King Saud University
College of Sciences
Biochemistry Department

الأيض (١)
Metabolism (1)
BCH 340

Lecture 10: Lipolysis in adipose tissues

Intended learning outcomes (ILOs)

By the end of this lesson, students will be able to:

- Define the various forms of fat storage in the human body.
- Explain the process of lipolysis, including the role of hormones in regulating this process.
- Explore the process of free fatty acid re-esterification.

Forms of fat storage in the body

- Adipose tissue (commonly known as body fat) can be categorized into two main types based on its location and function.

1. Tissue lipids:

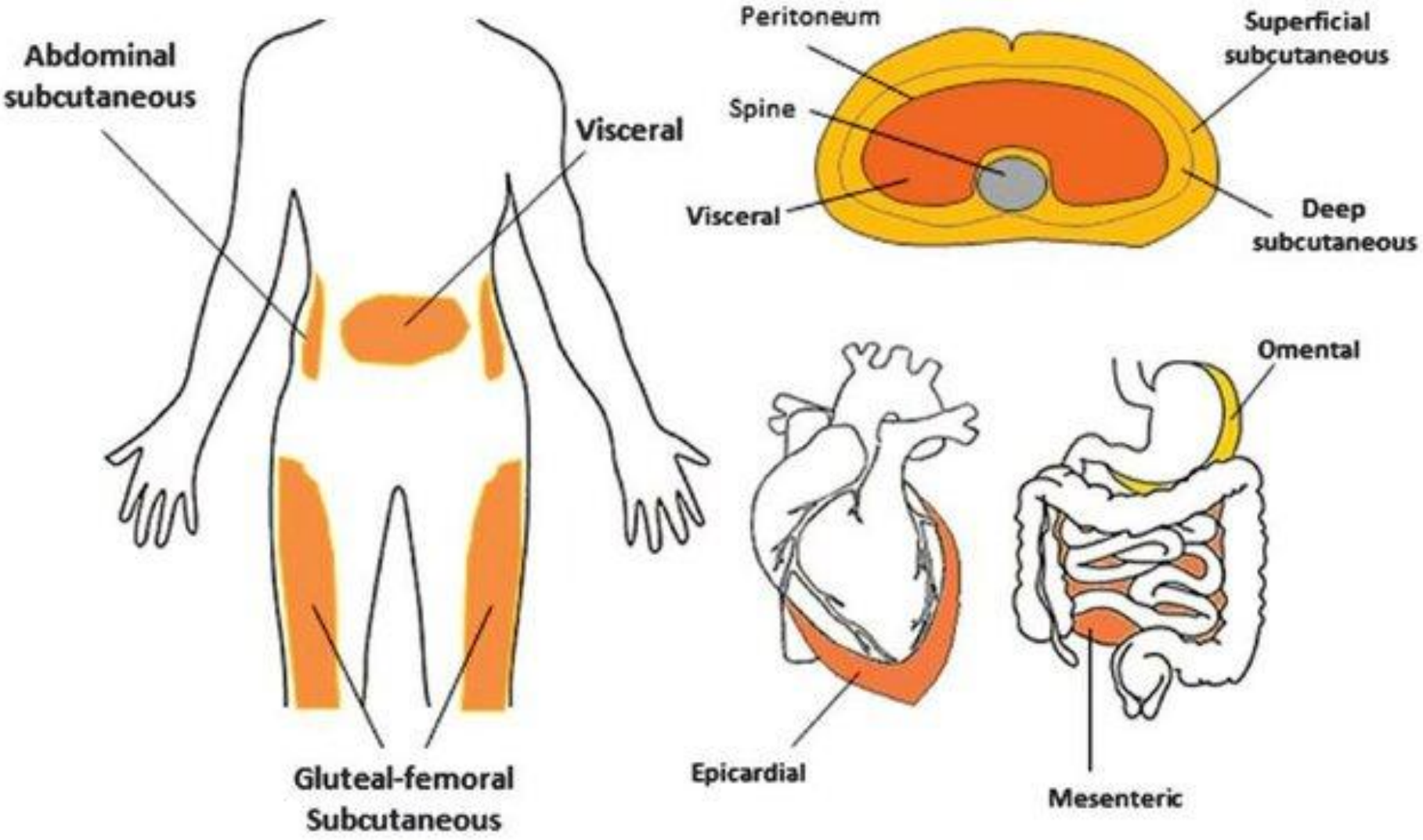
- Tissue lipids refer to the fats that are stored within various tissues of the body, such as muscle tissue and organ tissue.
- These lipids are primarily used for local energy production within the specific tissue where they are stored.
- Tissue lipids play important roles in cellular function, serving as sources of structural components for cell membranes.

Forms of fat storage in the body (cont.)

2. Depot Fat:

- Depot fat (body fat) specifically refers to the fat stored in adipose tissue, which acts as a reserve for energy in times of need.
- It is stored beneath the skin (subcutaneous fat) and around internal organs (visceral fat).
- The primary function of depot fat is to store excess energy in the form of triglycerides, which can be mobilized and used by the body during times of energy deficit.
- It also serves as insulation to help regulate body temperature and provides cushioning and protection for organs.

Distribution of adipose tissue depots in humans



Forms of fat storage in the body (cont.)

2. Depot Fat (cont.):

- Adipocytes are the primary cells found in adipose tissue throughout the body that store fat in the form of triglycerides and release it when needed for energy.

- **Fat stored in the adipocytes:**
  - Triglycerides are the most abundant lipid molecules in depot fat.
  - Free fatty acids (they can be produced and released into the bloodstream through a process called lipolysis).
  - Phospholipids and cholesterol (in small amounts).

White and brown adipocytes

- White and brown adipocytes are two types of fat cells found in the body, each with distinct functions and characteristics.

White adipocytes:

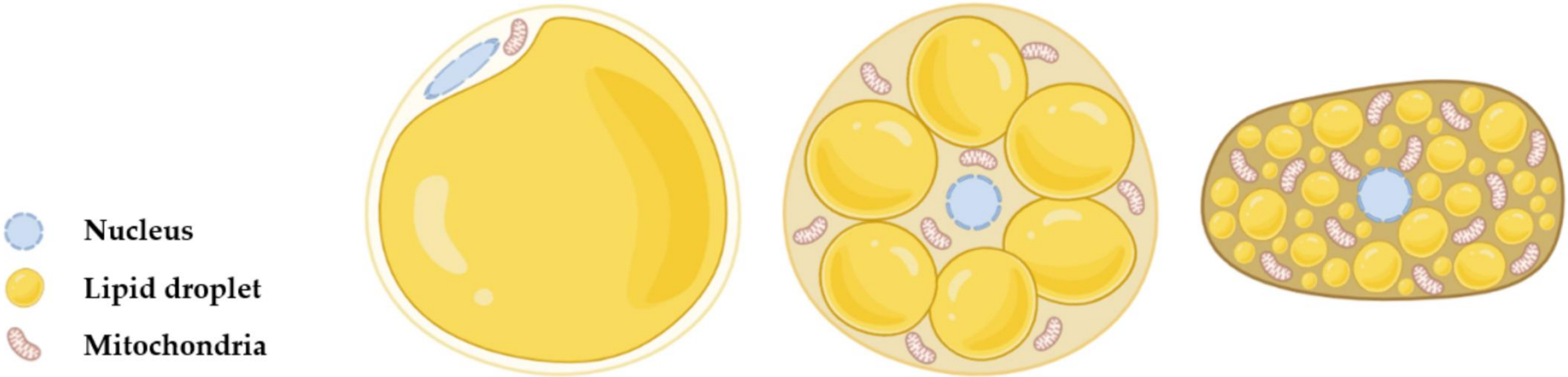
- These are the most common type of fat cells found in the body.
- White adipocytes store energy in the form of triglycerides.
- They are also involved in insulation, cushioning of organs, and hormone production.
- Excessive accumulation of white adipose tissue is associated with obesity and related metabolic disorders such as type 2 diabetes and cardiovascular diseases.

White and brown adipocytes (cont.)

Brown adipocytes :

- Brown adipocytes contain a higher number of mitochondria and iron compared to white adipocytes, which gives them their characteristic brown color.
- They are specialized in generating heat through a process called thermogenesis, which helps in maintaining body temperature.
- Brown adipose tissue is more abundant in infants and gradually decreases with age, although small deposits persist in specific regions in adults.
- Activation of brown adipose tissue can increase energy expenditure and may have implications for weight management burning excess calories.

Characteristics of white, beige, and brown adipocytes



	White adipocyte	Beige/brite adipocyte	Brown adipocyte
UCP1 expression	Negative	Positive	Positive
Mitochondria density	Low	Medium	High
LD morphology	One large lipid droplet	Small multiple droplet	Small multiple droplet
Function	Store excess energy as fat	Heat generation	Heat generation

Lipid metabolism in adipose tissue

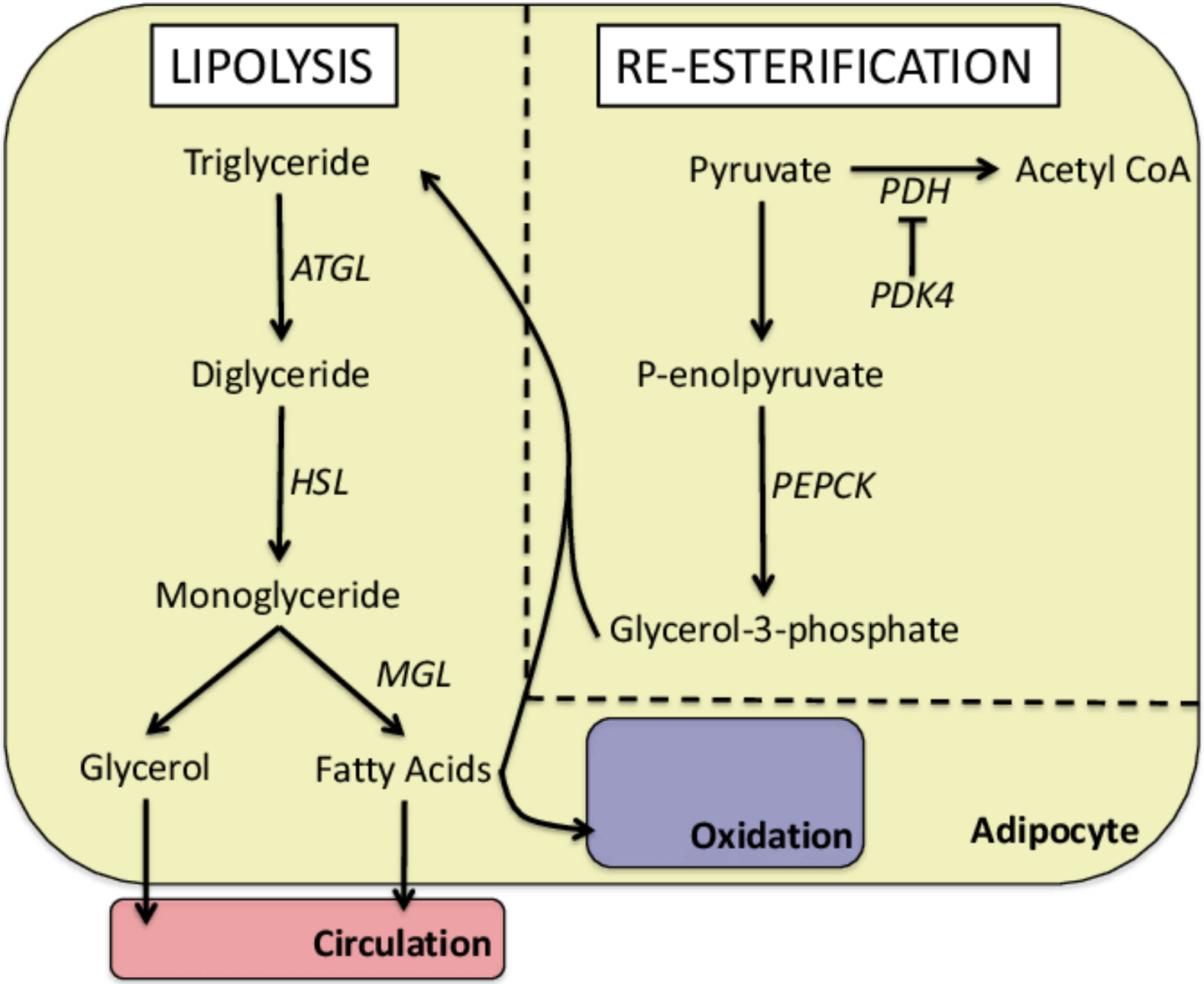
- Lipid metabolism in adipose tissue plays a crucial role in energy homeostasis and overall metabolic balance.
- Adipose tissue is primarily responsible for storing excess energy in the form of triglycerides and releasing it when needed.
- Key processes involved in lipid metabolism in adipose tissue include:
  - Lipolysis
  - Lipogenesis
  - Triglyceride synthesis and storage
  - Fatty acid oxidation
  - Adipokine secretion

Lipolysis

- Lipolysis is the process of breaking down triglycerides into fatty acids and glycerol for energy production.
- During times of energy deficit, such as fasting or exercise, hormones like epinephrine and norepinephrine activate lipolysis in adipose tissue.
- Lipolysis is primarily catalyzed by hormone-sensitive lipase (HSL) and adipose triglyceride lipase (ATGL), which are activated in response to hormonal signals.
- Once activated, lipases break down triglycerides stored in fat cells (adipocytes) into fatty acids and glycerol. These breakdown products are then released into the bloodstream.

Lipolysis (cont.)

- Fatty acids released from adipocytes bind to carrier proteins in the bloodstream (such as albumin) for transport to various tissues throughout the body.
- Fatty acids are taken up by tissues (such as muscle, liver, and heart) where they can be oxidized for energy through a process called β-oxidation.
- Glycerol is taken up by the liver, where it undergoes conversion into glucose through gluconeogenesis. This glucose can then be used as an energy source by various tissues in the body.


LIPOLYSIS
RE-ESTERIFICATION
Triglyceride
ATGL
Diglyceride
HSL
Monoglyceride
MGL
Glycerol
Fatty Acids
Pyruvate
PDH
Acetyl CoA
PDK4
P-enolpyruvate
PEPCK
Glycerol-3-phosphate
Oxidation
Adipocyte
Circulation

Regulation of lipolysis

- Lipolysis is crucial for energy production, hormone regulation, and various metabolic functions. Several hormones regulate lipolysis, they include:

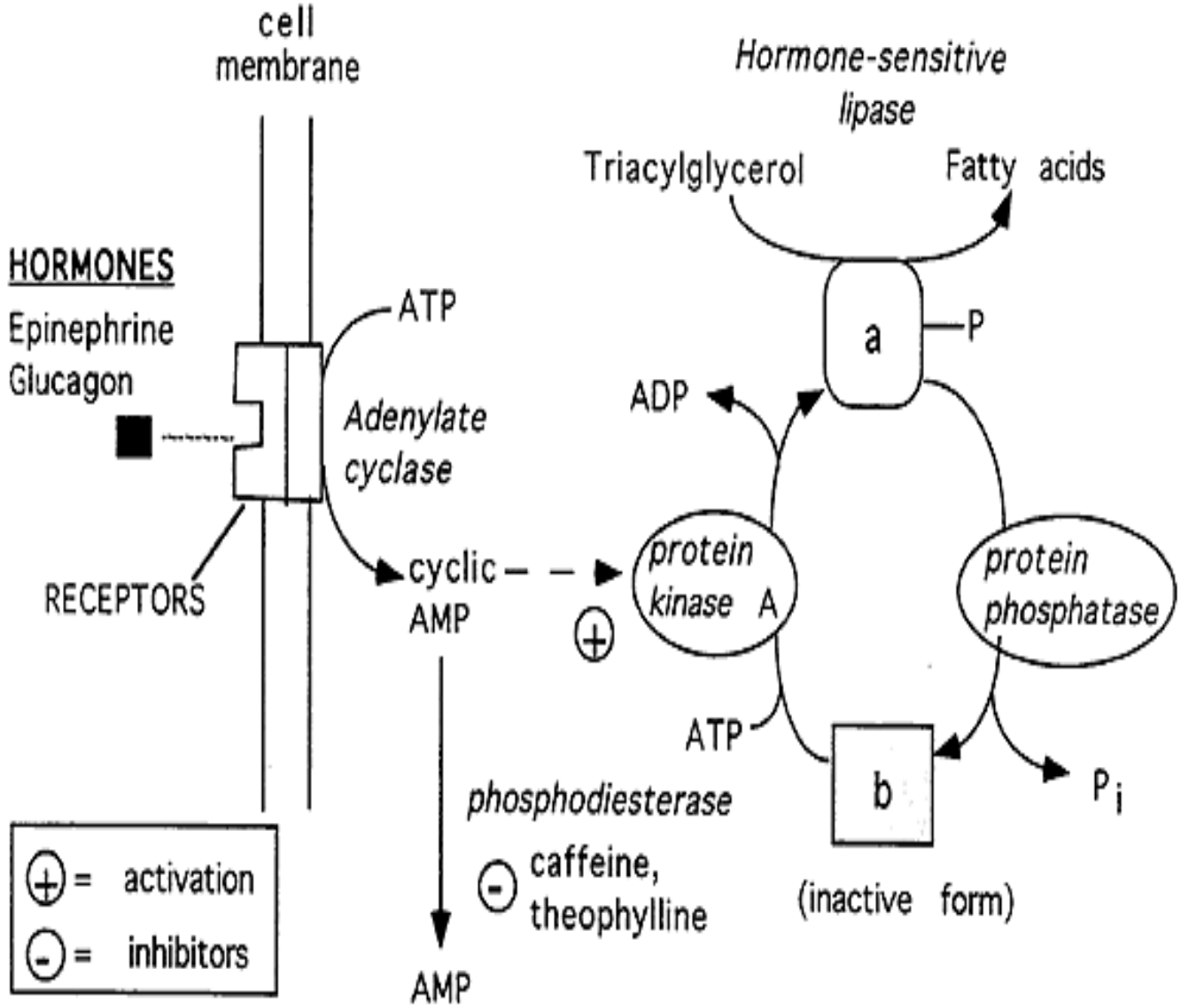
- During stress, adrenaline and noradrenaline stimulate lipolysis by activating adenylate cyclase, which increases cyclic AMP (cAMP) levels and activates hormone-sensitive lipase (HSL).

- In the fed state, insulin inhibits lipolysis by activating phosphodiesterase, which decreases cAMP levels, thereby suppressing HSL activity and triglyceride breakdown.

- During fasting, glucagon promotes lipolysis by activating adenylate cyclase, increasing cAMP, and stimulating HSL activity.

- Cortisol activates lipolysis indirectly by increasing adipocyte sensitivity to adrenaline and noradrenaline.

Regulation of lipolysis

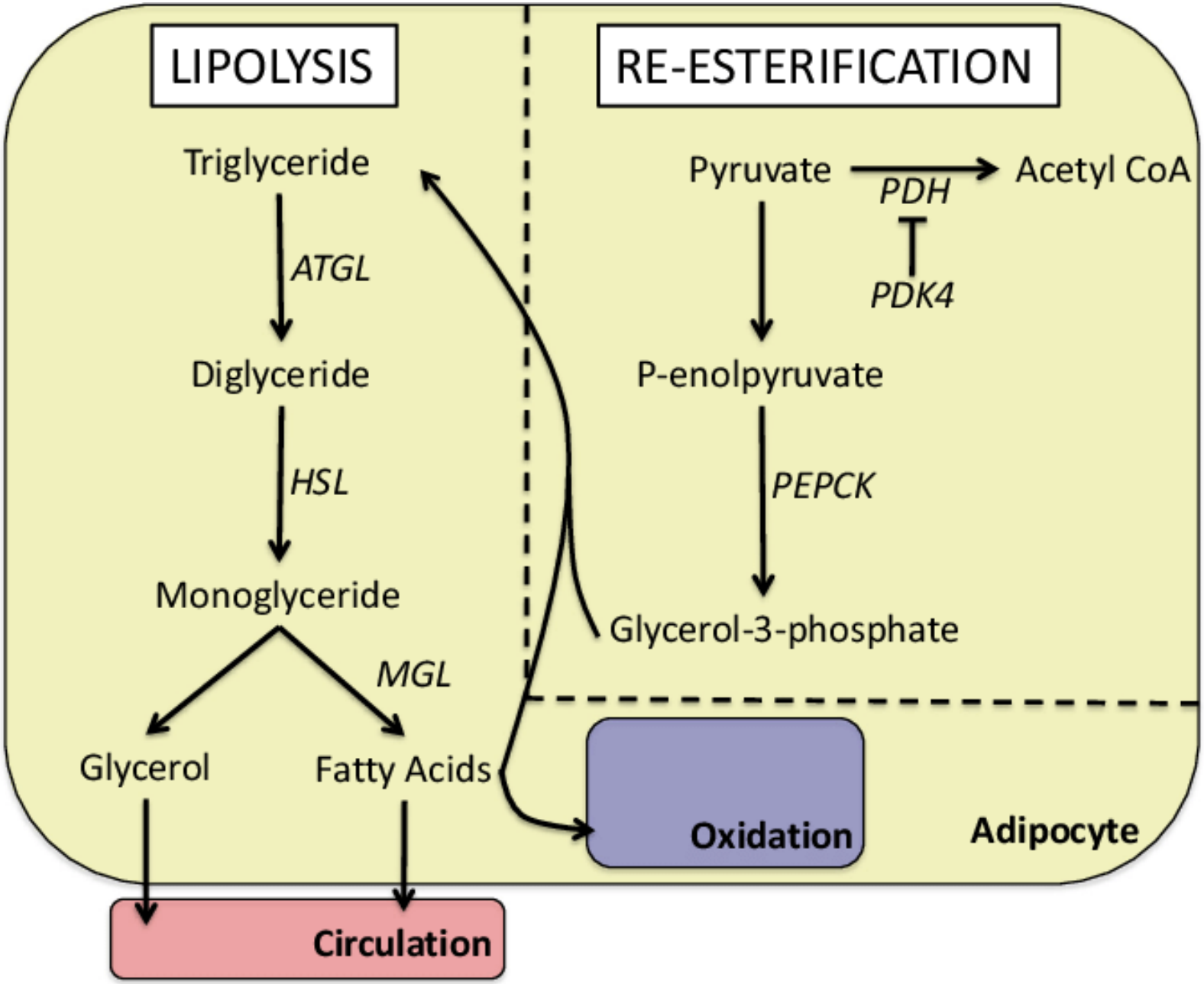


Excessive lipolysis

- Excessive lipolysis can occur due to various factors, both physiological and pathological. These factors include:
  - Stress
  - Fasting (or caloric restriction)
  - During growth
  - Exercise
  - Diabetes
  - Certain infectious diseases
  - Hormonal imbalance

Free fatty acid re-esterification

- After released during lipolysis, free fatty acids can be reassembled back into triglycerides through a process called fatty acid re-esterification.
- This typically occurs in the liver and adipose tissue.
- This process allows excess energy to be stored as triglycerides for future use, helping to maintain overall energy balance.
- When the rate of lipolysis exceeds that of re-esterification, free fatty acids bind to serum albumin and are transported to tissues such as muscle or liver for oxidation.
- The balance between lipolysis and fatty acid re-esterification determines the size of the free fatty acid pool in adipose tissue, which in turn influences the level of circulating FFAs in plasma.


LIPOLYSIS
RE-ESTERIFICATION
Triglyceride
ATGL
Diglyceride
HSL
Monoglyceride
MGL
Glycerol
Fatty Acids
Pyruvate
PDH
Acetyl CoA
PDK4
P-enolpyruvate
PEPCK
Glycerol-3-phosphate
Oxidation
Adipocyte
Circulation

Fatty acid pools in adipose tissue

- The overall term "fatty acid pool" refers to the collective reservoir of free fatty acids stored within adipocytes.
- These pools have distinct characteristics and functions. They can be categorized as following:

Fatty Acid Pool 1 (FAP1):

- The free fatty acids in this pool is primarily formed by the process of lipolysis, which involves the hydrolysis of triglycerides stored within adipocytes by the enzyme hormone-sensitive lipase (HSL).
- Once released from adipocytes, these free fatty acids can be:
  - Re-esterified within adipose tissue
  - Release into plasma

Fatty acid pools in adipose tissue (cont.)

Fatty Acid Pool 2 (FAP2):

- Fatty acids present in this pool are primarily derived from the hydrolysis of triglycerides found in circulating lipoproteins such as chylomicrons and very low-density lipoproteins (VLDLs).
  - The action of the enzyme lipoprotein lipase facilitates the release of fatty acids from these circulating lipoproteins, allowing them to be taken up by adipose tissue for storage or utilization.

- Fatty acids in pool 2 can reconverted to acyl-CoA and re-esterified within adipose tissue or may be oxidized to give energy.

Summary

- Adipose tissue stores energy in the form of triglycerides in white adipocytes and generates heat in brown adipocytes.

- Triglycerides are broken down into free fatty acids and glycerol during energy deficit; hormones like adrenaline and noradrenaline, insulin, glucagon, and cortisol tightly regulate this process.

- Released fatty acids can be reassembled into triglycerides or transported to other tissues for oxidation; the balance between lipolysis and re-esterification determines circulating FFA levels and energy homeostasis.