Glycogen Metabolism

Clinical Chemistry Unit
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Objectives:

By the end of this lecture, students should be familiar with:

1. **The need to store carbohydrates in muscle**
2. **The reason for carbohydrates to be stored as glycogen**
3. **An overview of glycogen synthesis (Glycogenesis)**
4. **An overview of glycogen breakdown (Glycogenolysis)**
5. **Key elements in regulation of both Glycogenesis and Glycogenolysis**

Location & Functions of Glycogen

Location of glycogen in the body

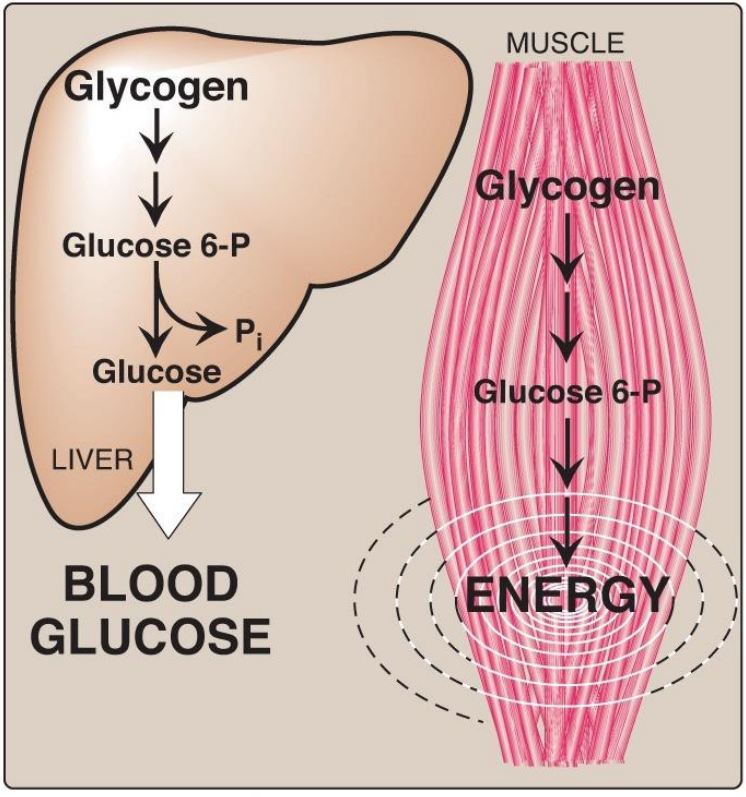
skeletal muscle & liver:

- 400 g in muscles (1-2% of resting muscles weight)
- 100 g in liver (~ 10% of well-fed liver)

Functions of glycogen:

Function of muscle glycogen: Fuel reserve (ATP) (during muscular exercise)

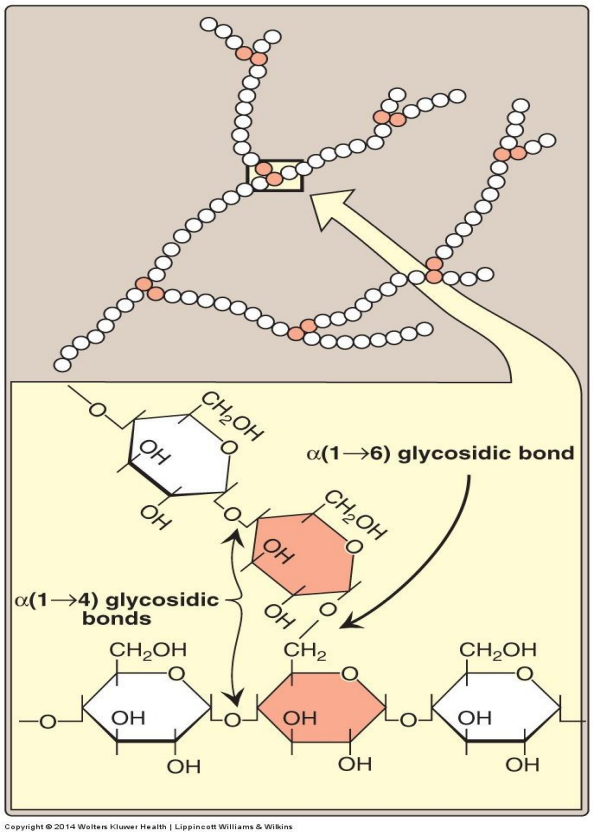
Function of liver glycogen: a source for blood glucose (especially during early stages of fasting)

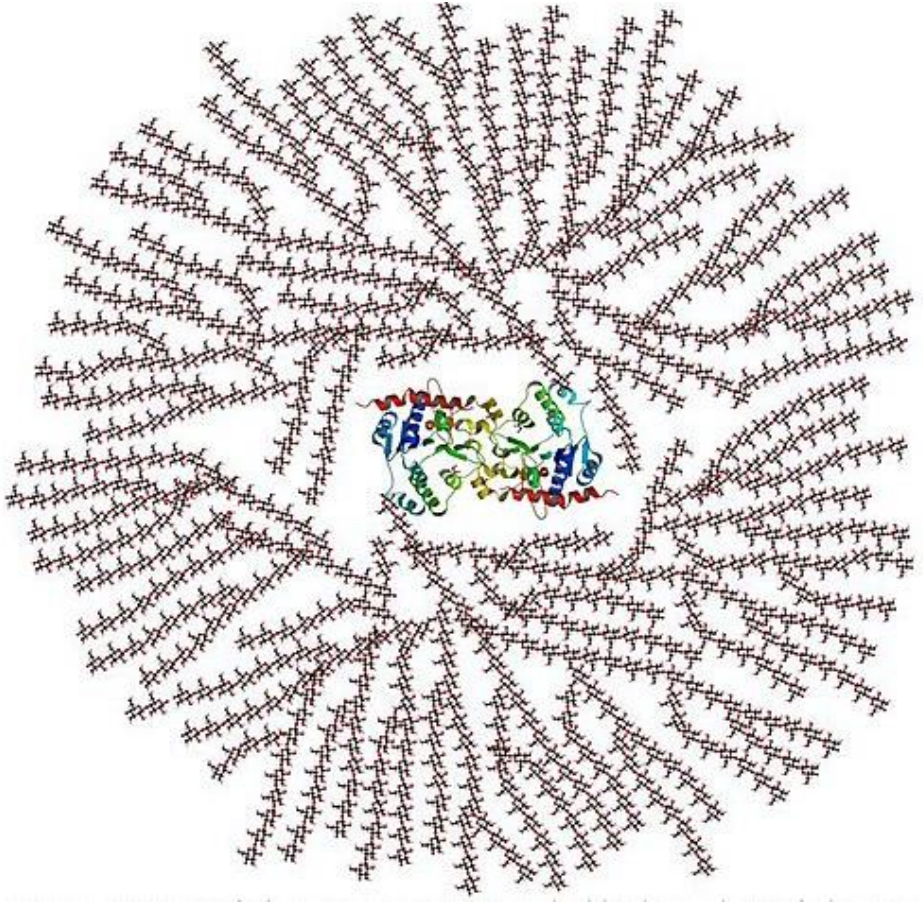


Structure of Glycogen

- **Glycogen is a branched-chain homopolysaccharide made exclusively from α- D-glucose**
- **Glucose residues are bound by α (1 - 4) glycosidic linkage**
- **Branches (every 8-10 residues) are linked by α(1-6) glycosidic linkage**
- **Glycogen is present in the cytoplasm in the form of granules which contain most of the enzymes necessary for glycogen synthesis & degradation**

Structure of Glycogen





Metabolism of Glycogen in Skeletal Muscle

Glycogenesis:

Synthesis of Glycogen from Glucose

Glycogenolysis:

Breakdown of Glycogen to Glucose-6-phosphate

GLYCOGENESIS

(*Synthesis* of Glycogen in Skeletal Muscles)

1- Building blocks: UDP-GLUCOSE

2- Initiation of synthesis:

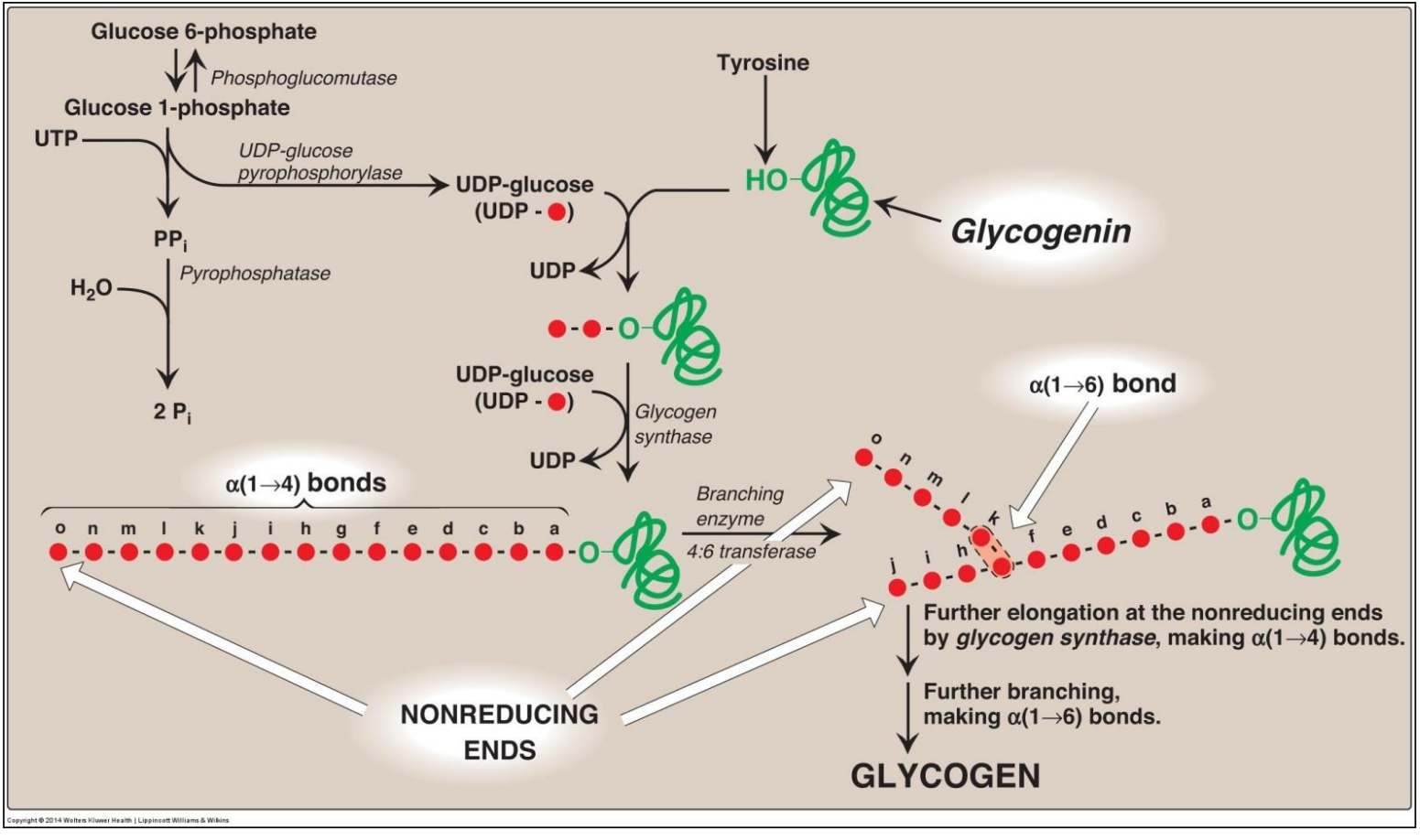
Elongation of pre-existing glycogen fragment
OR
The use of glycogen primer (glycogenin)

3- ELONGATION: Glycogen synthase (for α1-4 linkages)

Glycogen synthase **cannot** initiate synthesis but only elongates pre-existing glycogen fragment or glycogen primer (glycogenin)

4- BRANCHING: Branching enzyme (for α1-6 linkages)

Synthesis of Glycogen



Glycogenolysis

(Breakdown of glycogen in skeletal muscles)

1- **Shortening of glycogen chain:** by **glycogen phosphorylase**

-Cleaving of α(1-4) bonds of the glycogen chain producing glucose 1-phosphate

-Glucose 1-phosphate is converted to **glucose 6-phosphate** (by mutase enzyme)

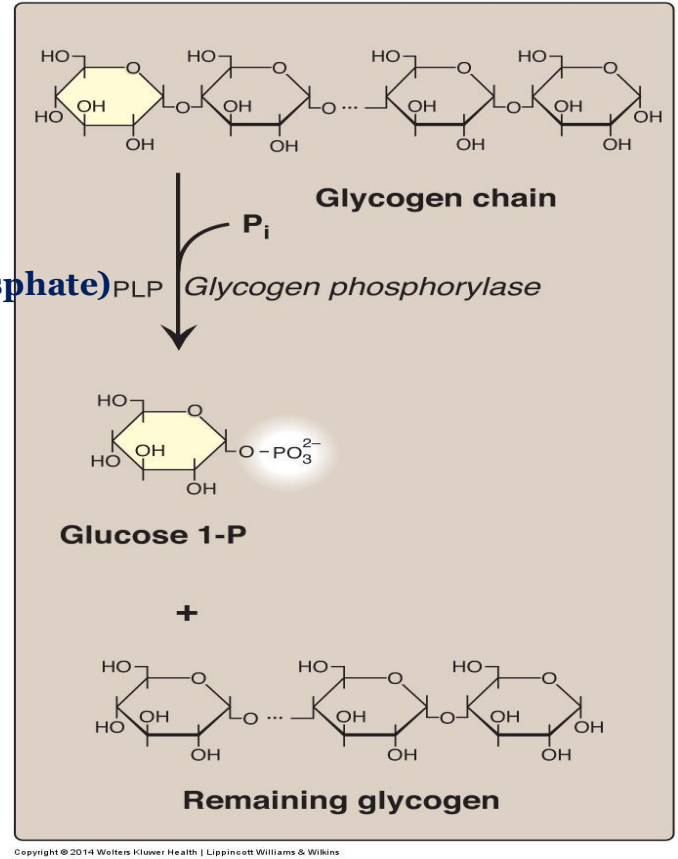
2- Removal of branches : by **debranching enzymes**

Cleaving of α(1-6) bonds of the glycogen chain producing **free glucose (few)**

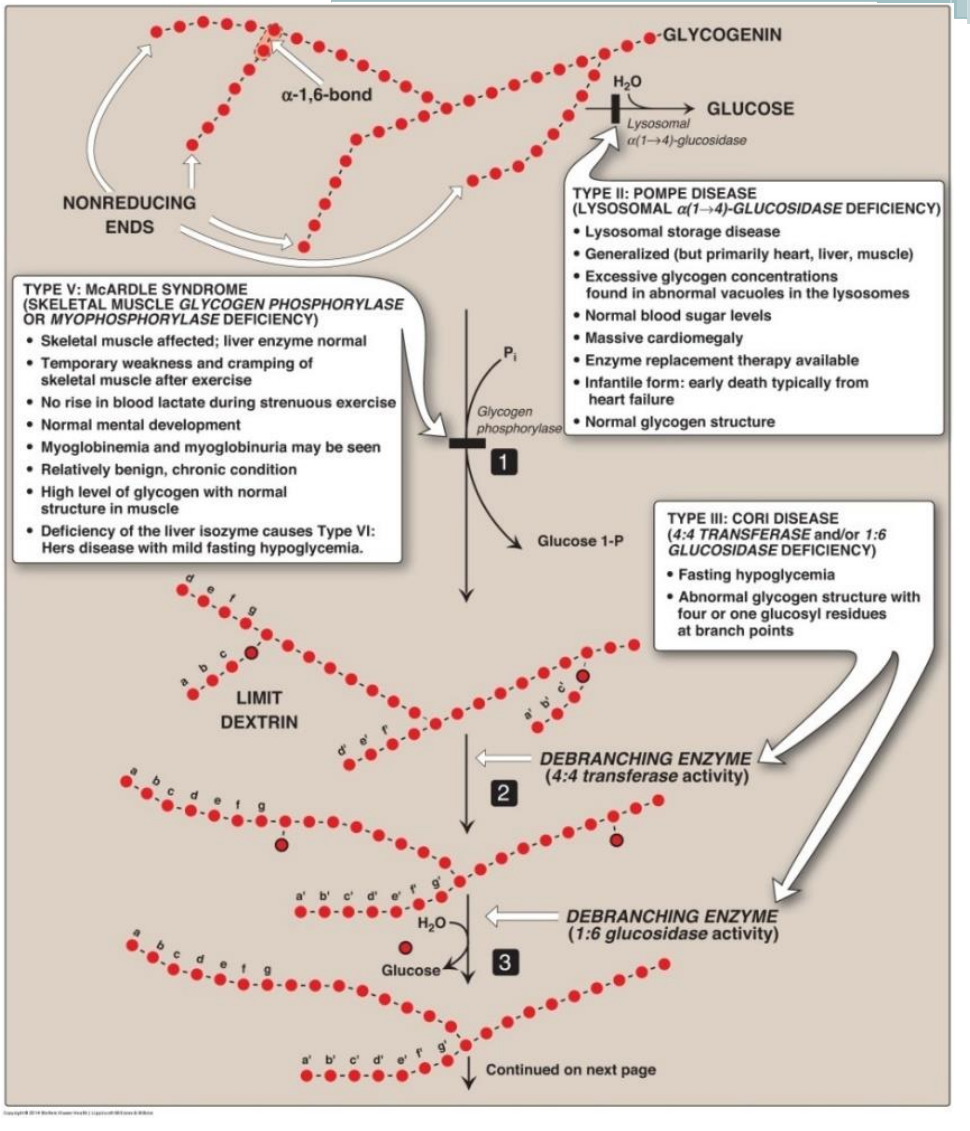
3- Fate of glucose 6-phosphate (G-6-P):

- G-6-P is ***not*** converted to free glucose
- It is used as a source of energy for skeletal muscles during muscular exercise (by anaerobic glycolysis starting from G-6-P step)

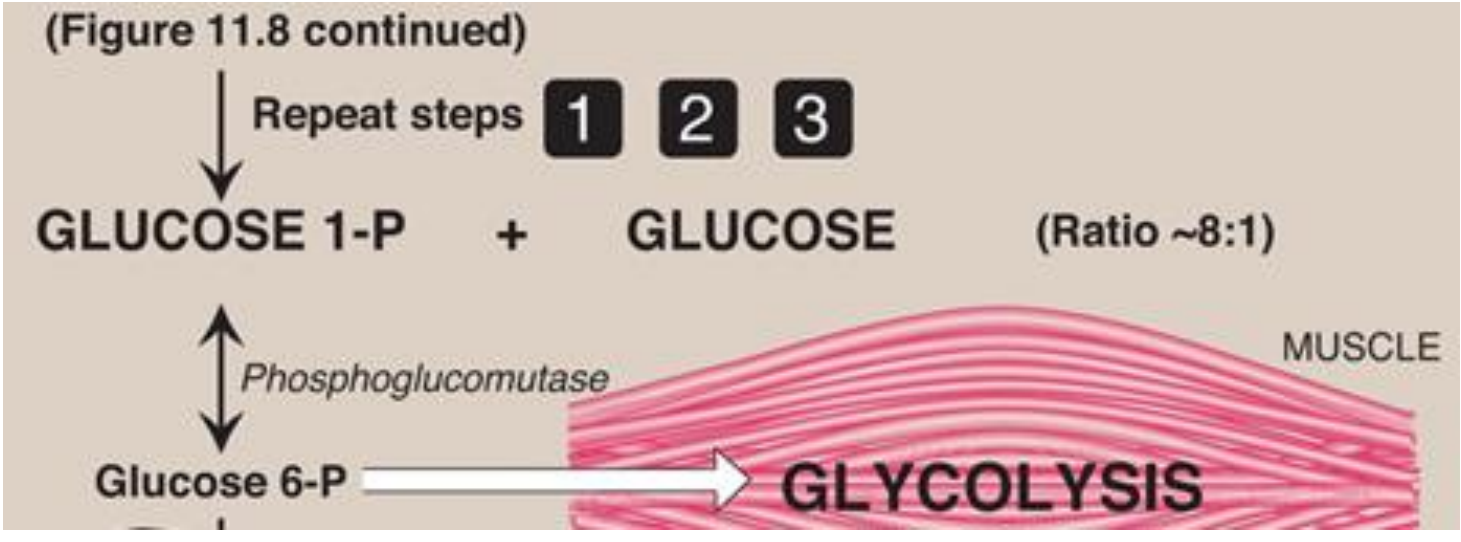
Glycogenolysis



Glycogenolysis



Glycogenolysis



Regulation of Glycogen Metabolism

Synthesis & degradation of glycogen are tightly regulated

In Skeletal Muscles:

- Glycogen **degradation** occurs during **active exercise**
- Glycogen **synthesis** begins when the **muscle is at rest**

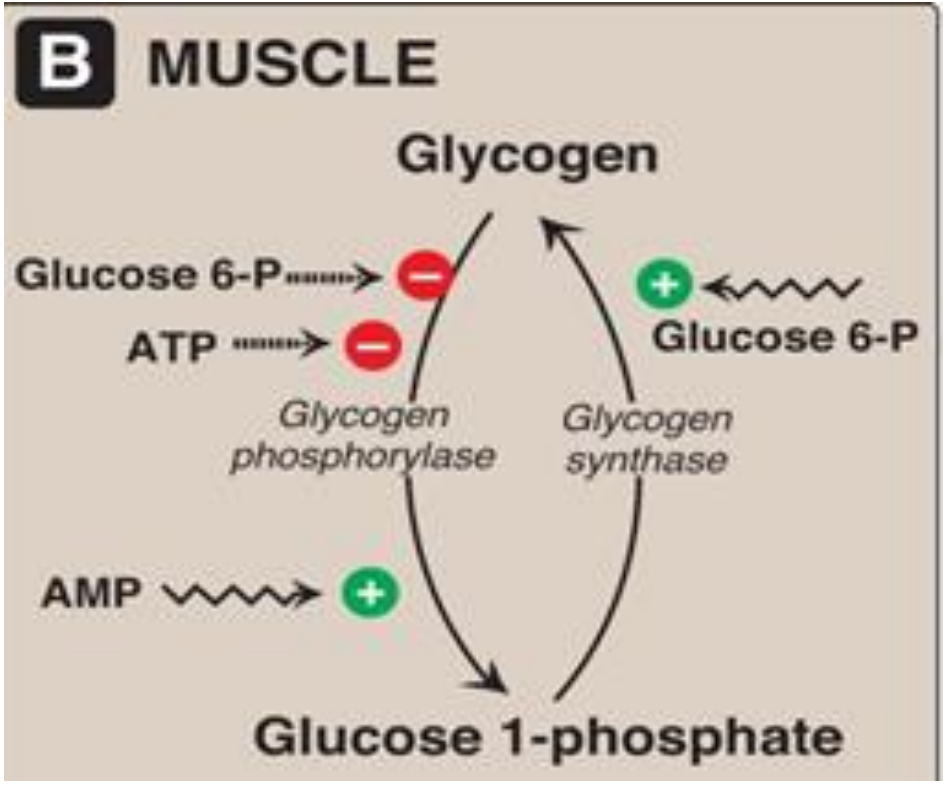
- **Regulation occurs by 2 mechanisms:**

  1- Allosteric regulation

  2- Hormonal regulation (Covalent modification)

Regulation of Glycogen Metabolism

1. Allosteric Regulation

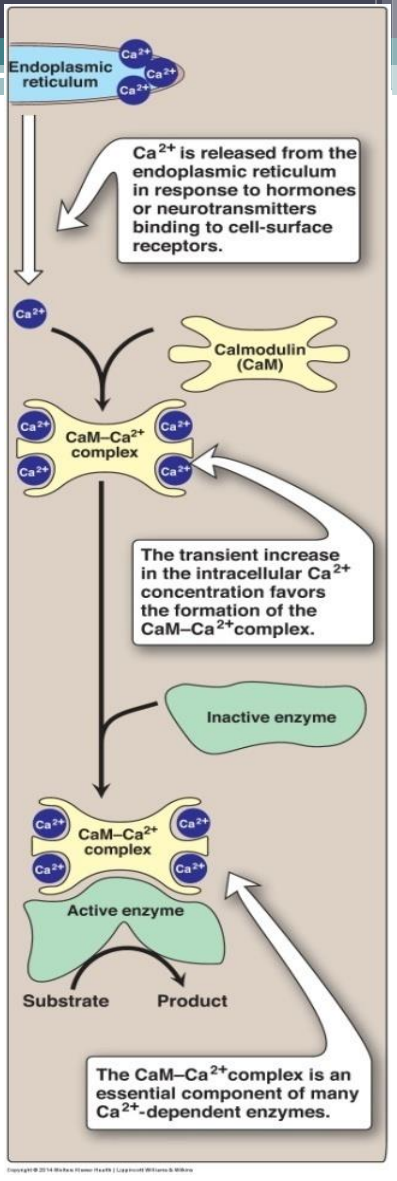


Regulation of Glycogen Metabolism

Increase of calcium during muscle contraction

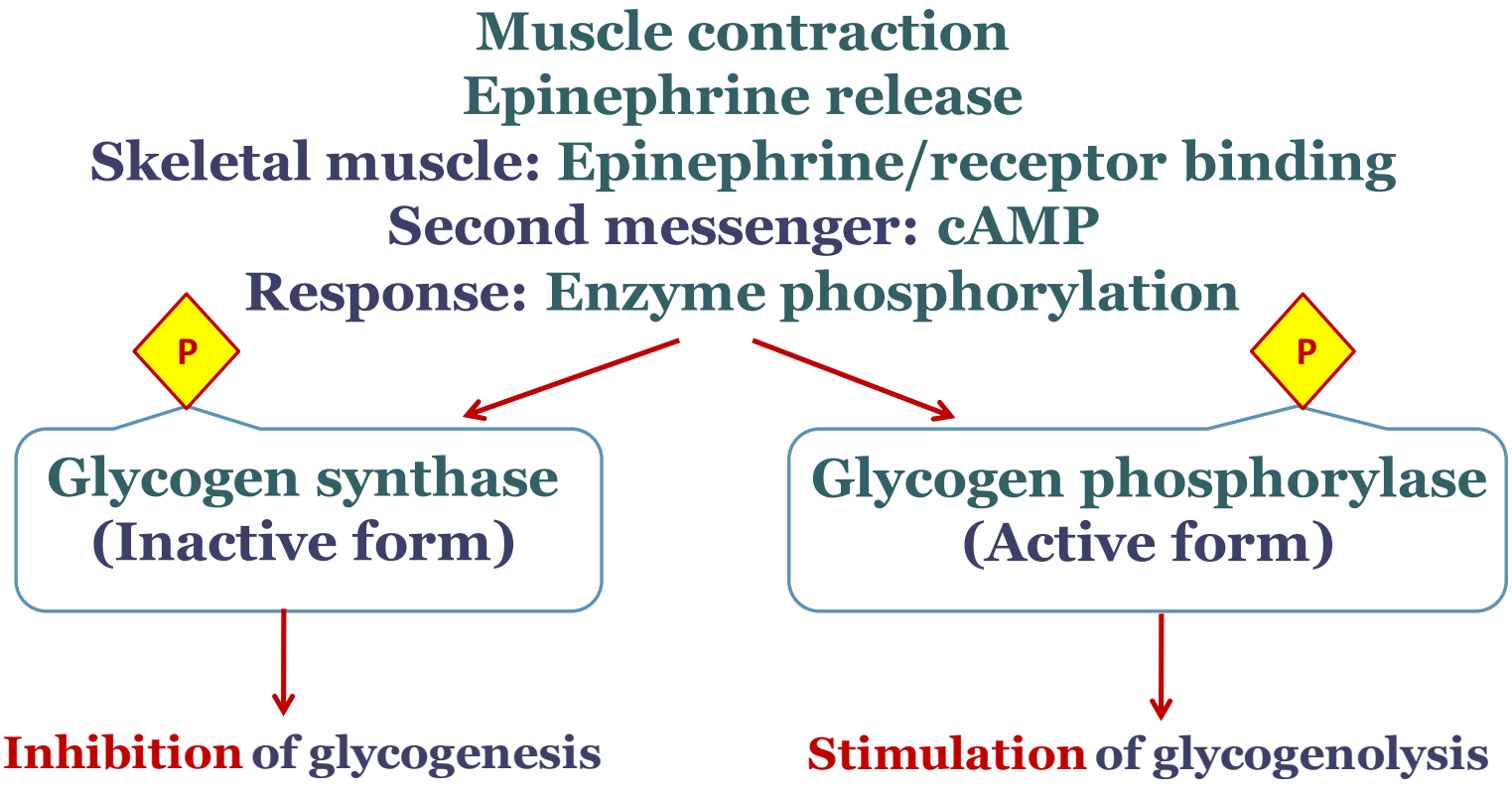
Formation of Ca^{2+} -calmodulin complex

Activation of Ca^{2+} -dependent enzymes, e.g., glycogen phosphorylase



Regulation of Glycogen Metabolism:

2. Hormonal Regulation by Epinephrine



Glycogen Storage Diseases (GSD)

A group of genetic diseases that result from a defect in an enzyme required for glycogen synthesis or degradation.

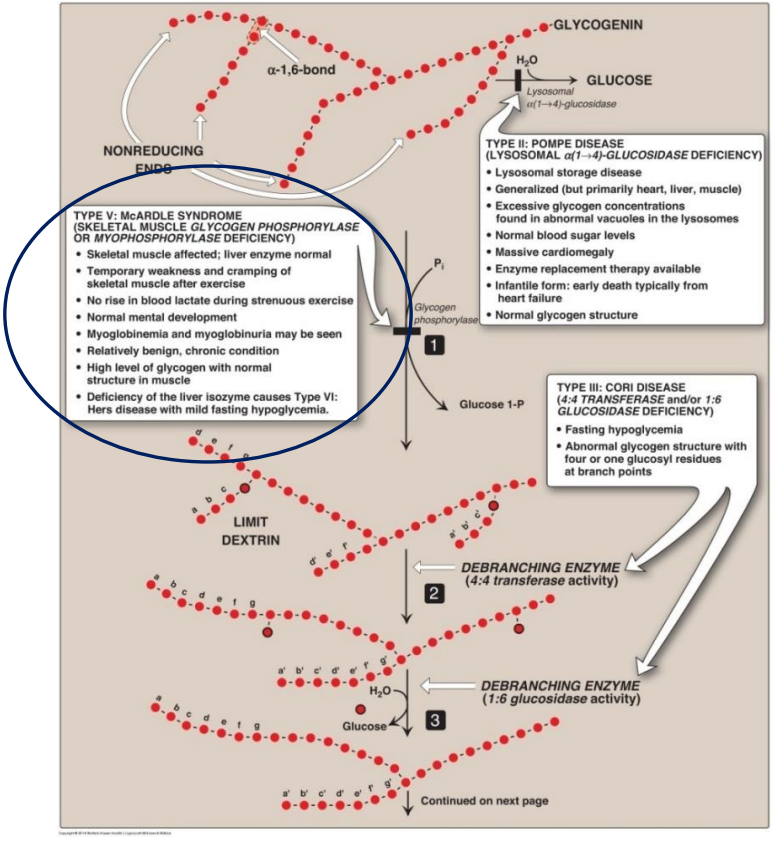
They result in:

- **Formation of abnormal glycogen structure**

OR

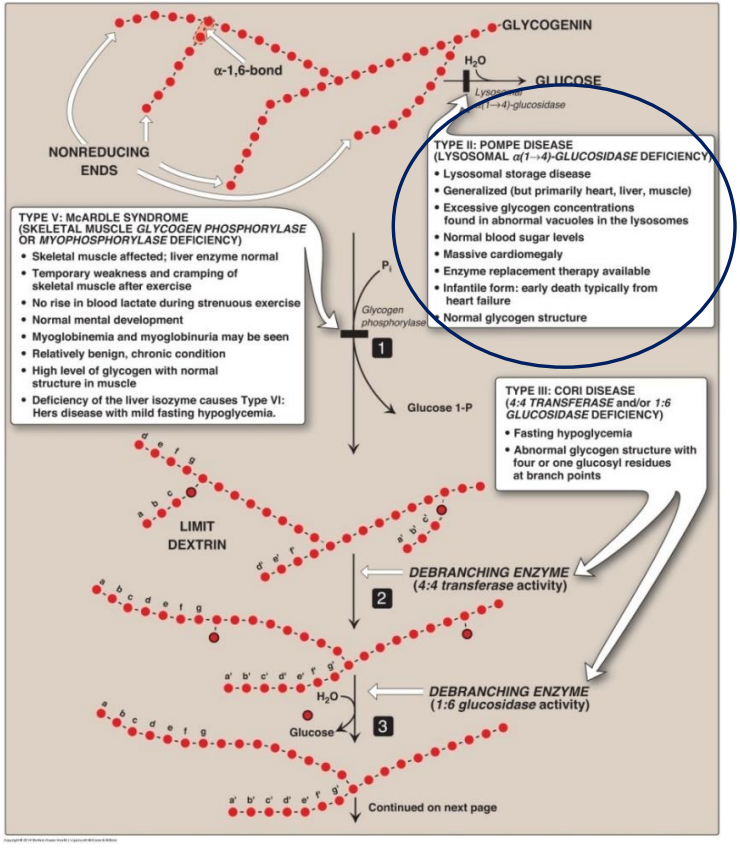
- **Excessive accumulation of normal glycogen in a specific tissue**

Glycogen Storage Diseases
GSD Type V (Mc Ardle Syndrome)



- **Deficiency of skeletal muscle glycogen phosphorylase**

Glycogen Storage Diseases
GSD Type II (POMPE DISEASE)



- **Deficiency of Lysosomal α(1-4) glucosidase.**

Reference

Lippincott's Illustrated Reviews Biochemistry: Unit II, Chapter 11, Pages 125 - 136.