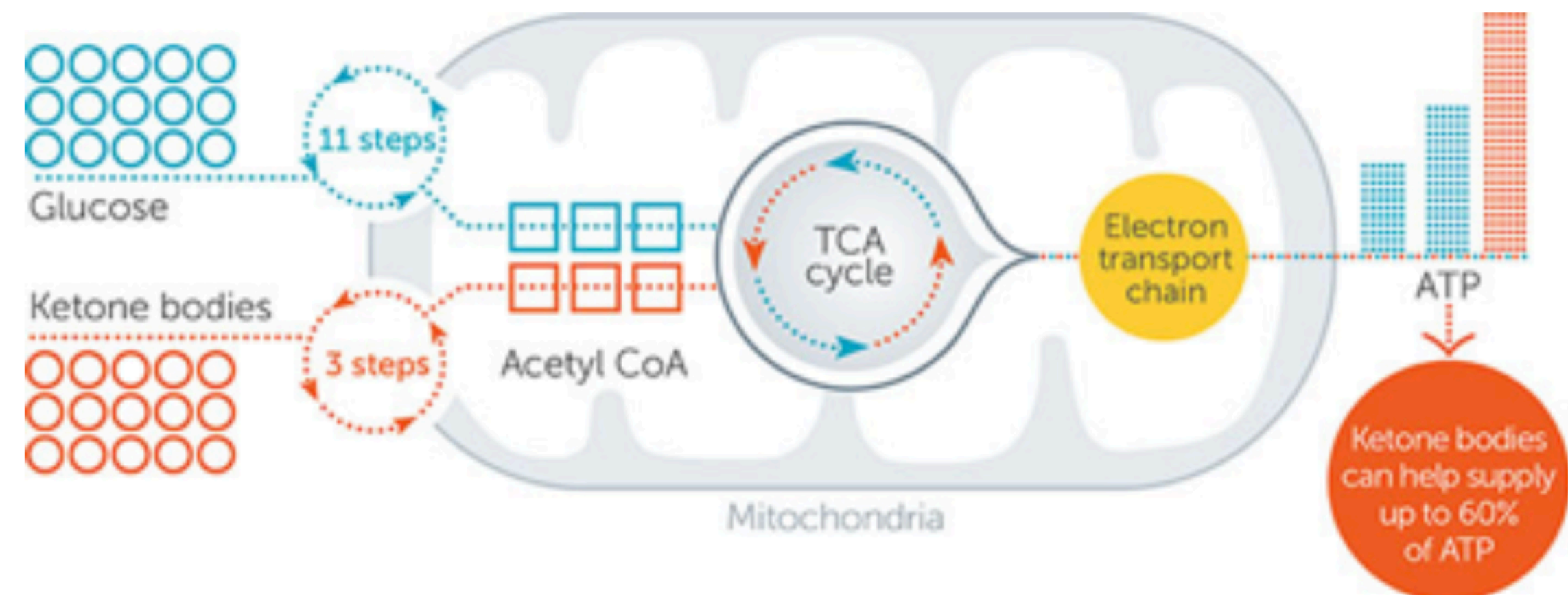
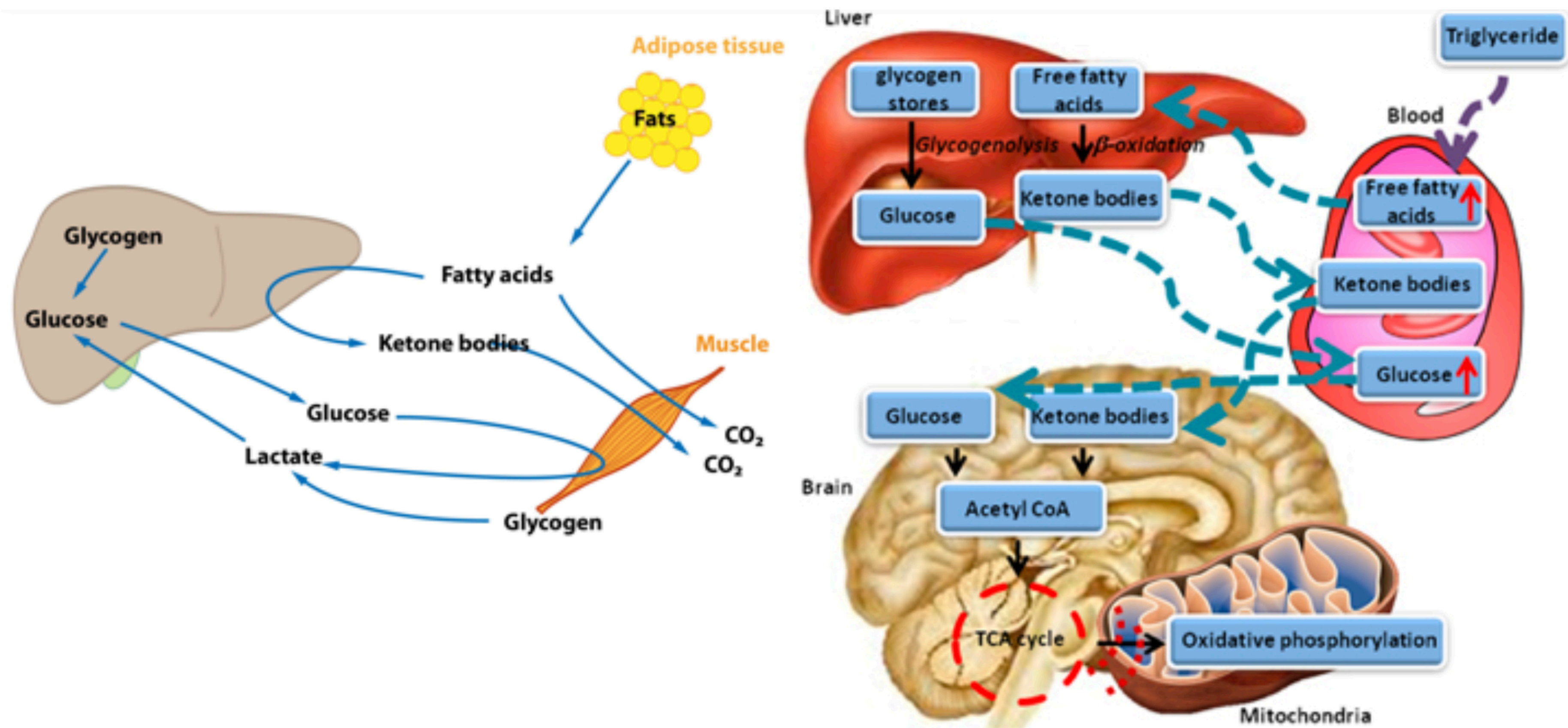
Ketone body

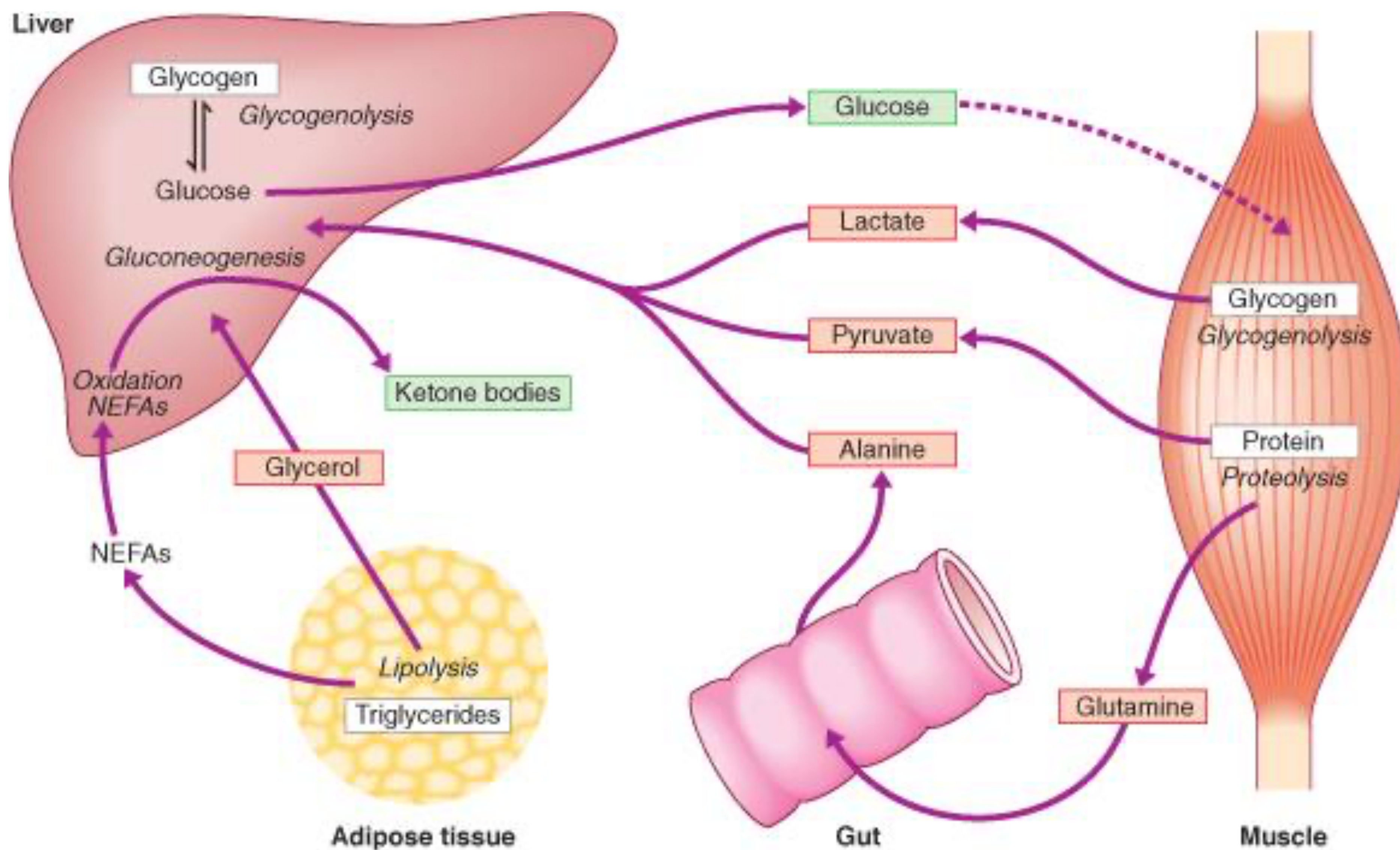
1. acetoacetic acid
2. acetone
3. beta-hydroxybutyric acid

장기간의 기아상태에서 뇌가 포도당 대신 케톤체를 에너지원으로 사용 → 단백질 분해, 소모 막아 체단백 보전 (기아로 인한 사망은 대개 저혈당이 아니라 단백질 소모에 기인하므로)

케톤증: 심한 산증, 혼수, 죽음에 이르게 할 수 있음.







저탄고지? 저탄고탄? 저지방?

어떤 영양소를 제한하는지보다 칼로리제한 자체가 중요함

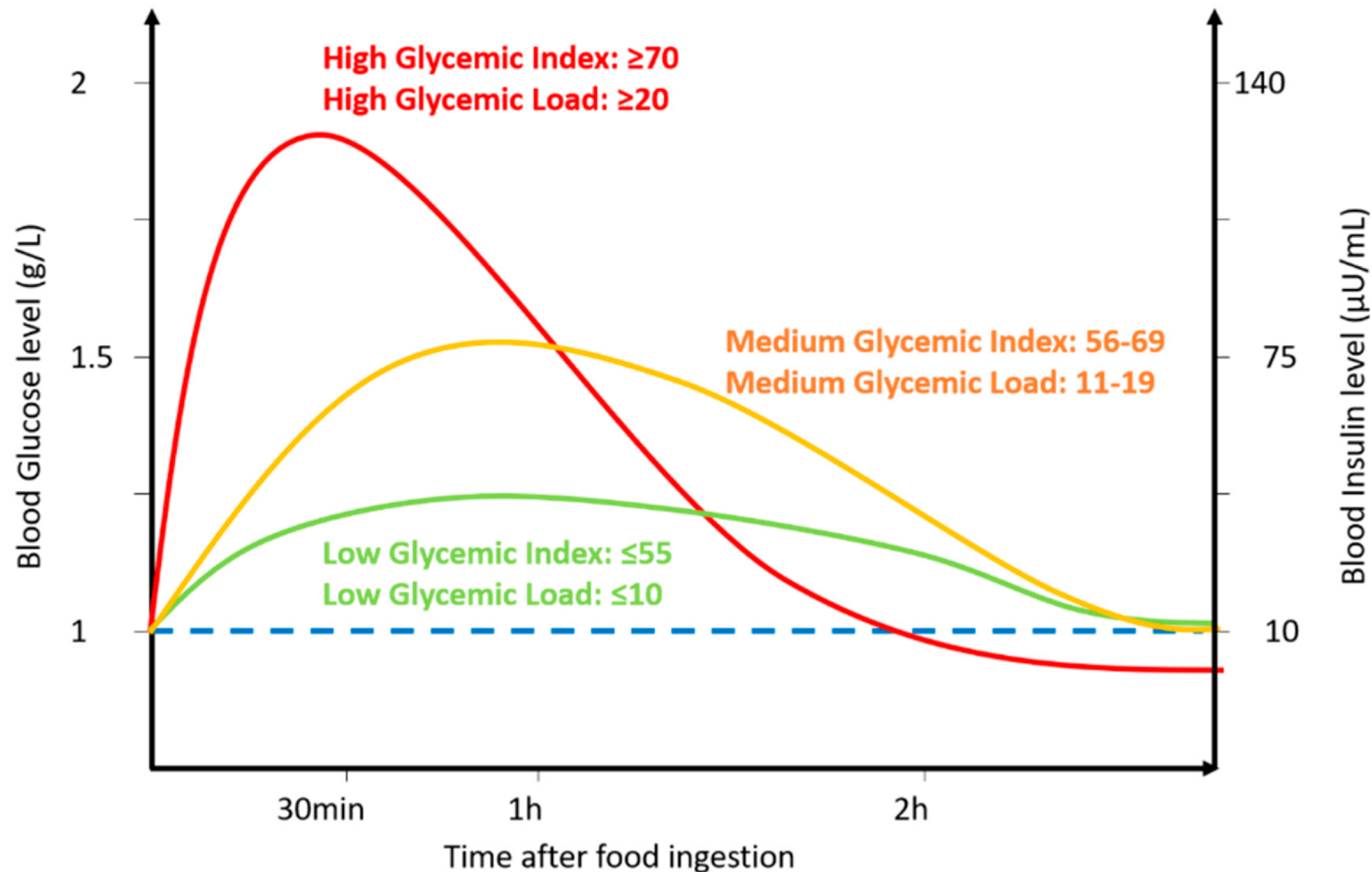
- 탄수화물을 제한하면 지방과 단백질을 제한 없이 마음껏 섭취해도 체중감량이 매우 잘 이루어질 수 있다. (저탄고지 식이요법, 앳킨스 다이어트)
- 그러나 저탄고지의 열정적 지지자들의 생각과 달리, 대부분의 경우 저탄고지 식단에서 칼로리 섭취가 실제로 감소함
- 적어도 현재까지의 다이어트 비교연구결과로는, 저탄고지 다이어트가 저지방 다이어트에 비해, **칼로리제한을 동일하게 제한했을 때** 더 효과적이지는 않았다.
- 핵심은 아마도 저탄 다이어트가 ‘섭취 칼로리가 줄어들었다’고 느끼지 못하는데 있을지도.
- 뇌의 포만/보상체계를 효과적으로 자극할 수 있다면 다이어트 성공가능성이 높아짐 (가공식품의 위험성)

다이어트 시 지나친 저탄수화물 식이의 문제점

- 기초대사량 자체가 지나치게 낮아짐
- 당신생 작용 활성화되어 근손실 발생 근육합성 어려움
- 근육내 글리코겐 함량이 적어지면 운동수행능력 저하 & 근육보유 수분량 감소로 근육볼륨 저하
- 올바른 탄수화물 섭취가 중요 (GI/GL 낮은 탄수화물 위주로)
- Cf. 탄수화물 사이클링(밴딩 & 로딩)

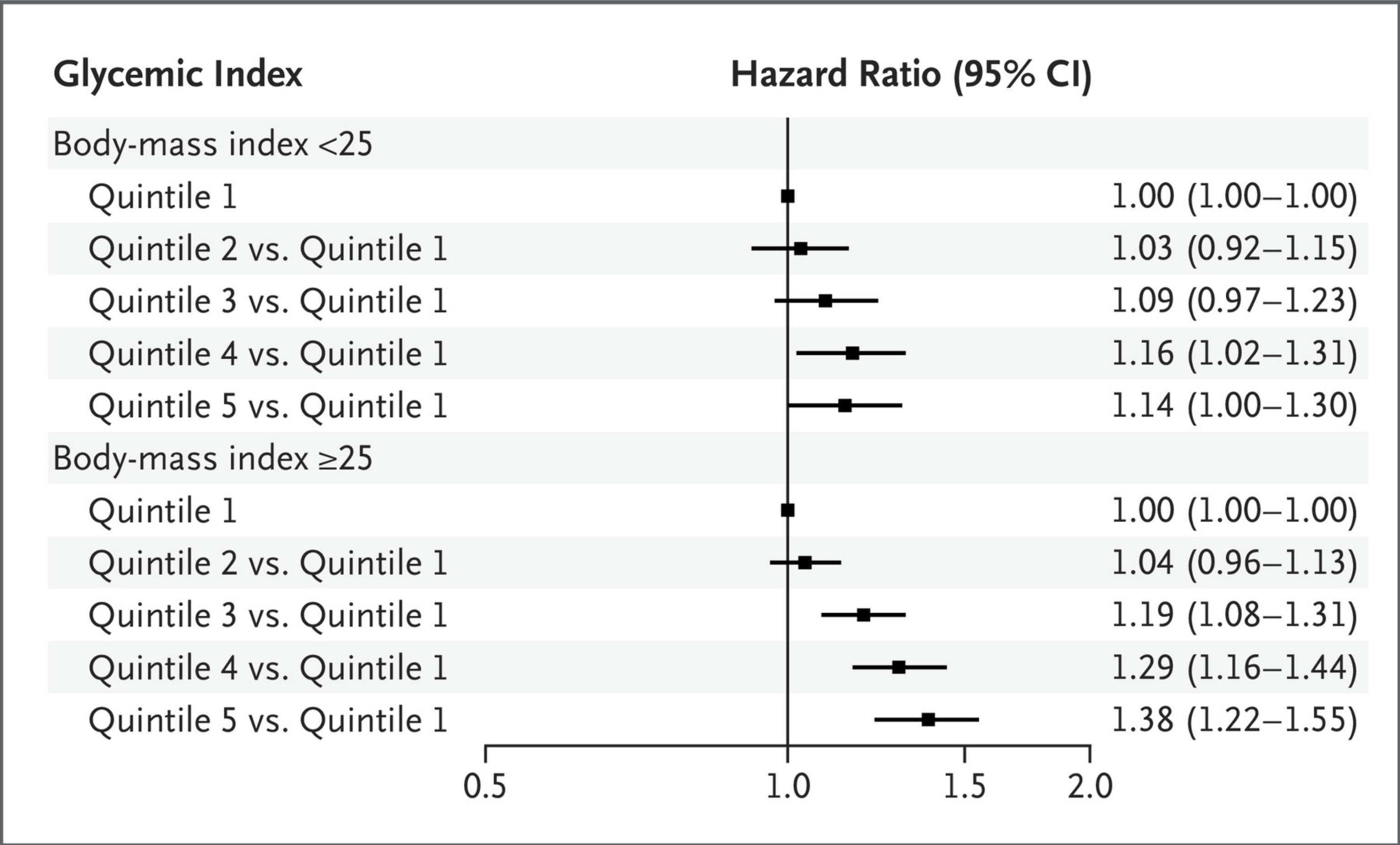
Glycemic Index & Glycemic Load

- The **glycemic index (GI)** is a number from 0 to 100 assigned to a food, with pure glucose arbitrarily given the value of 100, which represents the relative rise in the blood glucose level two hours after consuming that food
- The **glycemic load (GL)** of food is a number that estimates how much the food will raise a person's blood glucose level after eating it. $(GI \times \text{1회섭취분 함유 탄수화물량})/100$



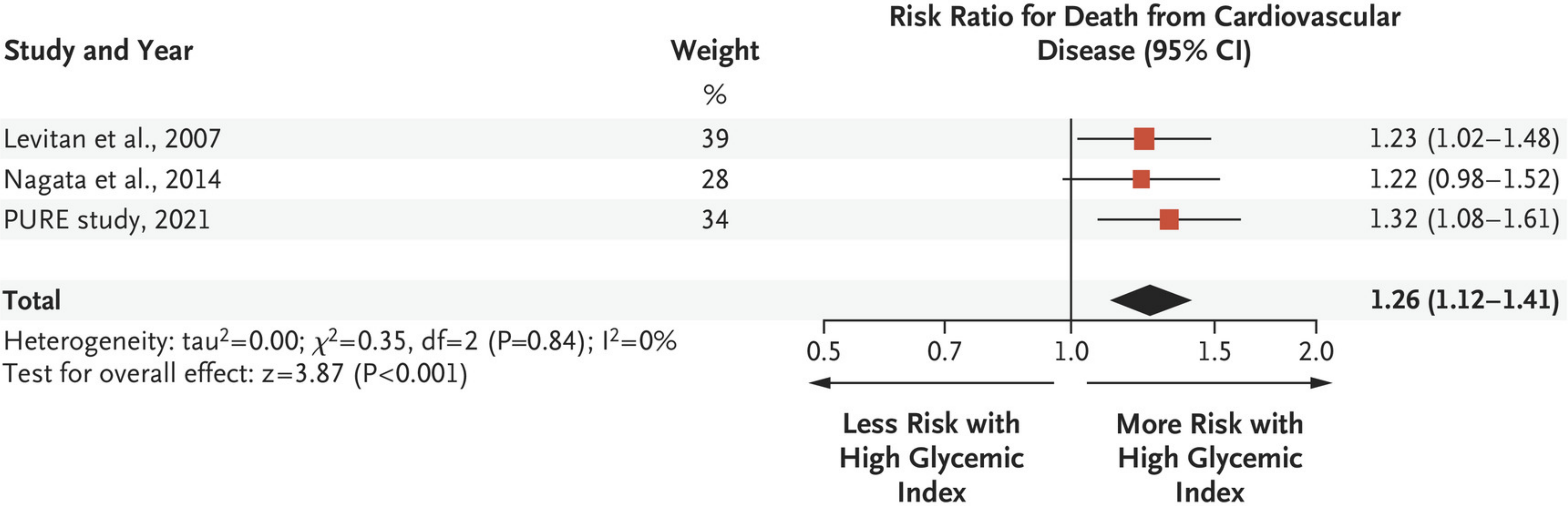
ORIGINAL ARTICLE

Glycemic Index, Glycemic Load,
and Cardiovascular Disease and Mortality



ORIGINAL ARTICLE

Glycemic Index, Glycemic Load, and Cardiovascular Disease and Mortality



영양성분표

상품명에 ‘프로틴’ 포함된 상품들이지만 실제 성분구성은 매우 상이함

영양정보 총 내용량 150 mL 105 kcal		
총 내용량당	1일 영양성분 기준치에 대한 비율	
나트륨	120 mg	6%
탄수화물	19 g	6%
당류	19 g	19%
지방	1.4 g	3%
트랜스지방	0 g	
포화지방	1.2 g	8%
콜레스테롤	5 mg	2%
단백질	4.7 g	9%
칼슘	130 mg	19%
1일 영양성분 기준치에 대한 비율(%)은 2,000 kcal 기준이므로 개인의 필요 열량에 따라 다를 수 있습니다.		

영양정보

1봉지(20 g)당	1일 영양성분 기준치에 대한 비율
나트륨 30 mg	1 %
탄수화물 9 g	3 %
당류 2 g	2 %
지방 6 g	11 %
트랜스지방 0 g	
포화지방 2.9 g	19 %
콜레스테롤 4 mg	1 %
단백질 5 g	8 %

1일 영양성분 기준치에 대한 비율(%)은 2,000 kcal 기준이므로 개인의 필요 열량에 따라 다를 수 있습니다.

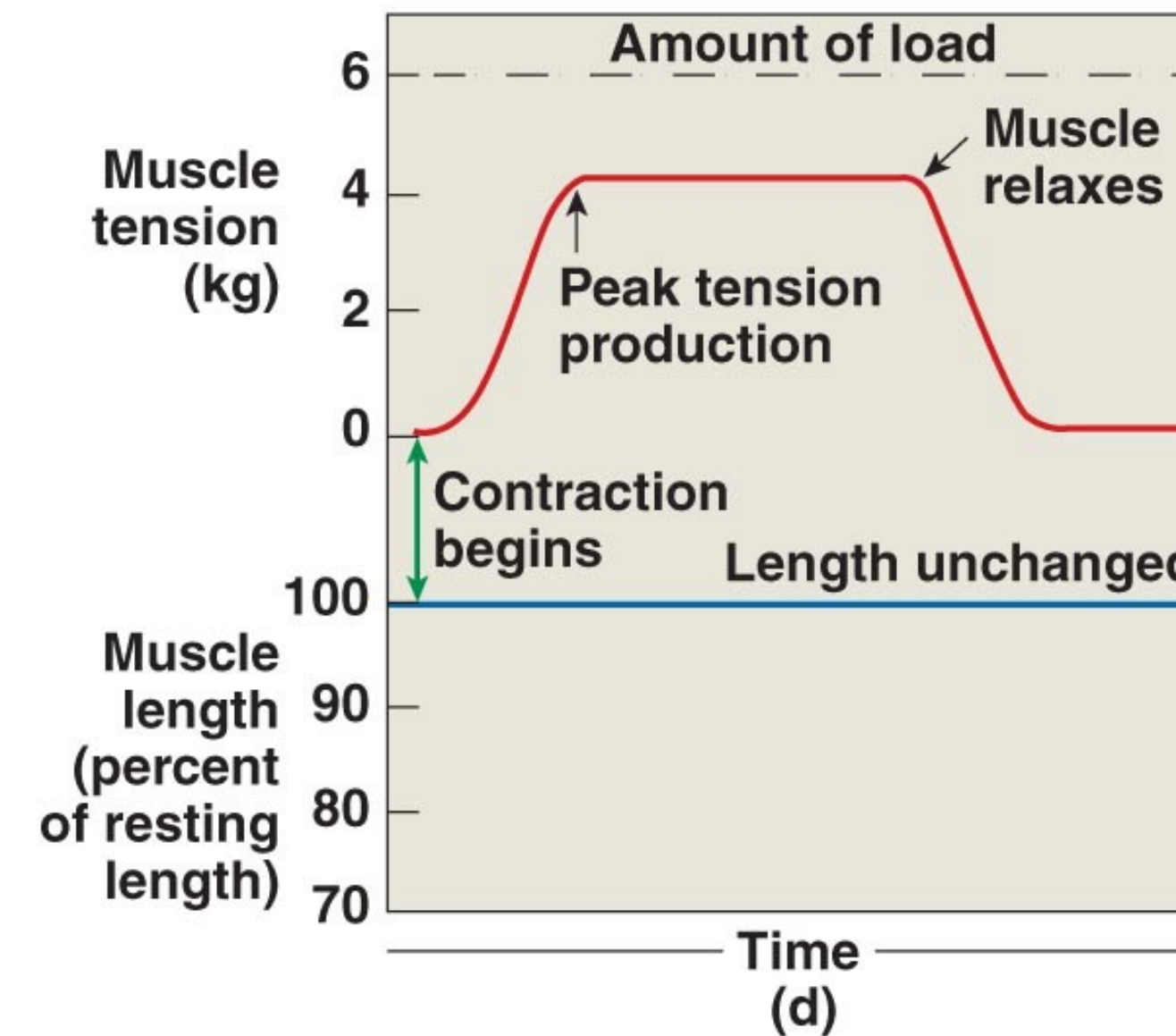
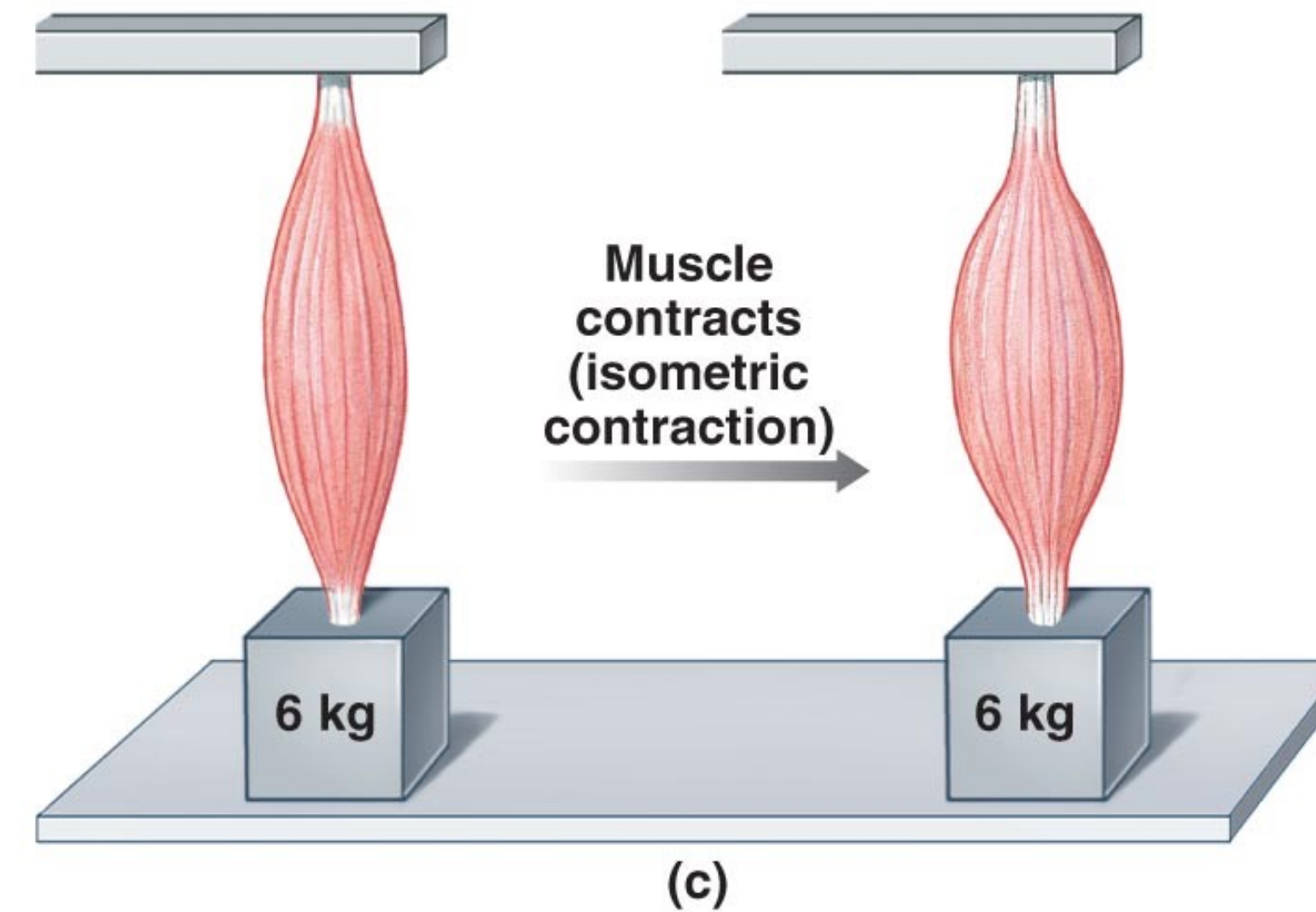
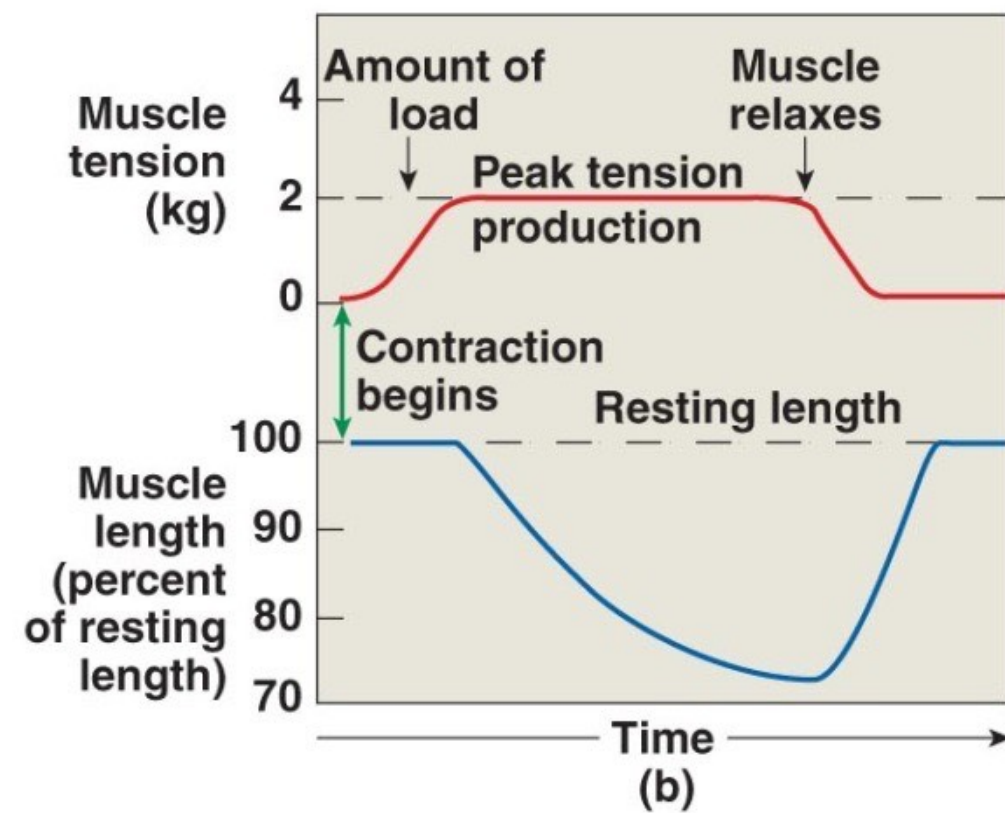
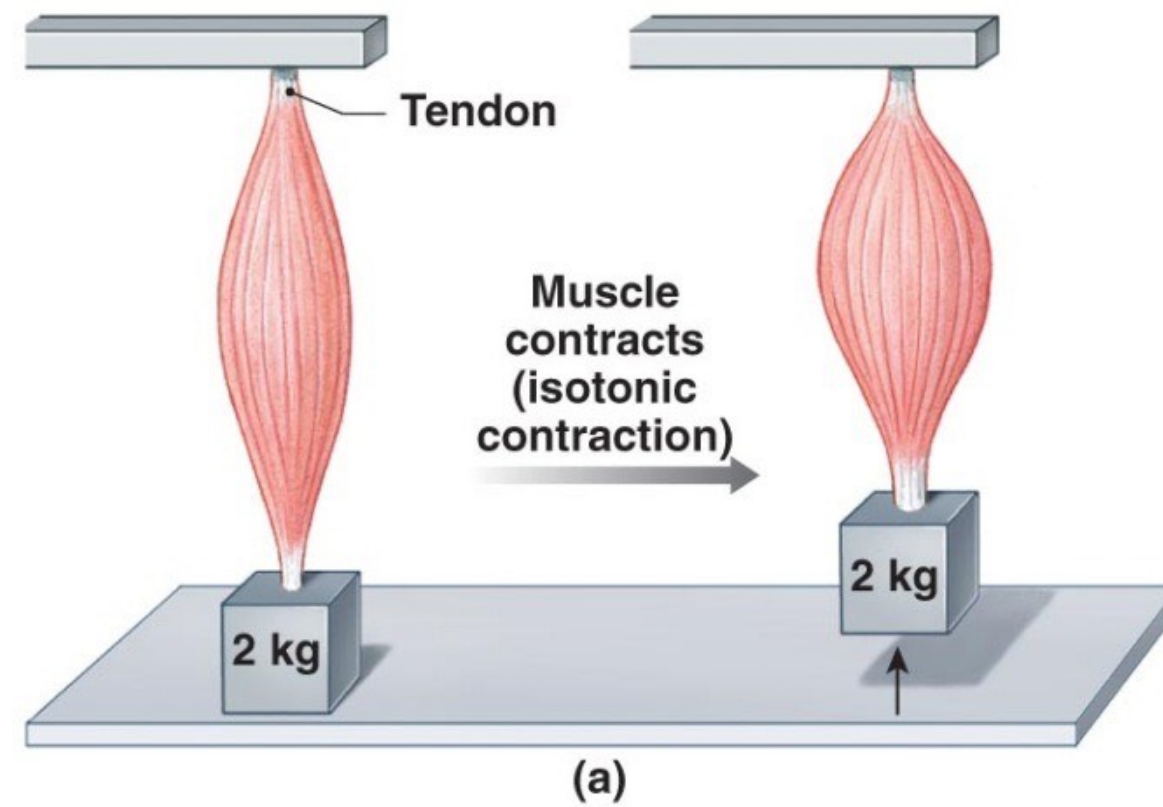
영양정보 총 내용량 190 ml 150 kcal		
총 내용량당	1일 영양성분 기준치에 대한 비율	
나트륨 150 mg	8%	아연 7 mg 82%
탄수화물 19.5 g	6%	비타민A 250 µgRE 36%
당류 8 g	8%	비타민B ₁ 0.8 mg 67%
식이섬유 4.5 g	18%	비타민B ₆ 1 mg 67%
지방 4.5 g	8%	비타민B ₁₂ 1 µg 42%
트랜스지방 0 g		비타민C 20 mg 20%
포화지방 1 g	7%	비타민D 10 µg 100%
콜레스테롤 5 mg	2%	비타민E 6 mgα-TE 55%
단백질 10 g	18%	엽산 120 µg 30%
칼슘 290 mg	41%	나이아신 5 mg NE 33%
칼륨 240 mg	7%	판토텐산 2 mg 40%
마그네슘 25 mg	8%	비오틴 9 µg 30%
※ 1일 영양성분 기준치에 대한 비율(%)은 2,000 kcal 기준이므로 개인의 필요 열량에 따라 다를 수 있습니다.		

영양정보		1개당	1일 영양성분 기준치에 대한 비율	1개당	1일 영양성분 기준치에 대한 비율
총 내용량 470g(47g x 10회) 1개(47g)당 178.5kcal	나트륨	20mg	1%	지방	2.1g 4%
	탄수화물	24g	7%	트랜스지방	0g -
	당류	2.8g	3%	포화지방	0.4g 3%
	콜레스테롤	0mg	0%	단백질	15.7g 29%
	마그네슘	51.9mg	16%		
1일 영양성분 기준치에 대한 비율(%)은 2,000kcal 기준이므로 개인의 필요 열량에 따라 다를 수 있습니다.					

- 단백질은 근성장을 목표로 하는 경우 kg당 1-2g 목표로(더 많다고 더 효과적이지 않다)
- 탄수화물은 식이섬유를 포함하므로, 탄수화물과 당을 함께 보는 것이 중요

운동생리학

Muscle Contraction Types



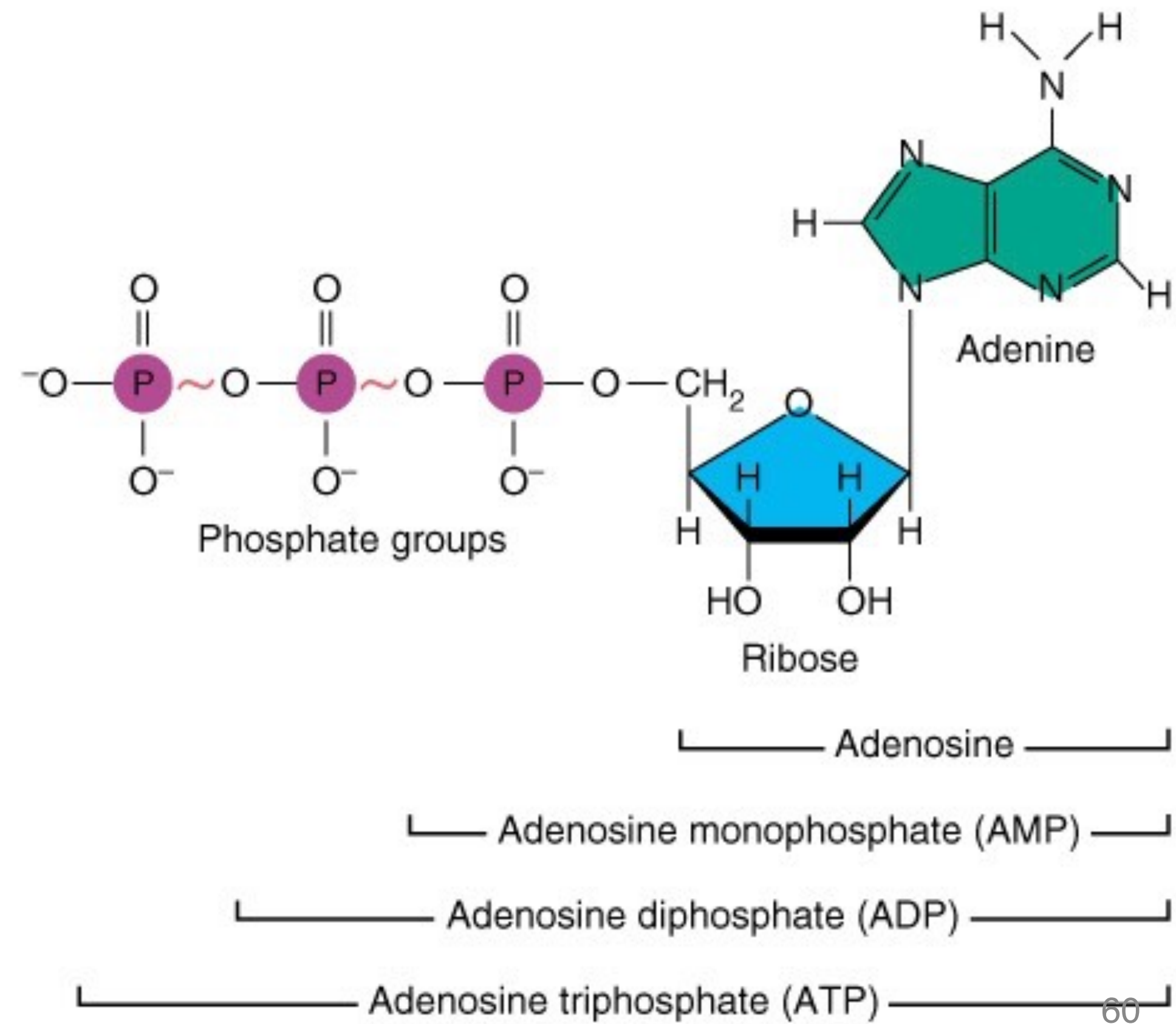
Isotonic:

Concentric: Overcomes opposing resistance and muscle shortens

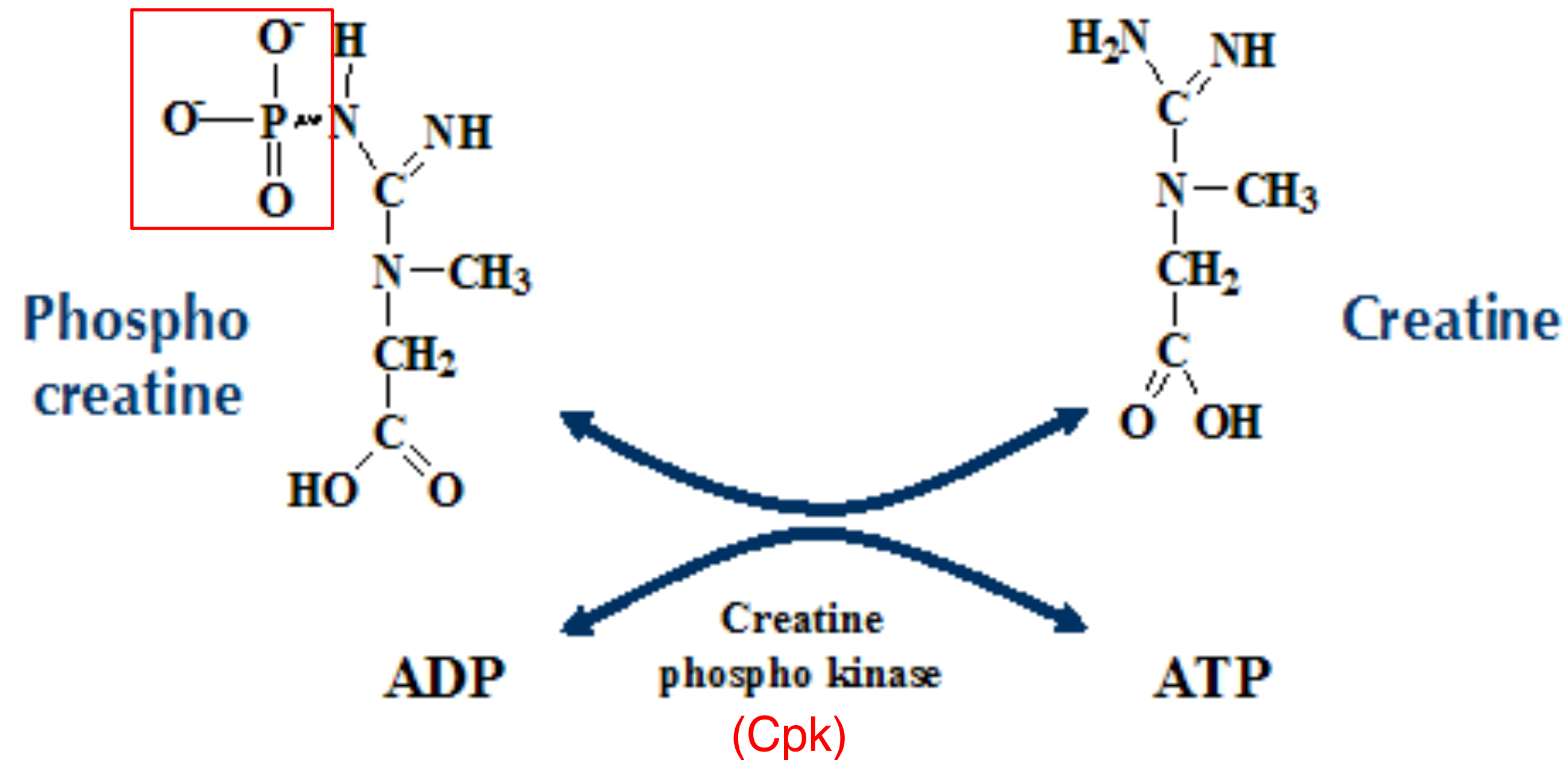
Eccentric: Tension maintained but muscle lengthens

골격근의 ATP 공급

- 1) 크레아틴 인산 creatine phosphate
- 2) 산화적 인산화 oxidative phosphorylation
- 3) 해당작용 glycolysis



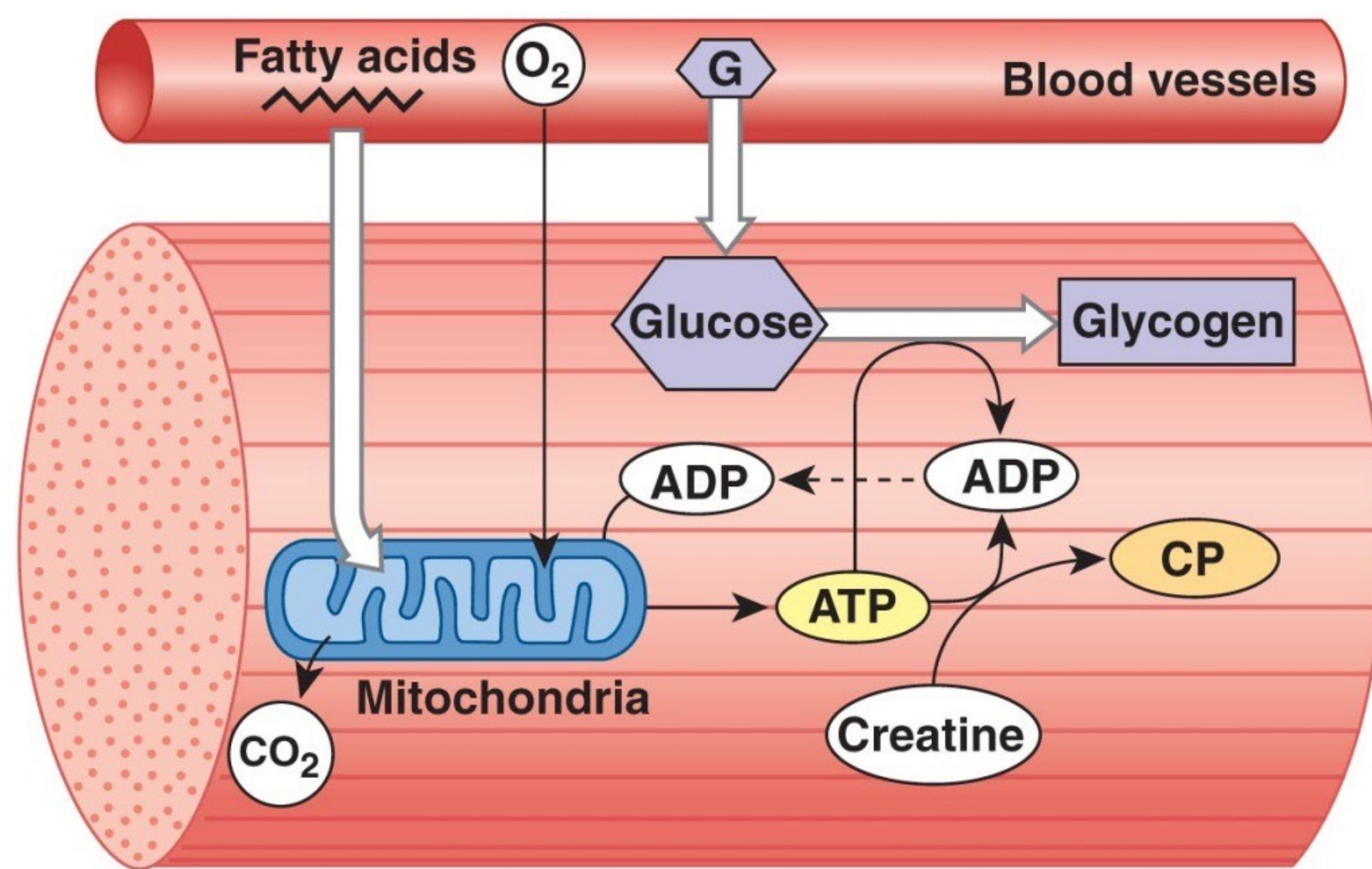
Creatine Phosphate-ATP interaction



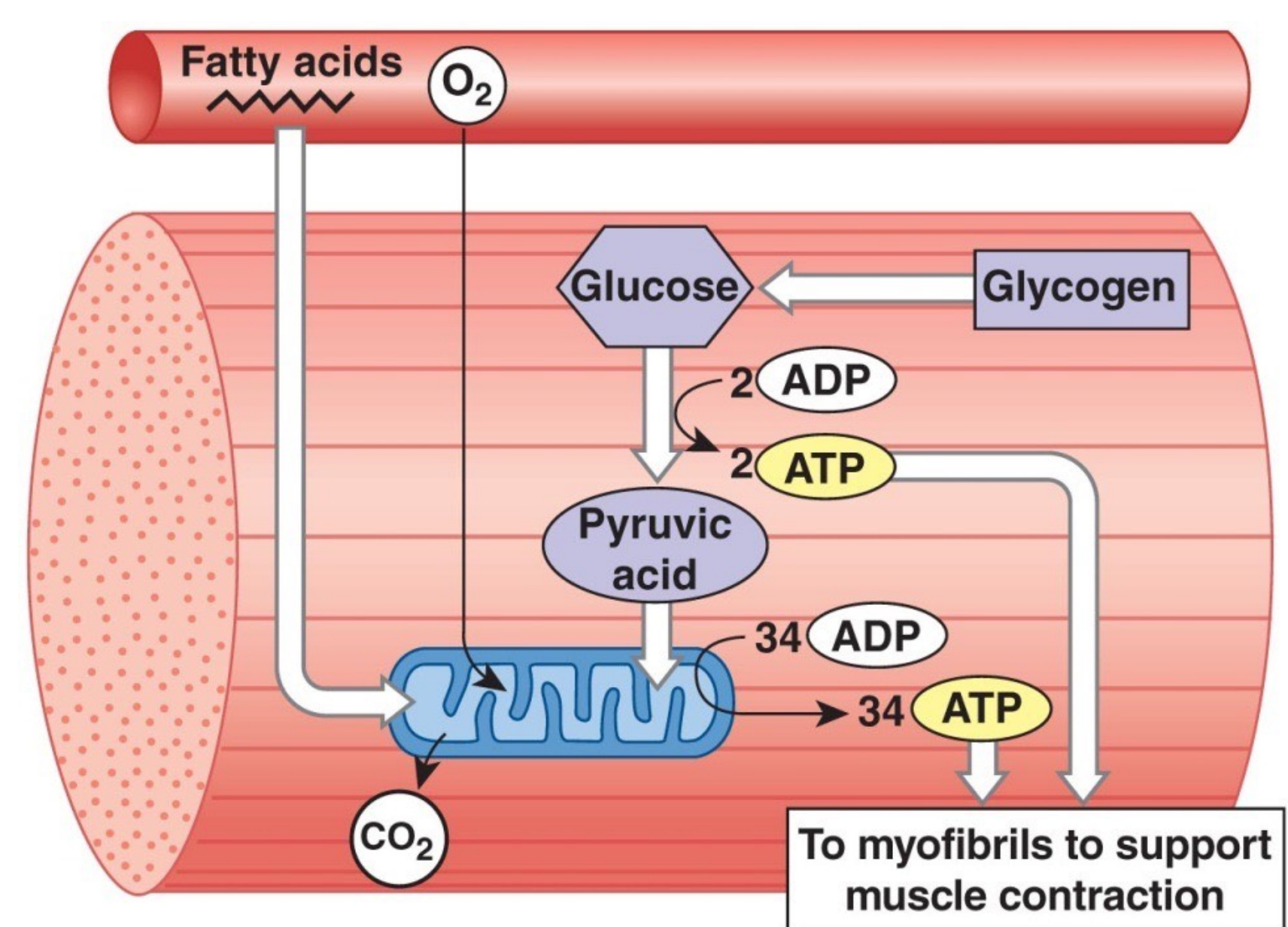
크레아틴이 인산기 갖고 있다가 ADP한테 줘서 ATP 만들어주기 (고강도 운동 초기 1분정도)

쉬고 있는 근육은 ATP보다 5배 많은 크레아틴 인산 함유. 즉, 대부분의 에너지가 크레아틴 인산 형태로 저장되어 있는 것.

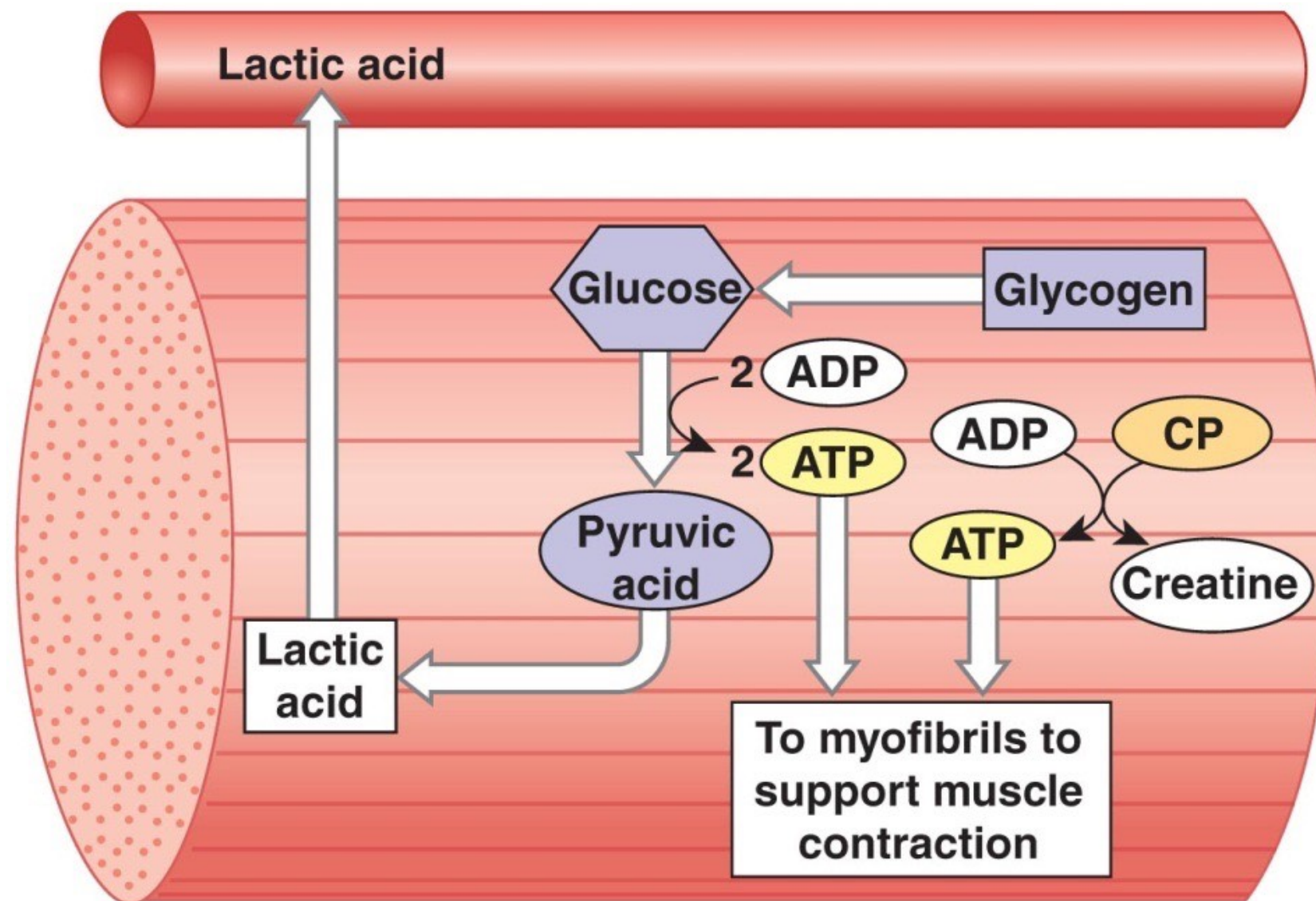
When cell muscles are damaged, this leaks across capillary beds and into the blood stream. Thus a high blood concentration of CPK is indicative of muscle tissue injury (MI, rhabdomyositis, myocarditis...)



(a) Resting muscle: Fatty acids are catabolized; the ATP produced is used to build energy reserves of ATP, CP, and glycogen.



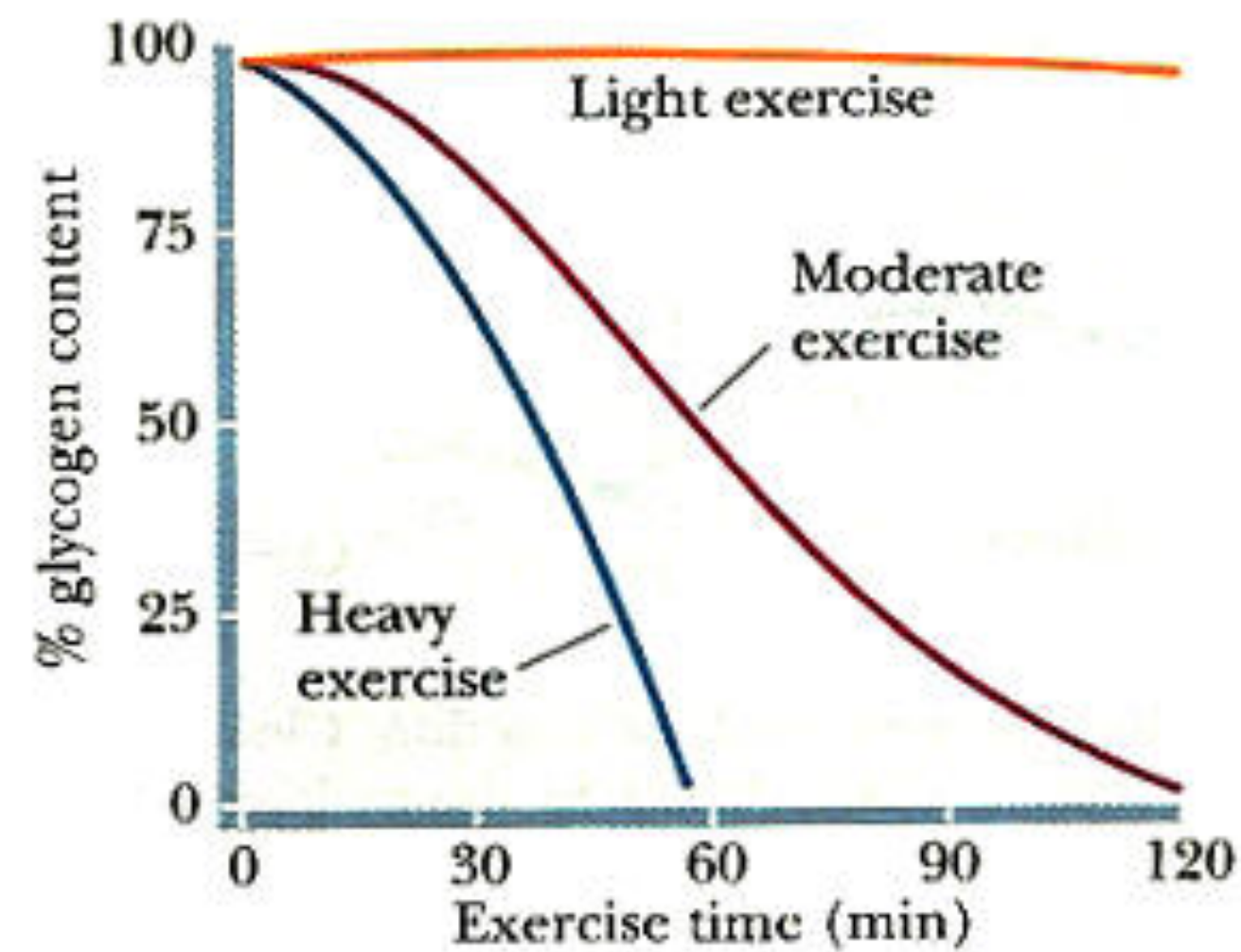
(b) Moderate activity: Glucose and fatty acids are catabolized; the ATP produced is used to power contraction.



(c) Peak activity: Most ATP is produced through glycolysis, with lactic acid as a by-product. Mitochondrial activity (not shown) now provides only about one-third of the ATP consumed.

- 격렬한 운동의 경우 훨씬 빨리 creatine phosphate 소진.
- 젖산의 축적은 metabolic acidosis 유발. → muscle fatigue
- 격렬한 운동후엔 운동후초과산소소비(EPOC:excess postexercise oxygen consumption) ← oxygen debt: 크레아틴 인산복구(몇분), 젖산을 다시 피루브산 → ATP생산 or 간에서 당신생후 글리코겐 저장.(몇시간)

Glycogen Utilization in Working Muscle

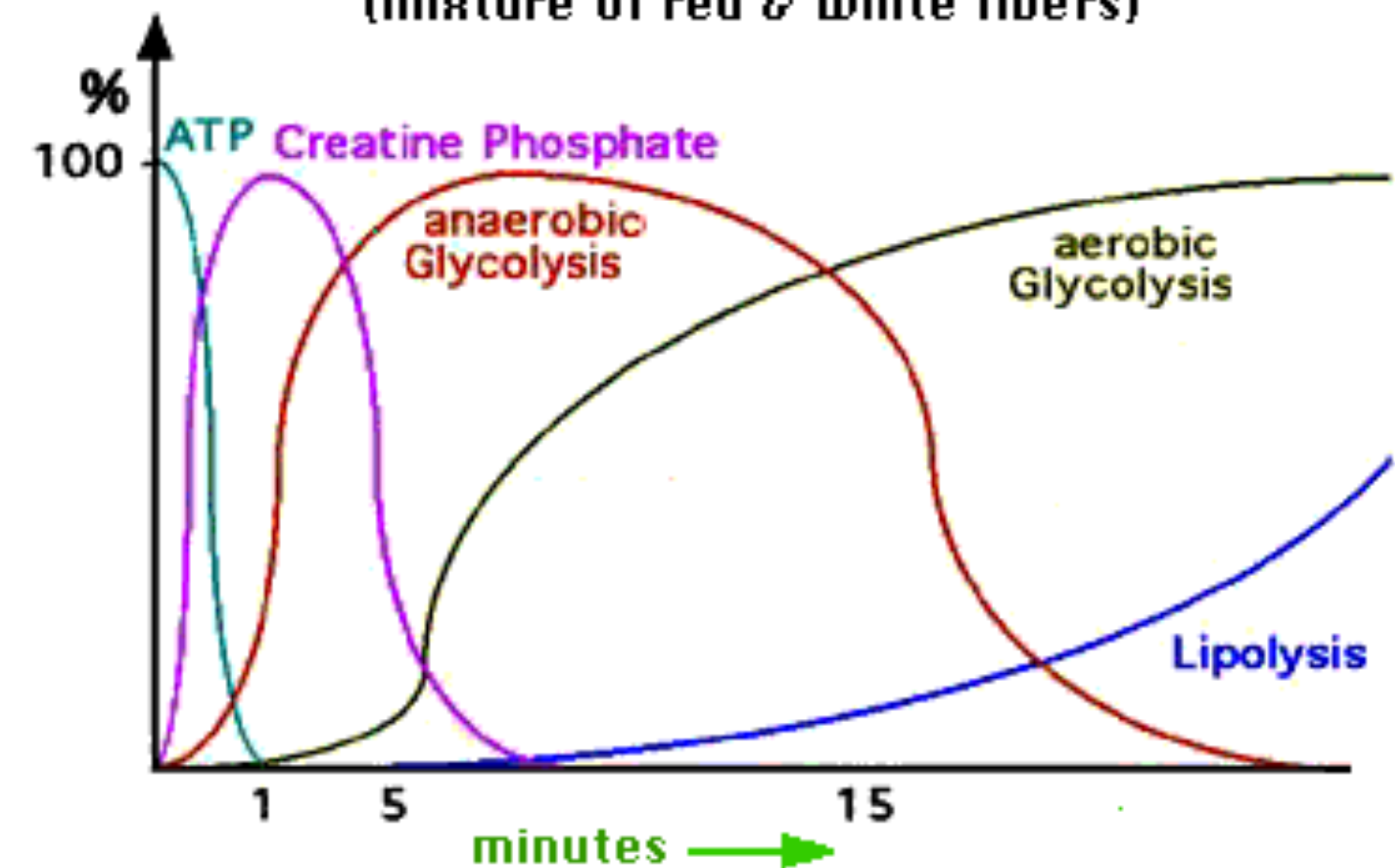


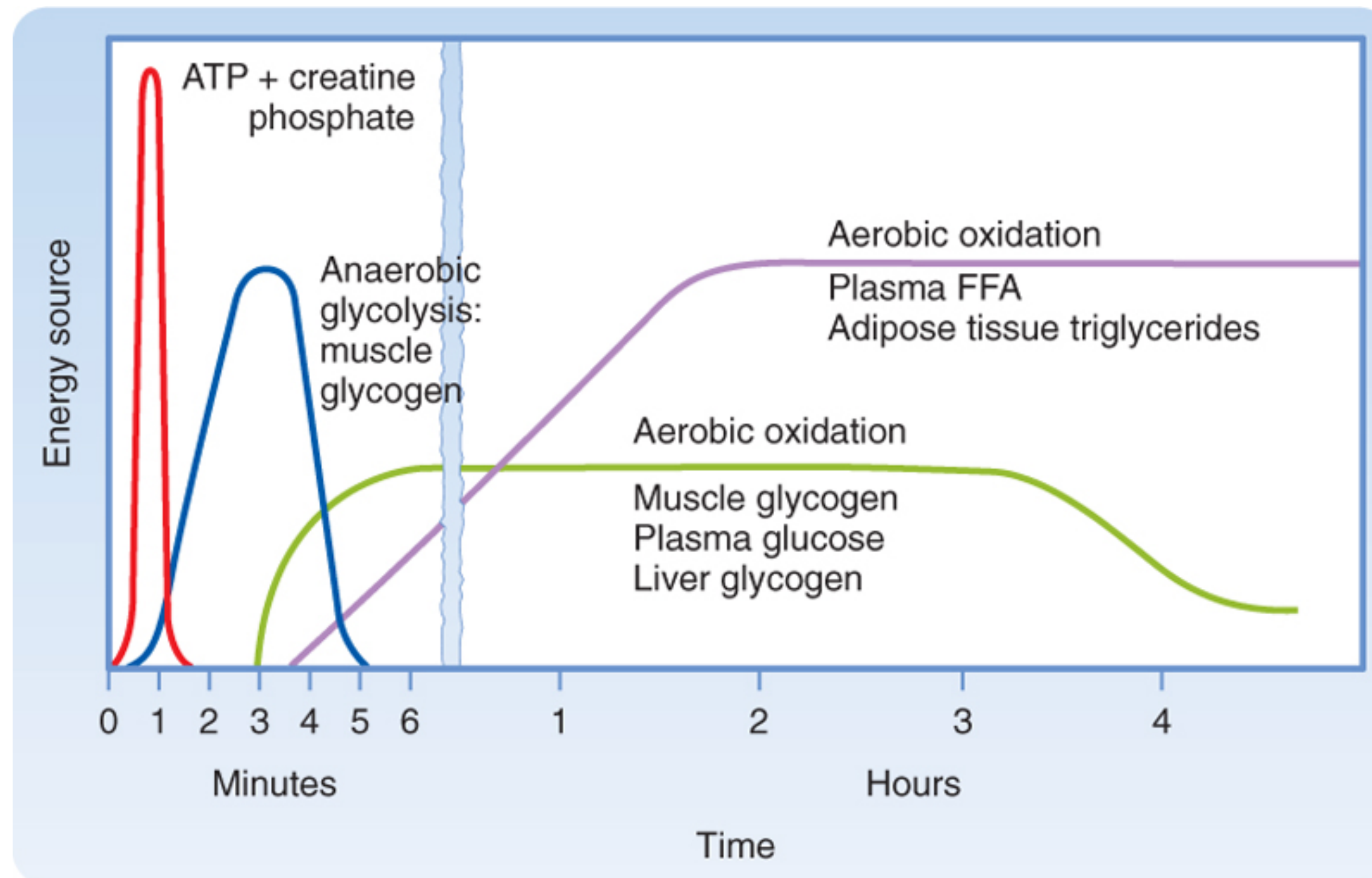
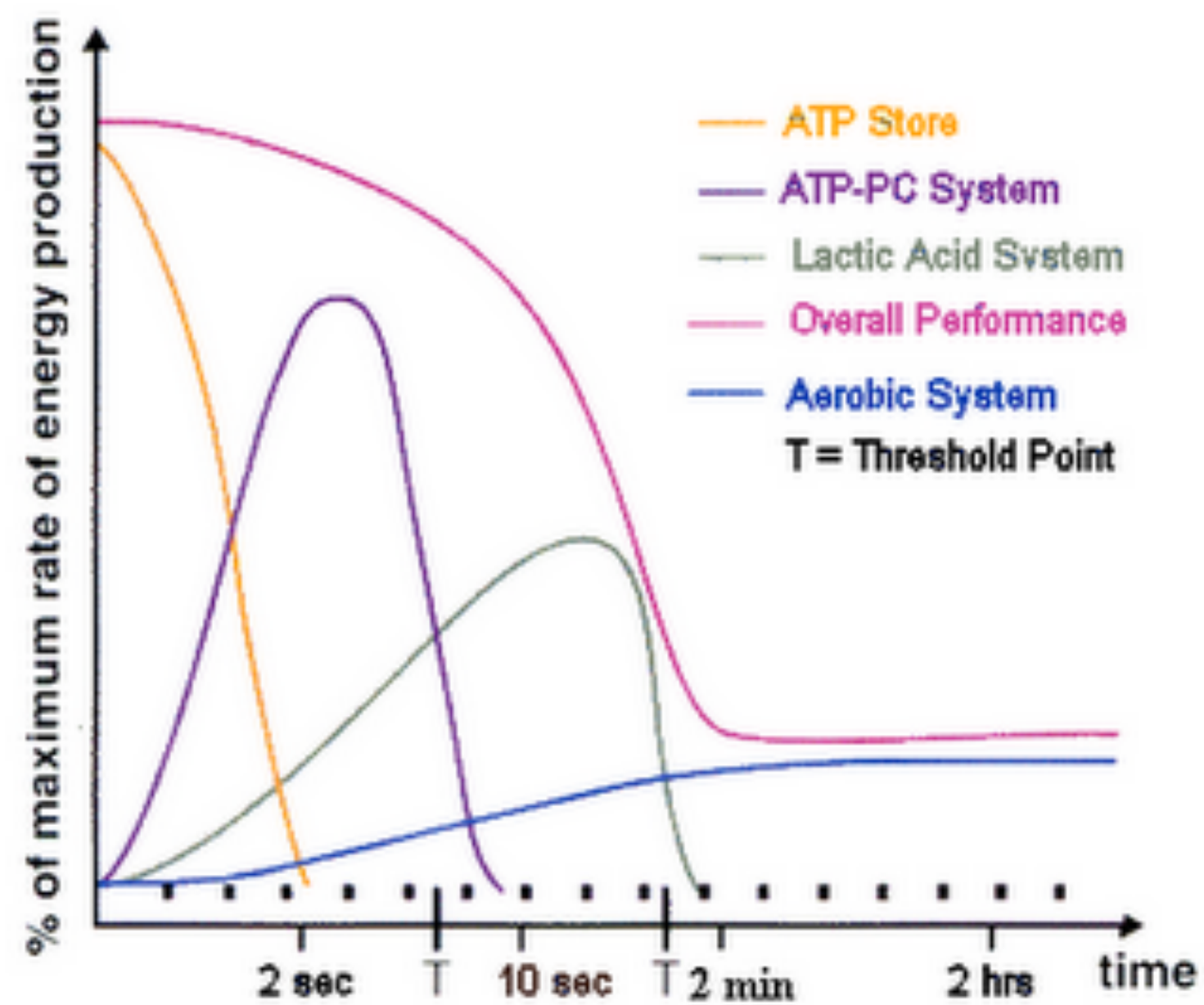
Biochemistry, 3. ed, Garrett and Grisham, 2004, p. 772

가벼운 운동의 경우 glycogen분해 필요 없이 혈중의 포도당과 지방산 이용.

시간이 지나고 에너지원이 바뀌면 운동 performance도 감소.

Energy Sources of Skeletal Muscle Change during Work
(mixture of red & white fibers)



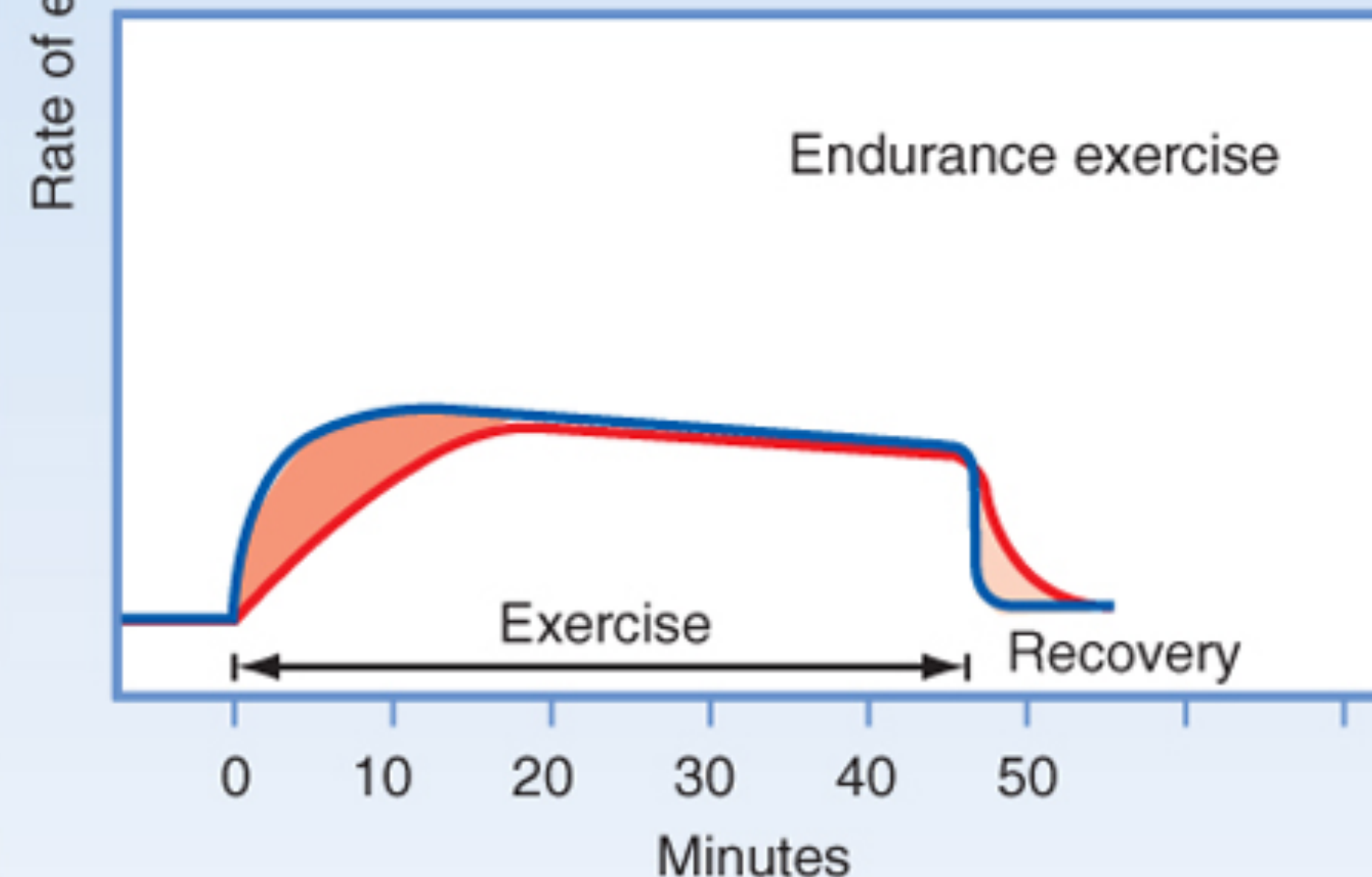
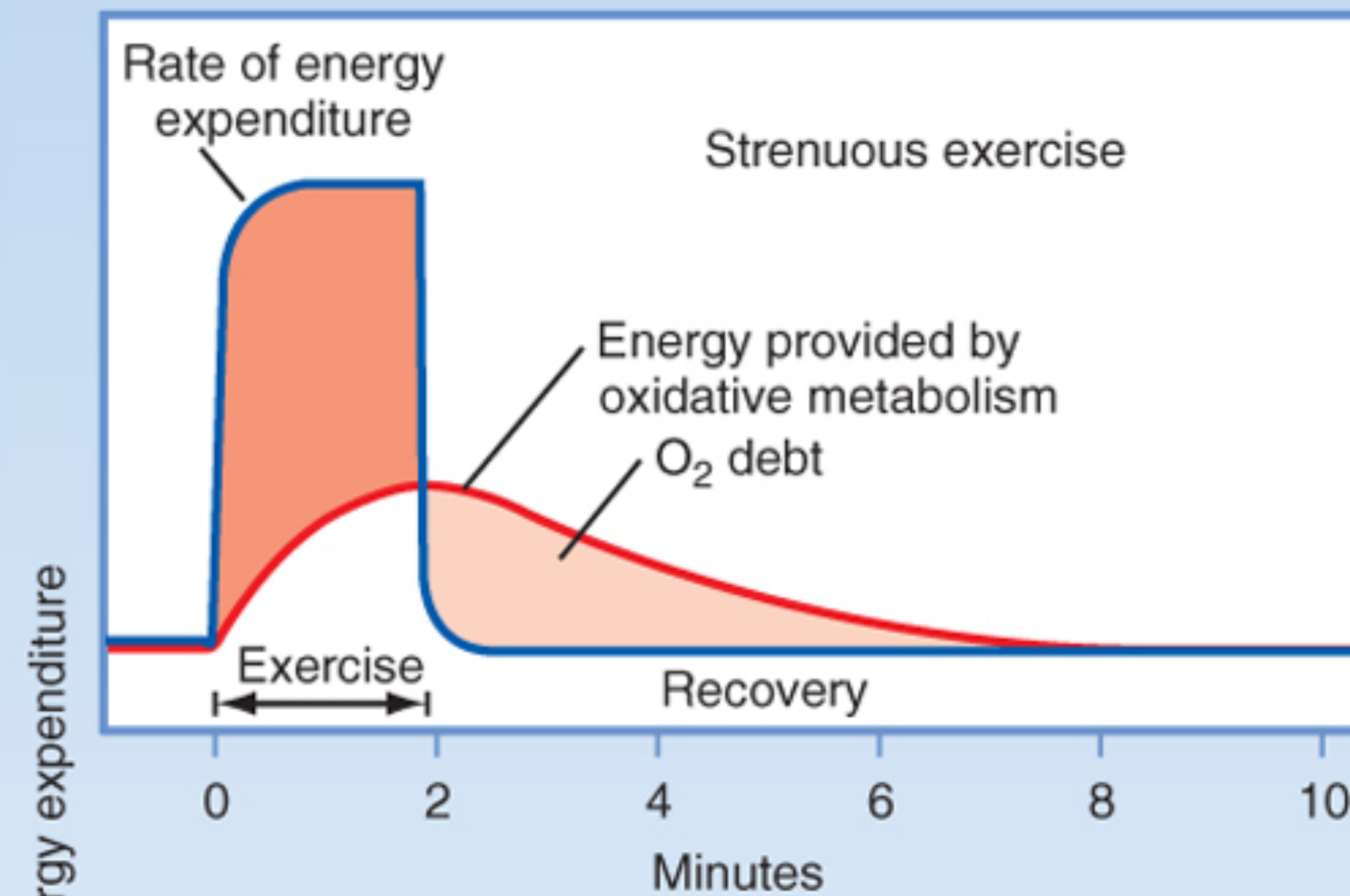


For very intense, short-term exercise (e.g., a 10- to 15-second sprint), stored creatine phosphate and ATP provide the energy at a rate of approximately 50 kcal/min. When these stores are depleted, additional intensive exercise for up to 2 minutes can be sustained by breakdown of muscle glycogen to G6P, with glycolysis yielding the necessary energy (at a rate of 30 kcal/min). **This anaerobic phase is not limited by depletion of muscle glycogen, but rather by the rapid accumulation of lactic acid in the exercising muscles and circulation.**

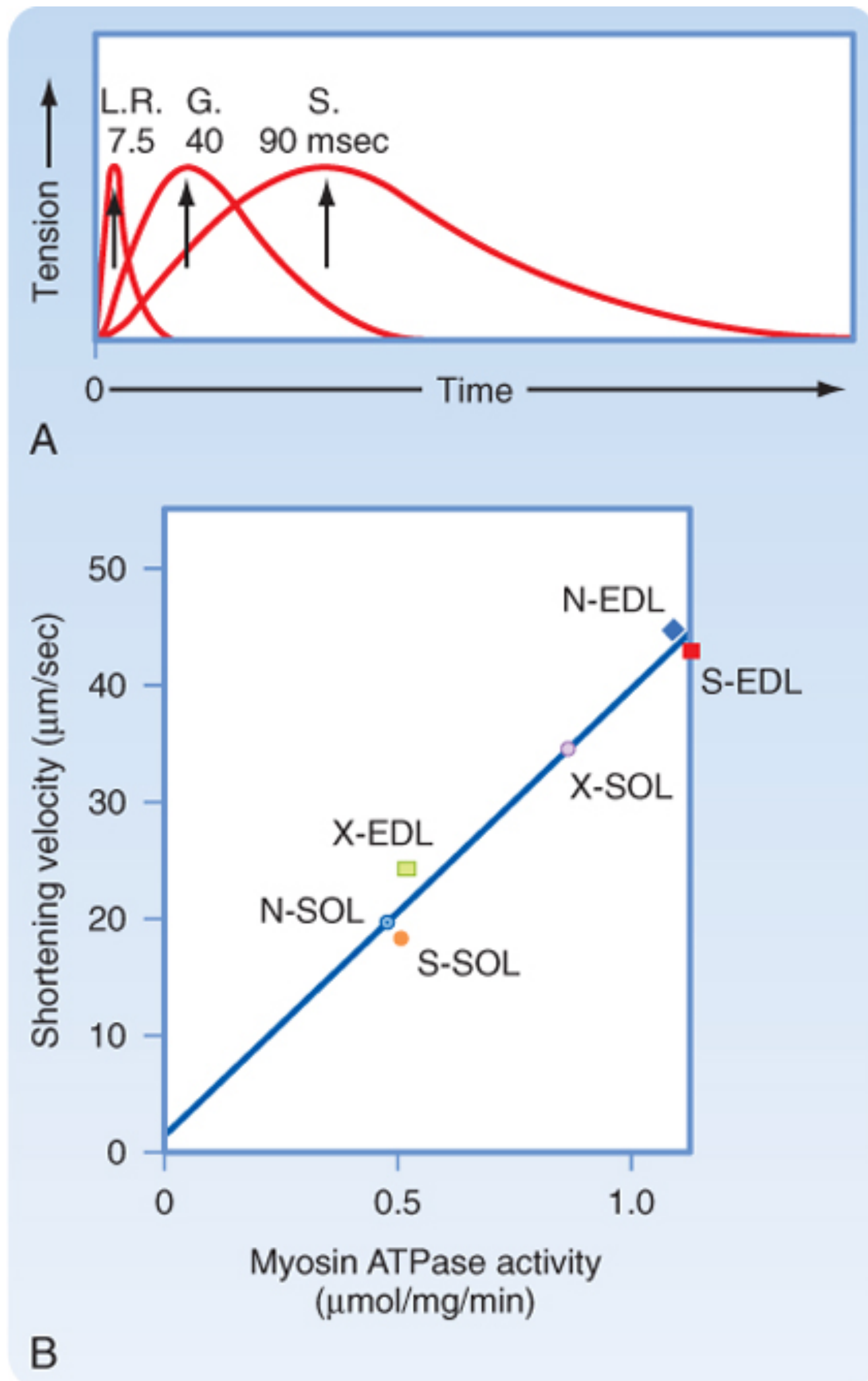
산소부채 (oxygen debt)

After completion of exercise, respiration remains above the resting level in order to "repay" this oxygen debt.

The extra oxygen consumption during this recovery phase is used to restore metabolite levels (such as creatine phosphate and ATP) and to metabolize the lactate generated by glycolysis



Muscles vary in terms of the speed of contraction -> 속근, 지근



G, gastrocnemius of the leg;
LR, lateral rectus muscle of the eye;
S, soleus muscle of the leg.

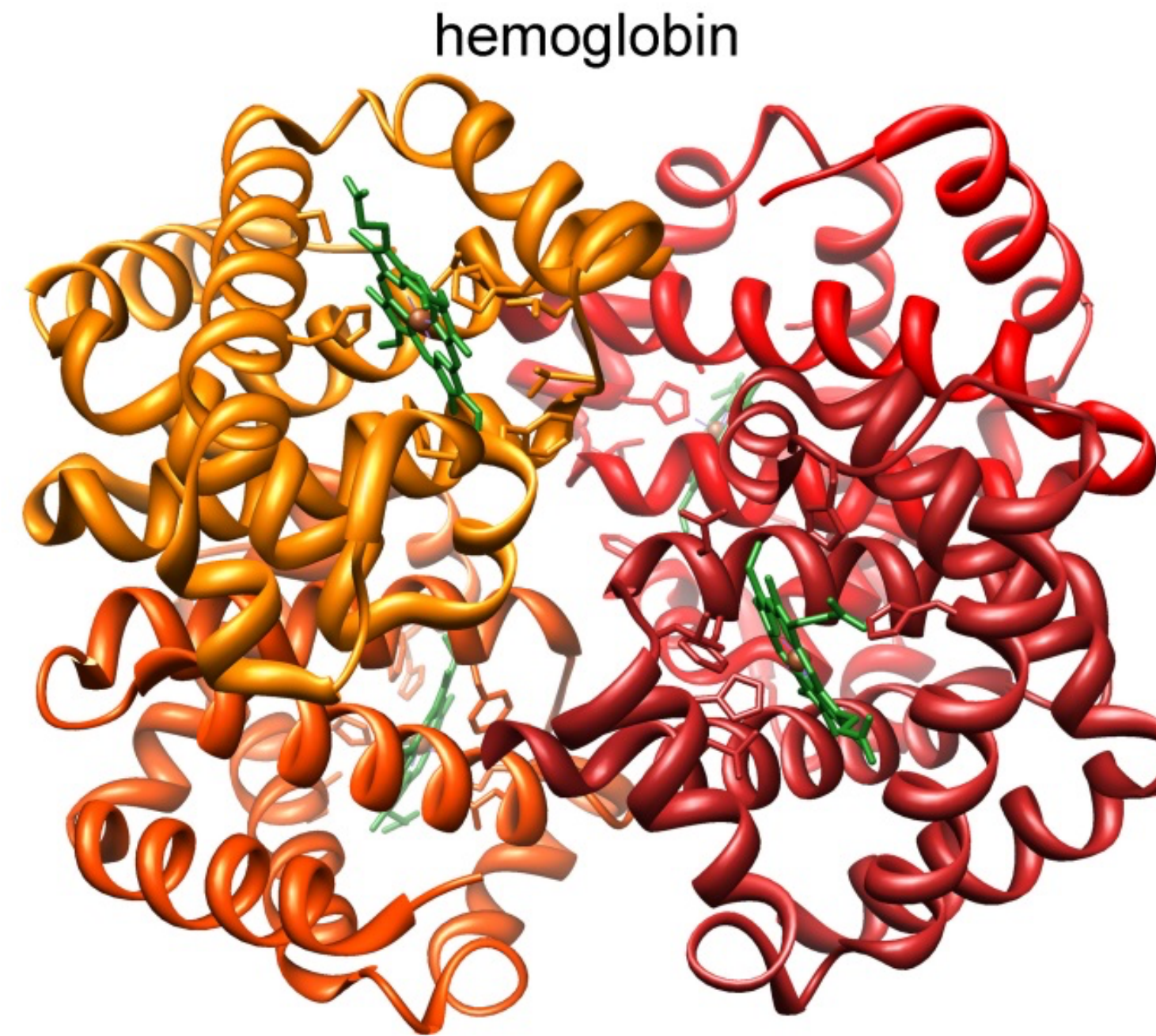
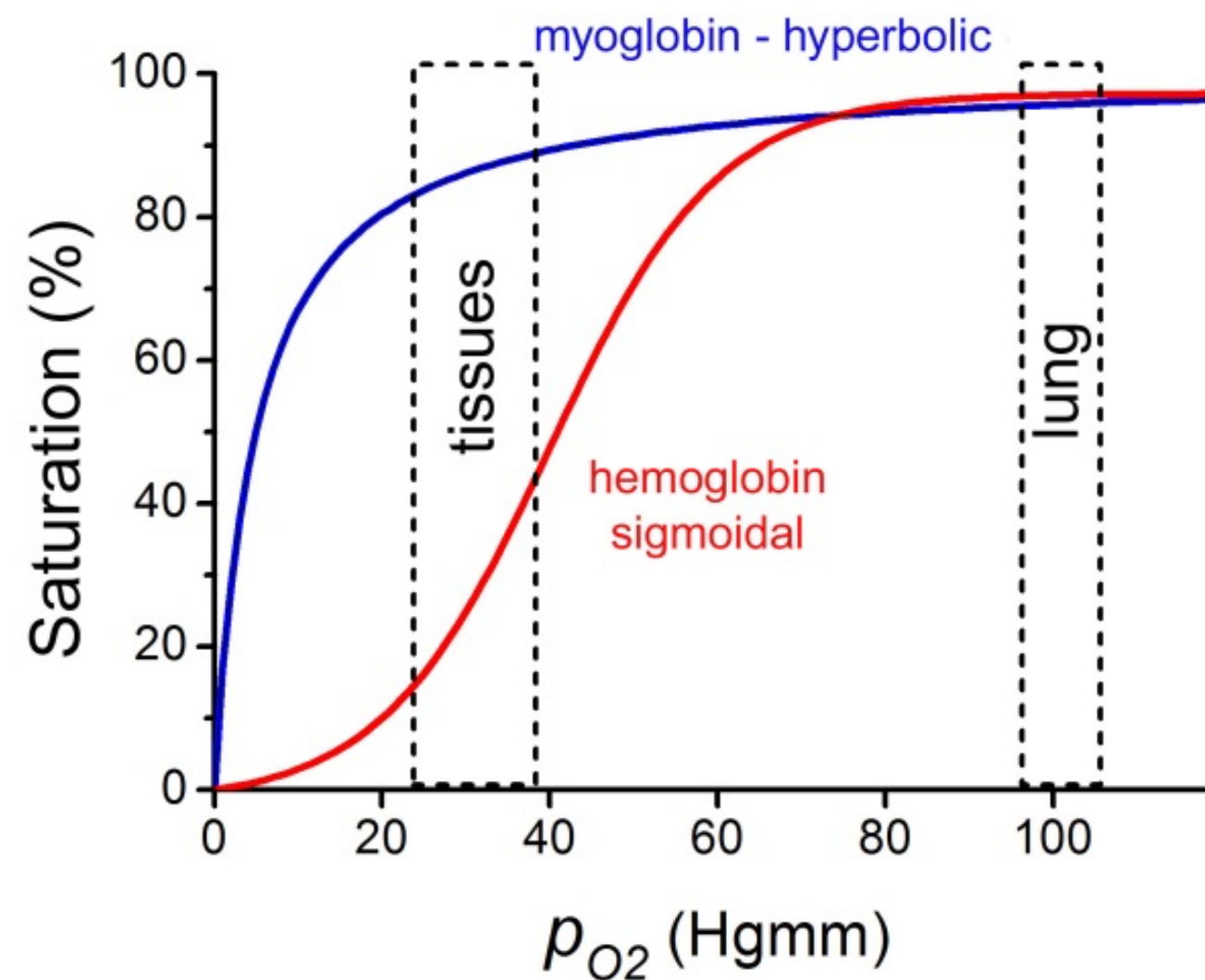
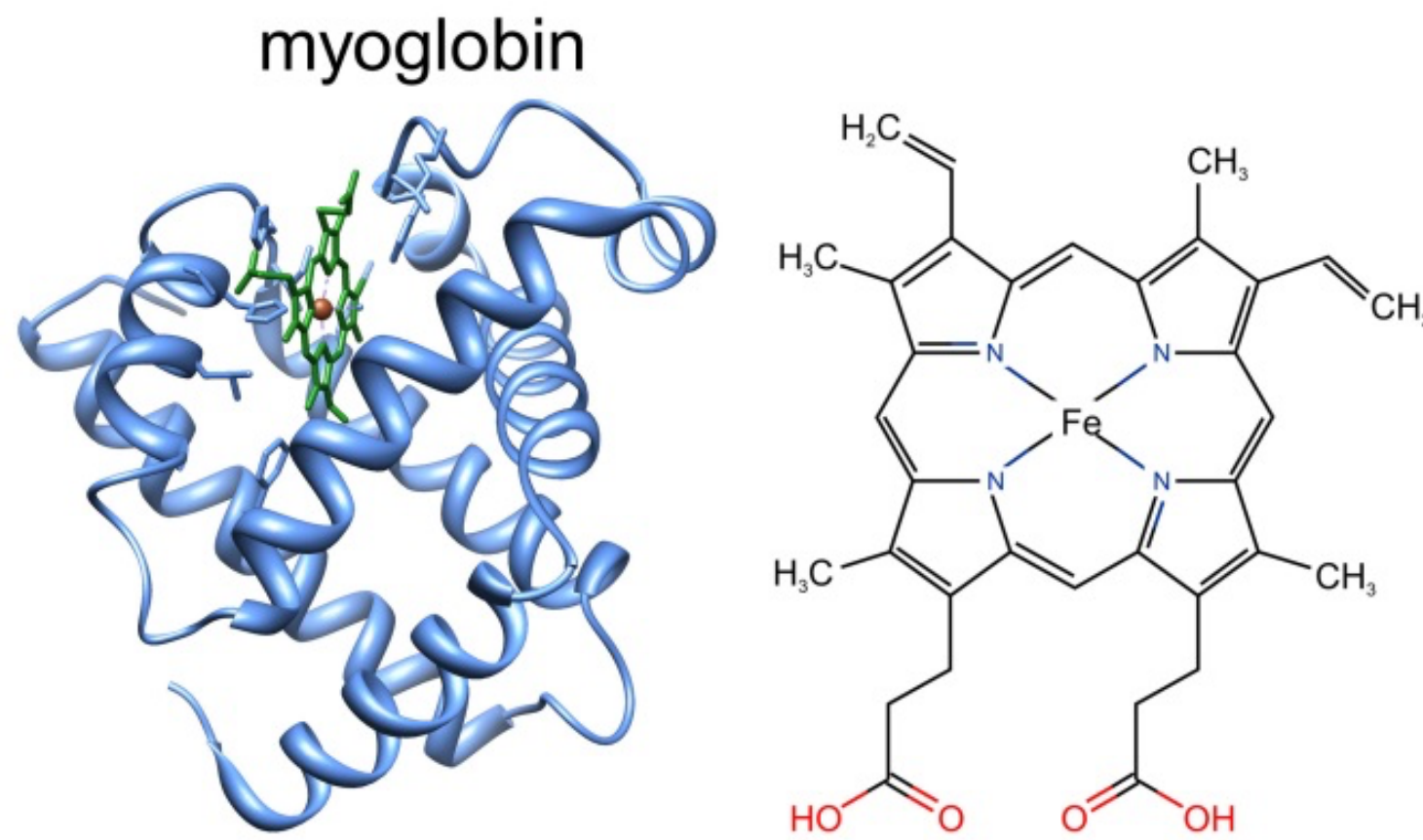
Slow and Fast Fibers

Table 9.4 Characteristics of Skeletal Muscle Fiber Types			
Characteristics	Slow-Twitch High-Oxidative Type I	Fast-Twitch Low-Oxidative Type IIa	Low-Oxidative Type IIx
Fiber diameter	Smallest	Intermediate	Largest
Myoglobin content	High -> '적근'	Intermediate	Low -> '백근'
Mitochondria	Many	Intermediate	Few
Capillaries	Many	Intermediate	Few
Metabolism	High aerobic capacity	Intermediate aerobic capacity	Low aerobic capacity
	Low anaerobic capacity	High anaerobic capacity	Highest anaerobic capacity
Fatigue	Resistant	Resistant	Not resistant
Rate of ATP breakdown by ATPase in myosin	Slow	Fast	Fast
Glycogen concentration	Low	High	High
Location where fibers are numerous (largely genetically determined)	Generally postural muscles and more in lower than upper limbs (e.g., in endurance athletes)	Can predominate in lower limbs (e.g., in athletes who are sprinters)	Upper limbs (more in upper than lower limbs and more in legs of athletes who are sprinters)
Functions	Endurance activities and posture	Endurance activities in endurance trained muscles	Rapid, intense movements of short duration

속근, 지근은 발생 단계에서 신경지배에 의해 결정됨

- Innervation of small motor axon -> type I (지근)
- Innervation of large motor axon -> type II (속근)

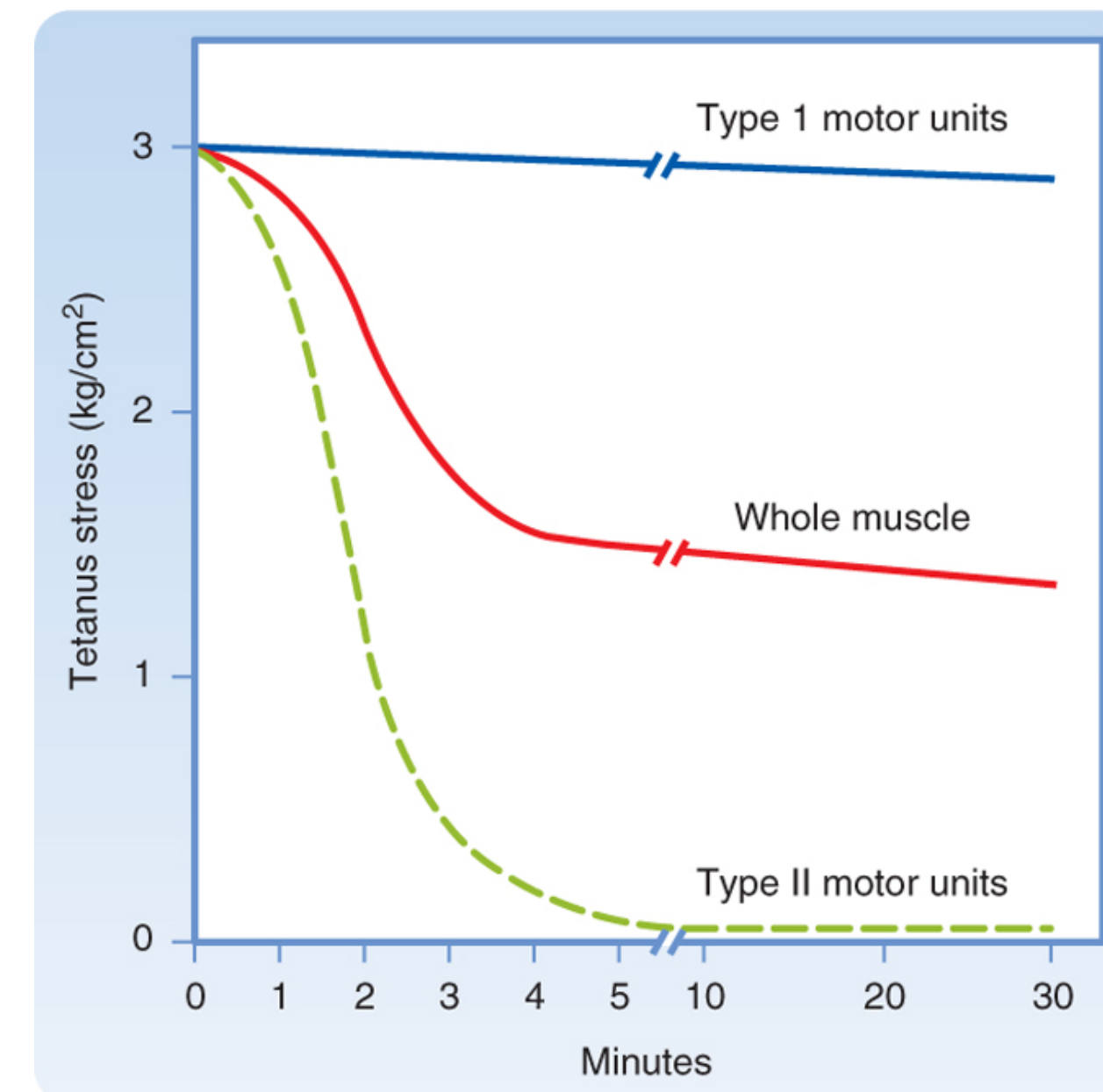
Myoglobin



- Hemoglobin and myoglobin transport oxygen; Hb is found in the blood and Mb is found in muscle tissue
- They both metalloproteins, containing iron at the center of a heme group
- Mb has much higher oxygen affinity at low P_{O_2}

근피로 (muscle fatigue)

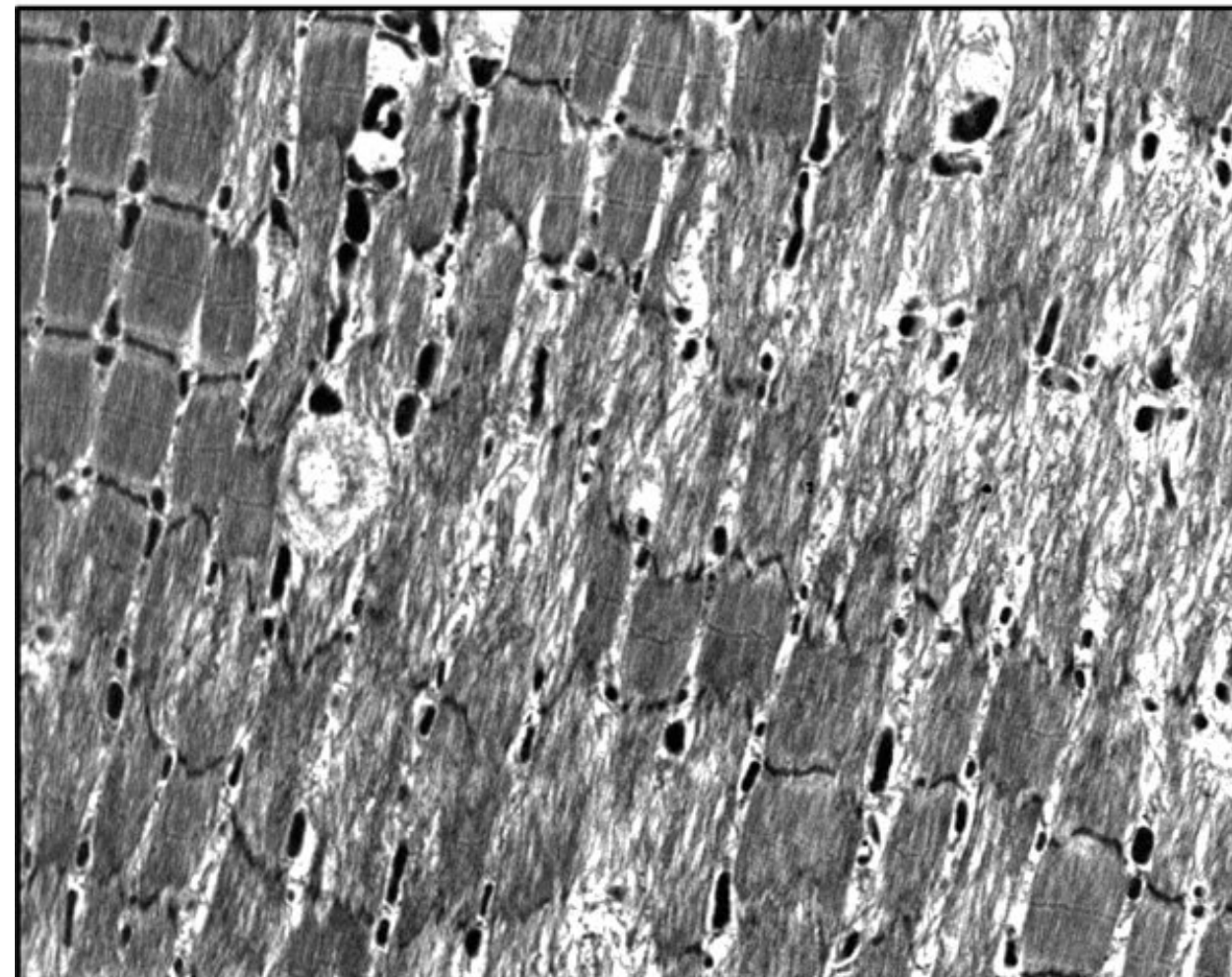
- Type 1 motor units(slow-twitch) are fatigue resistant.
- 직관적인 추측과 달리, not the result of depletion of energy stores. (근피로시 세포내 ATP 양이 현저한 수준으로 감소하지는 않음).
- 운동시 발생하는 metabolic byproducts가 중요한 유발 인자로 생각되고 있음. (lactic acid, phosphate 등)
- CNS 요인도 있음.
- ATP 가 치명적인 수준으로 감소되기 전에 보호기전이 작동하여 근피로를 유발하는 것.



DOMS (Delayed Onset Muscle Soreness)

- 근육 운동 이후 보통 24-48 hrs 이후 나타나는 근육의 통증
- 과거엔 젖산이 원인인 것으로 잘못 알려져있었으나, 현재는 젖산은 관련이 없는 것으로 믿어지고 있으며, 근섬유 미세구조의 손상과 회복과정에서의 다양한 기전들이 관련하는 것으로 추정되고 있으나 정확한 원인은 알려져있지 않음
- 평소 익숙치 않았던 운동을 할 경우 강하게 나타나며, 적응될수록 줄어들지만, 그렇다고 운동효과가 없어지는 것은 아님(근육의 성장과 DOMS의 상관성에 대한 근거는 없음)
- Concentric contraction보다 eccentric contraction에 의해 강하게 유발
- 폼롤러, 마사지 등이 통증 완화에 효과가 있는 것으로 보고되고 있음
- 운동을 처음 하거나, 오랜만에 하는 경우, 새로운 운동을 하는 경우 등엔 점진적으로 강도를 늘려나갈 수 있도록 매우 신경써야 함(생각보다 적은 운동량으로 심각한 DOMS, 심지어 Rhabdomyolysis가 발생할 수도 있다)

Exercised



Control

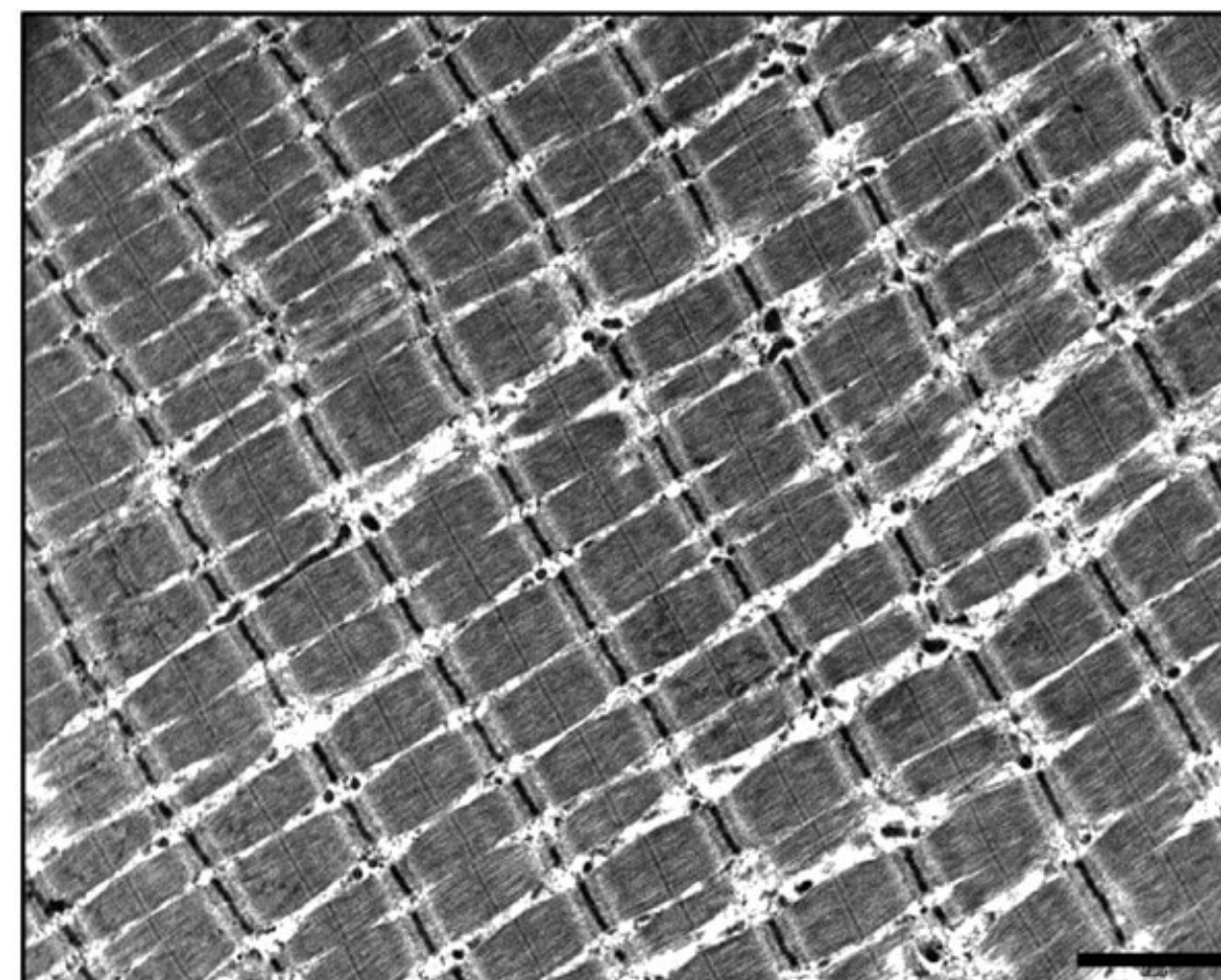
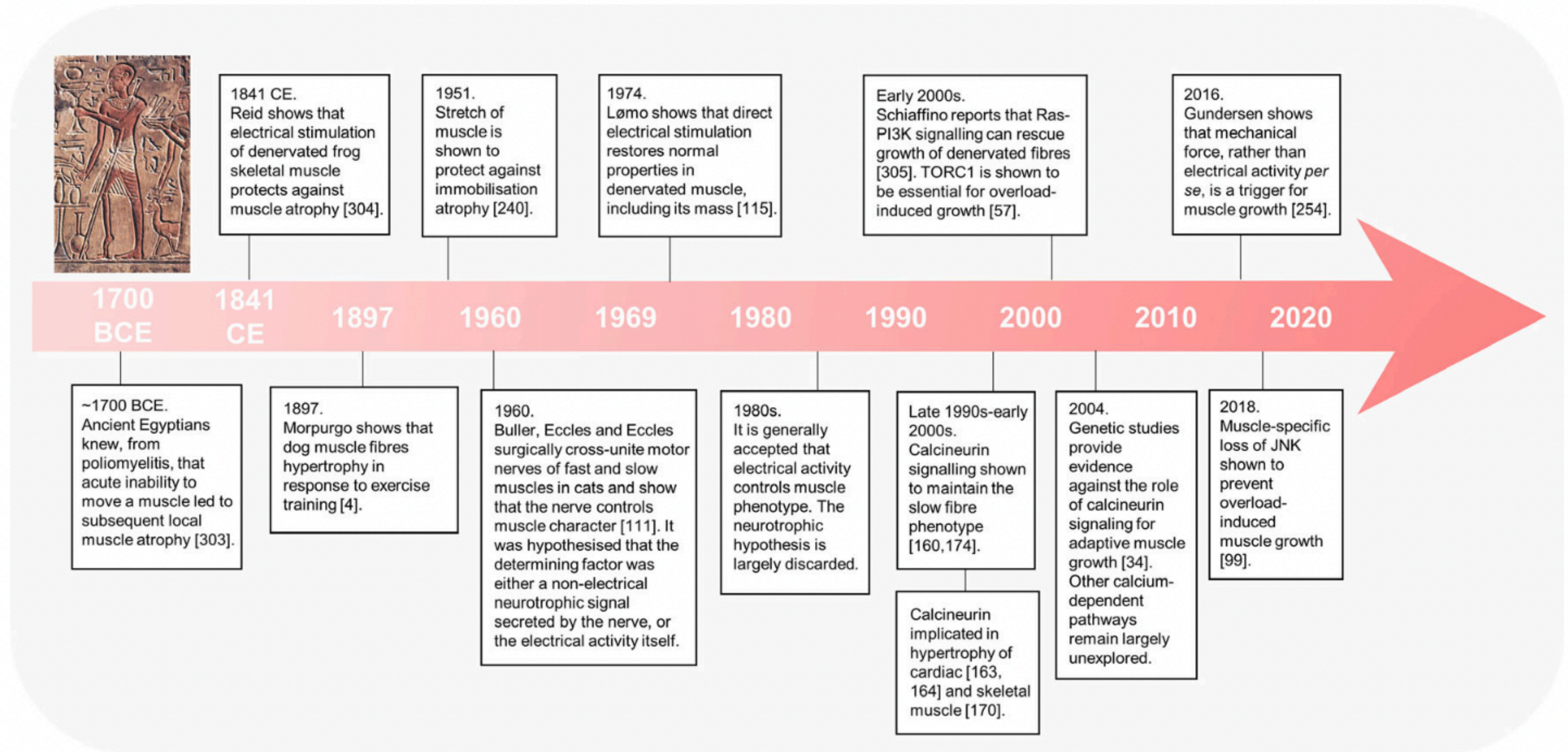
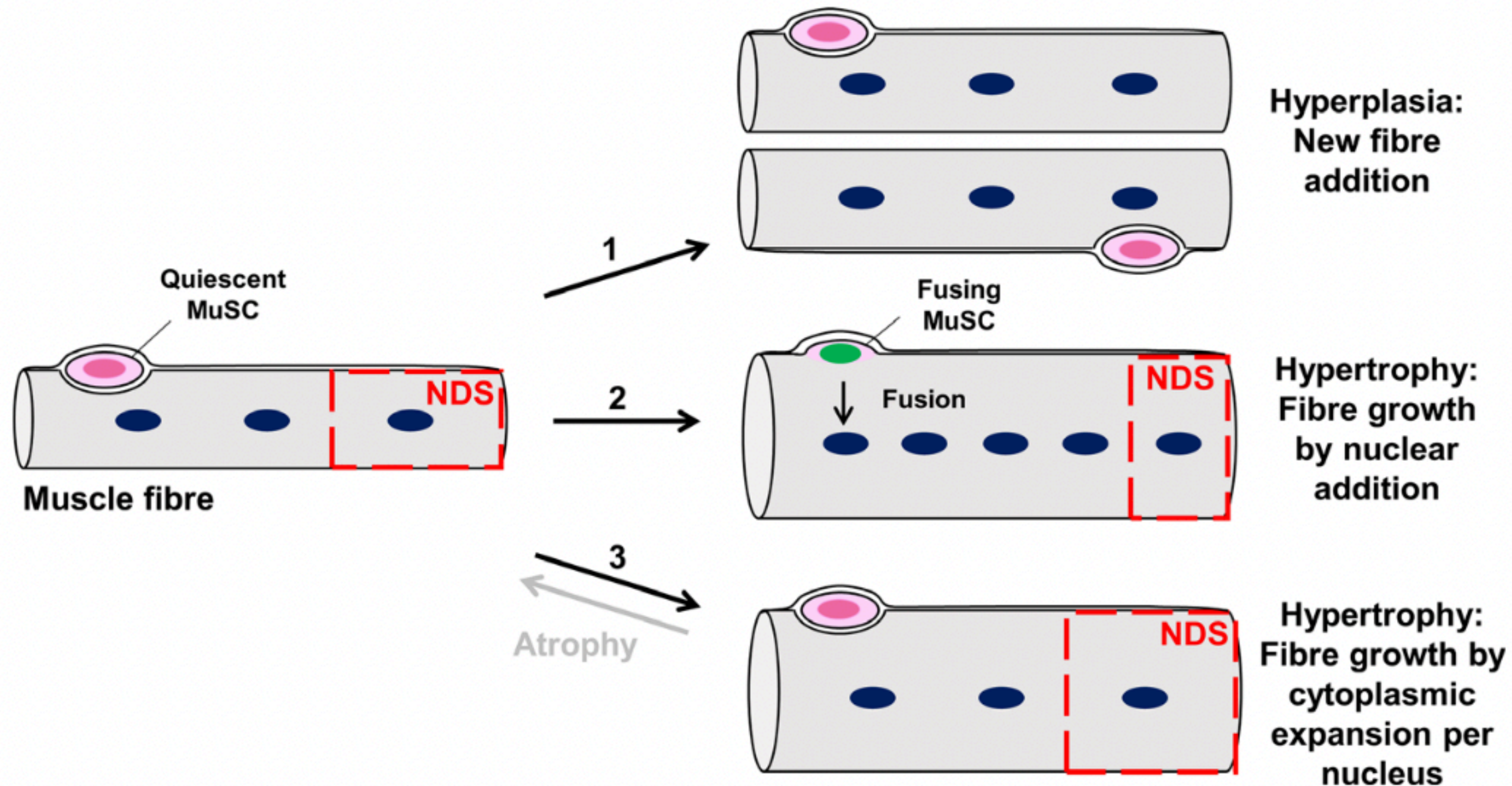


Image of muscle from an electron microscope after eccentric exercise. (<http://jap.physiology.org/content/107/2/570>)

Timeline of major studies that paved the way to current understanding of how physical activity controls muscle size



Distinct cellular processes in three modes of muscle growth.



근육성장과 수행능력, 건강

- 근육의 성장(근비대)과 근력증가는 밀접한 상호관련성이 있지만 반드시 비례하지는 않음
- 근력 및 운동수행능력은 근육비대 뿐 아니라 근신경계 및 인대와 건 조직의 종합적인 협응에 의해 발휘됨
- 체급경기이자 지구력이 중요한 격투기에선 동일한 근매스 대비 높은 수행능력이 좋지만, 근비대를 목적으로 고립운동에 보다 집중하는 보디빌더에게는 수행능력대비 더욱 큰 근육이 좋은 것 (관절과 인대, 건에 부담이 가는 고중량 운동은 그 자체가 목적이 아니라 근비대를 위한 수단일 뿐)
- 그러나 전문운동선수나 준선수급이 아닌 일반적인 생활체육단계에서 이러한 차이는 거의 두드러지지 않으며 건강적인 측면에서도 보디빌딩식 웨이트훈련을 폼하하는 것은 옳지 않음(상대적으로 유산소 운동이 부족한 경향이 있을수는 있음)
- 보디빌딩식 웨이트에 몰입하는 생활체육인들에게 가장 필요한 부분은 고중량 운동 욕심에 수반되는 부상에 대한 예방과 치료(특히 회복이 느린 인대와 건의 부상)

운동과 식사시간

- 가장 중요하고 확실한 사실: 가능하면 운동전 3-4시간 전부터는 식사를 피할 것(식후 소화시간과 근육운동이 겹치면 매우 비효율적)
- 아침 공복상태의 운동 이후 식사가 체지방 감소에 효과적이라는 연구결과가 널리 알려져있음
- 근력운동 직후 ‘기회의 창’에 단백질을 섭취해야 한다는 오래된 믿음은 근거가 없으며, 운동생리학 연구결과들과 맞지 않음(근력 운동후 단백질합성이 증가하는 기간은 상당히 길다)
- 간과 근육에 글리코겐이 부족한 공복상태에서 근력운동시 이론적으로 당신생이 작용하여 근손실 유발 가능성이 있음. 아침운동과 같이 피할수 없는 경우라면(아침운동 3시간 전 식사는 불가능하므로) 소화에 부담이 덜한 액상형태로 탄수화물 섭취(꿀, 스포츠 음료등)
- 운동전 단백질섭취가 근육합성에 도움이 된다는 연구결과도 존재. 역시 아침운동과 같이 피할수 없는 경우라면 액상형태로 단백질 섭취
- 고강도의 운동 이후엔 전략적으로 흡수가 빠른 단당류나 흰쌀밥 등을 섭취할 수도