



# Bile acids

Bile acids are hydroxylated steroids, synthesized in the liver from cholesterol. Peroxisomal enzymes assist in the hepatic biosynthesis of bile acids.

Bile acids are found predominantly in the bile of mammals and other vertebrates. Diverse bile acids are synthesized in the liver.

Bile acids are conjugated with taurine or glycine residues to give anions called bile salts

Bile acid synthesis occurs in liver cells, which synthesize primary bile acids (cholic acid and chenodeoxycholic acid in humans) via cytochrome P450-mediated oxidation of cholesterol in a multi-step process.

Approximately 600 mg of bile salts are synthesized daily to replace bile acids lost in the feces

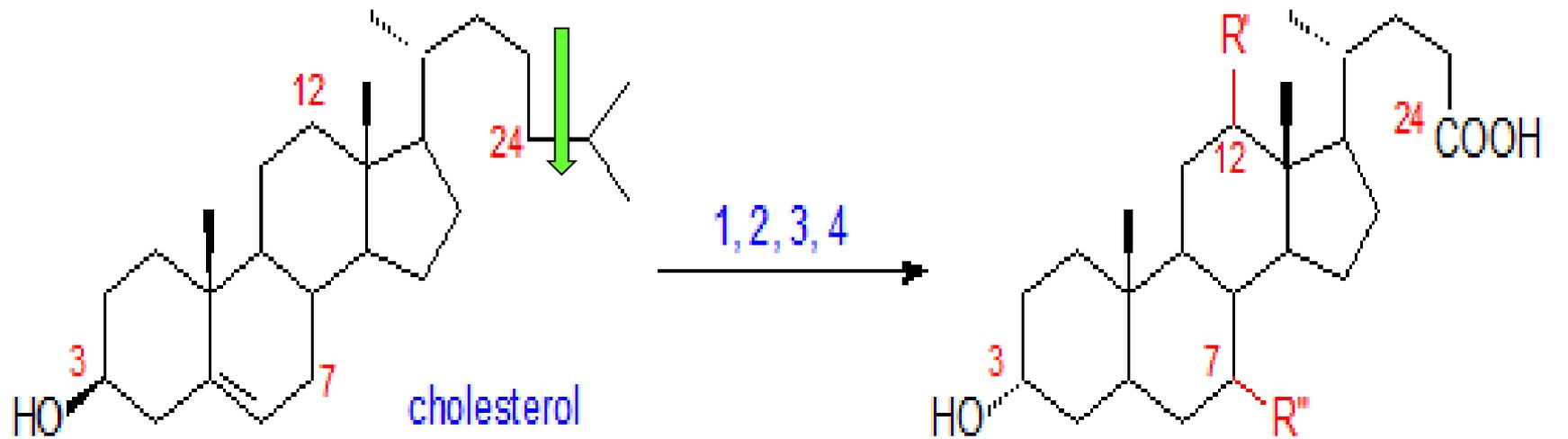
## Classification of bile acids/salts

- Bile acids: primary & secondary.
- Bile acids: conjugated & non-conjugated.
- Bile salts: sodium & potassium salts of bile acids.

## Bile acids: structure

- Bile salts constitute a large family of molecules, composed of a **steroid structure** with four rings, a side-chain terminating in a **carboxylic acid**, and the presence of **different numbers of hydroxyl groups**.
- All bile acids have a 3-hydroxyl group, derived from the parent molecule, cholesterol.
- **Bile acids/salts** are polar derivatives of cholesterol.
- Bile acids are **amphipathic**.

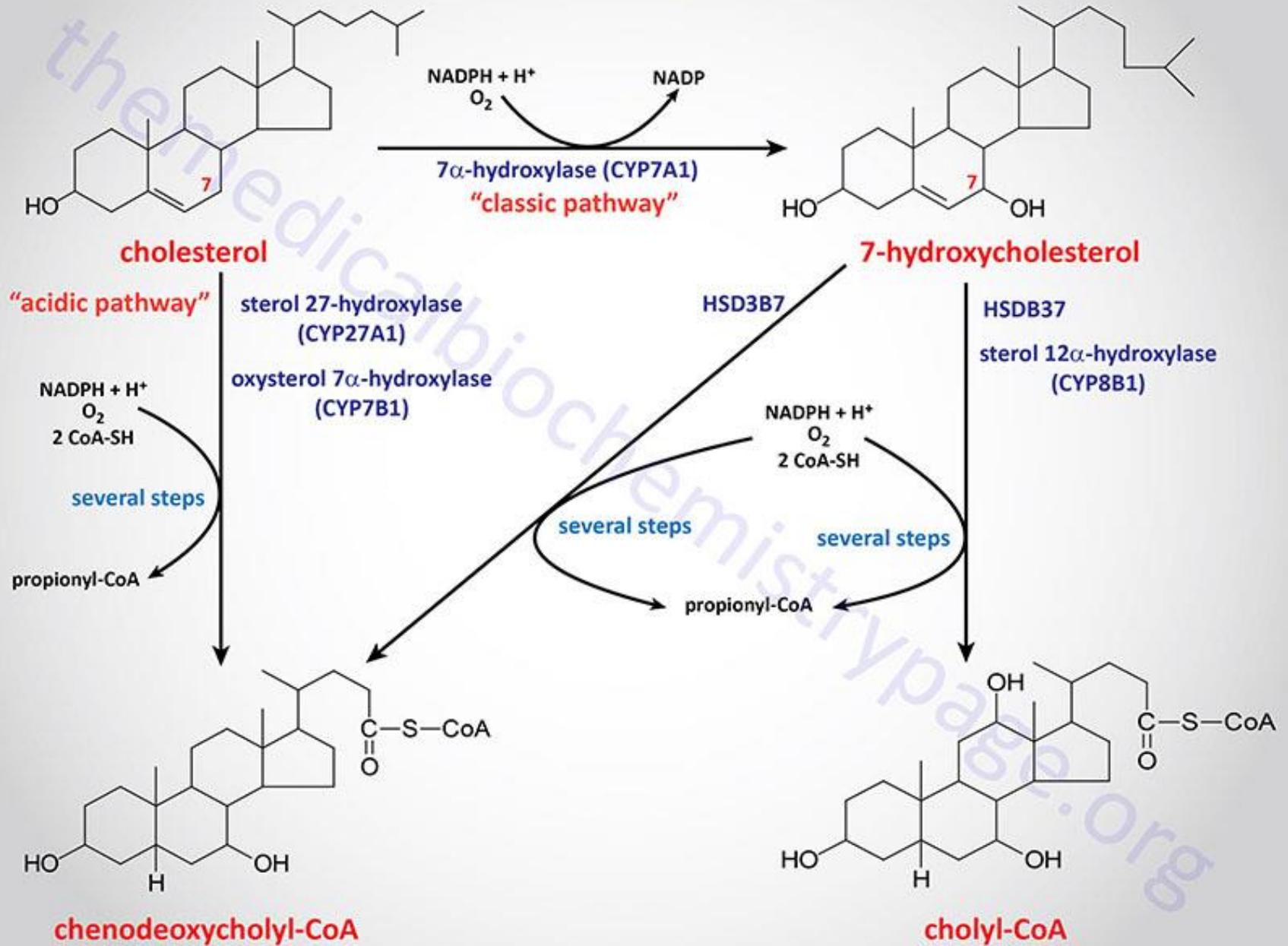
# Biosynthesis of bile acids



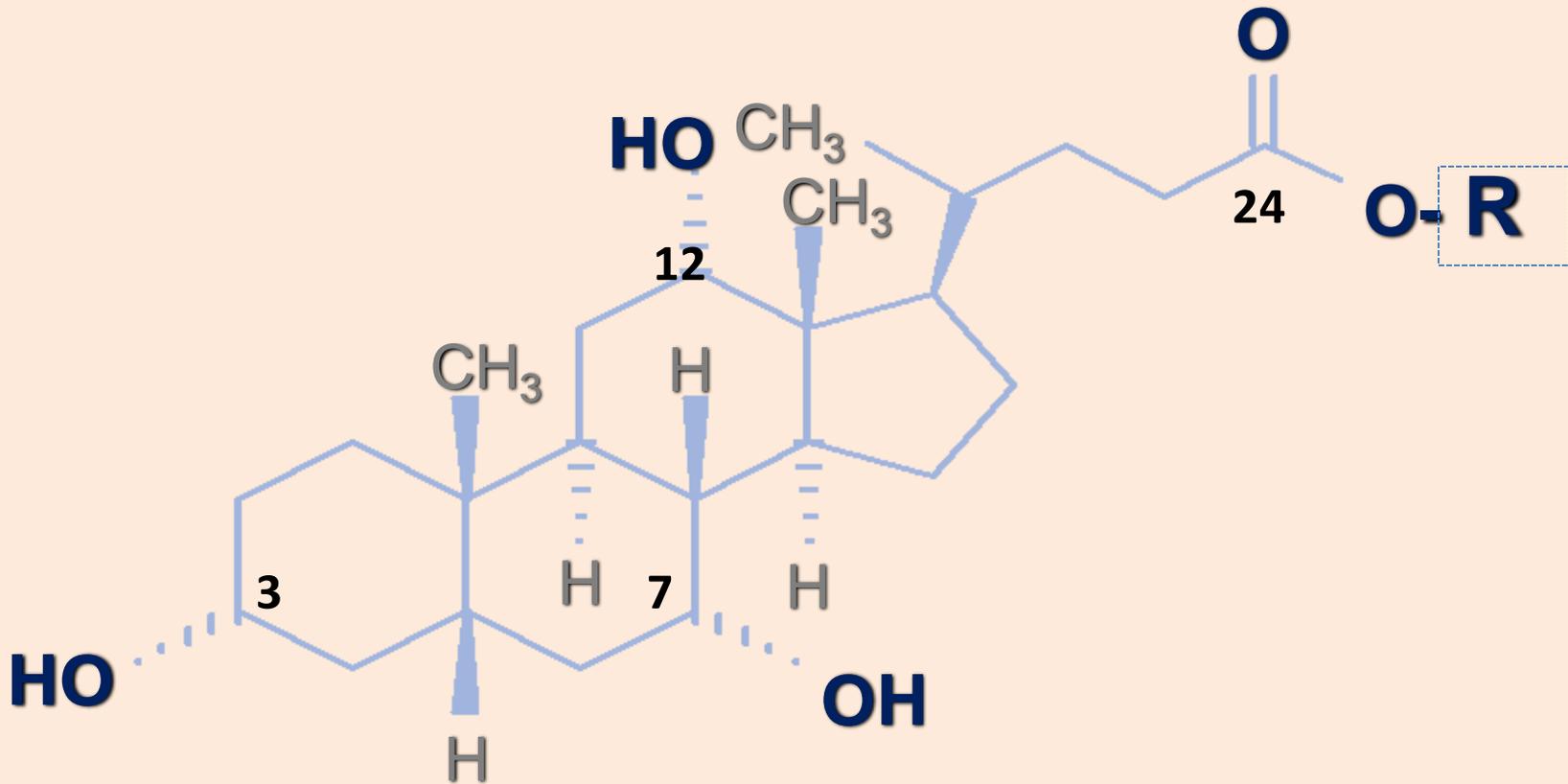
- 1, hydroxylation reactions
- 2, epimerization of the  $3\beta$ -hydroxyl group
- 3, saturation of the double bond
- 4, side-chain cleavage/oxidation

- $R' = H, R'' = OH$ , chenodeoxycholic acid  
 $R' = OH, R'' = OH$ , cholic acid  
 $R' = OH, R'' = H$ , deoxycholic acid

↓  
glycine and taurine conjugates



# Bile acids/salts



R= H in non-conjugated bile acids.

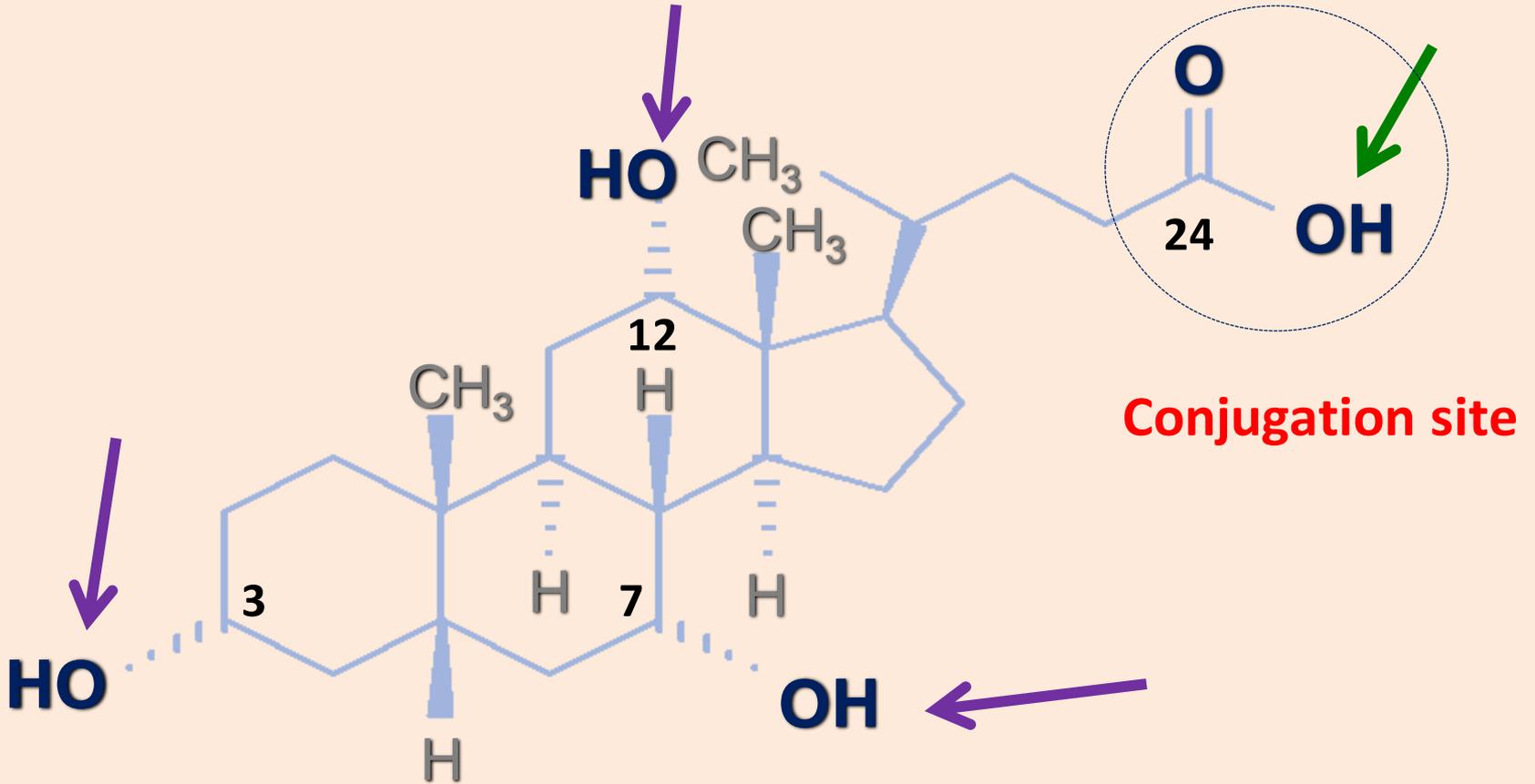
R= Na<sup>+</sup>/K<sup>+</sup> in non-conjugated bile salts.

R= glycine/taurine in conjugated bile acids.

R= Na<sup>+</sup>/K<sup>+</sup> salts of glycine/taurine in conjugated bile salts.

# Bile acids: Cholic acid

non-conjugated bile acid



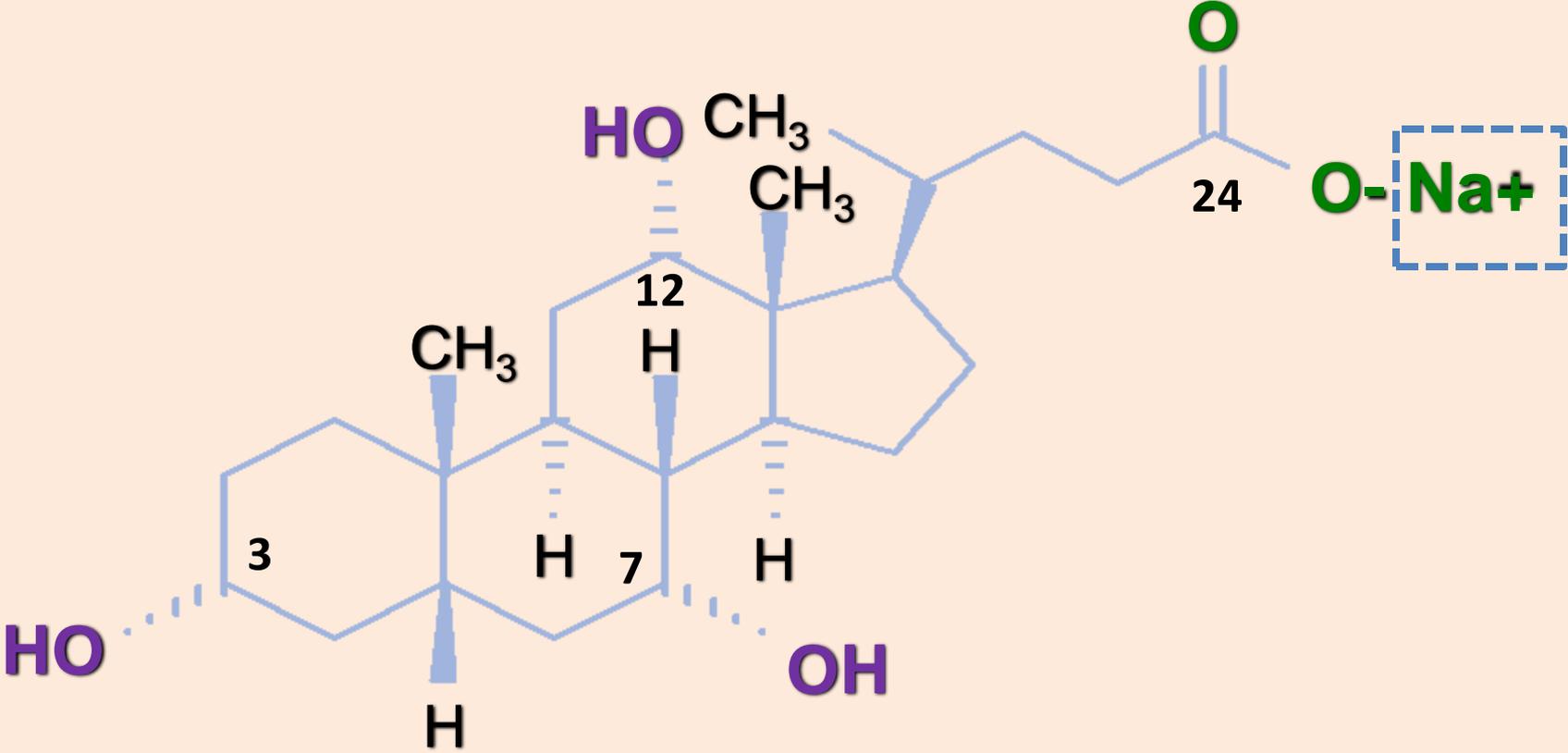
Polar groups are:

- OH groups
- COOH group

**Cholic acid** is the most common bile acid. It contains 3 OH groups at 3, 7, 12.

# Bile salts: Sodium cholate

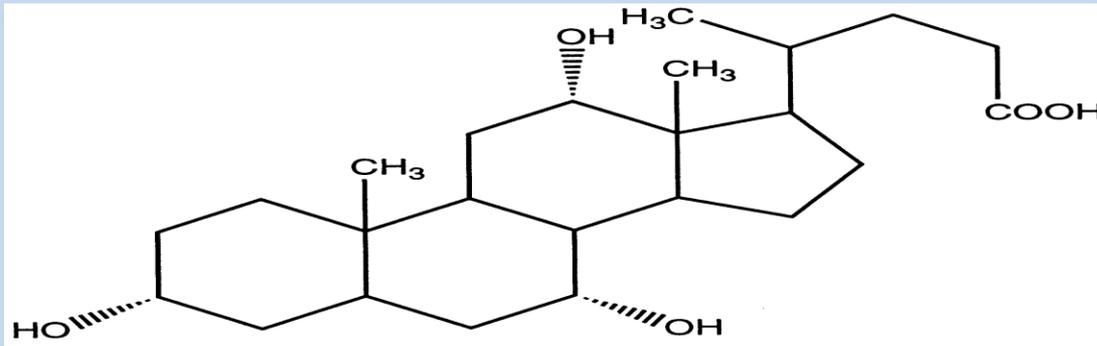
(non-conjugated bile salt)



# Conjugation

- Prior to secreting any of the four bile acids, liver cells conjugate them with one of two amino acids, **glycine** or **taurine**, to form a total of 8 possible conjugated bile acids.
  - **Glycine** =  $\text{NH}_2\text{-CH}_2\text{-COO}^-$
  - **Taurine** =  $\text{NH}_2\text{-CH}_2\text{-CH}_2\text{-SO}_3^-$
- Conjugated bile acids are almost always in their deprotonated ( $\text{A}^-$ ) form in the duodenum, which makes them much more water soluble thus, able to emulsify fats.

# Bile Acid Conjugation

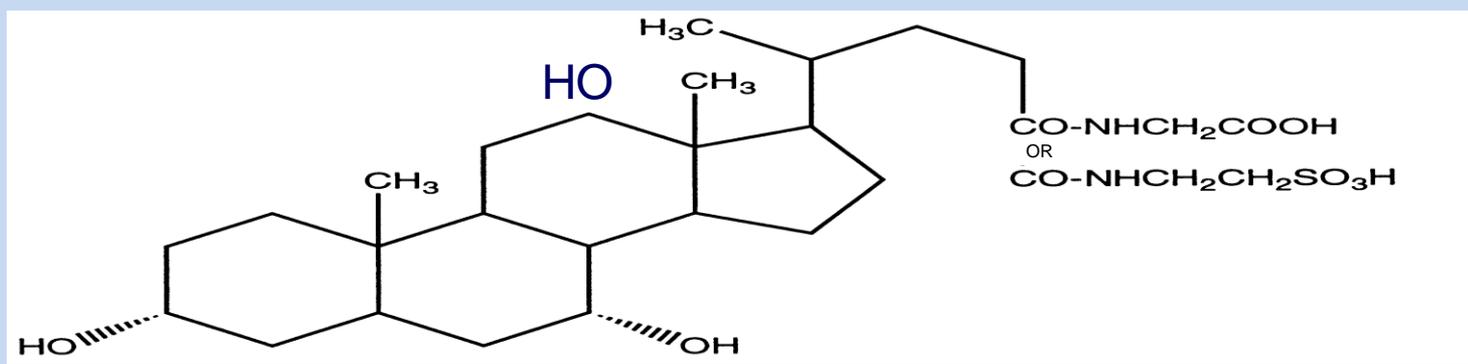


Cholic acid

Bile Acids



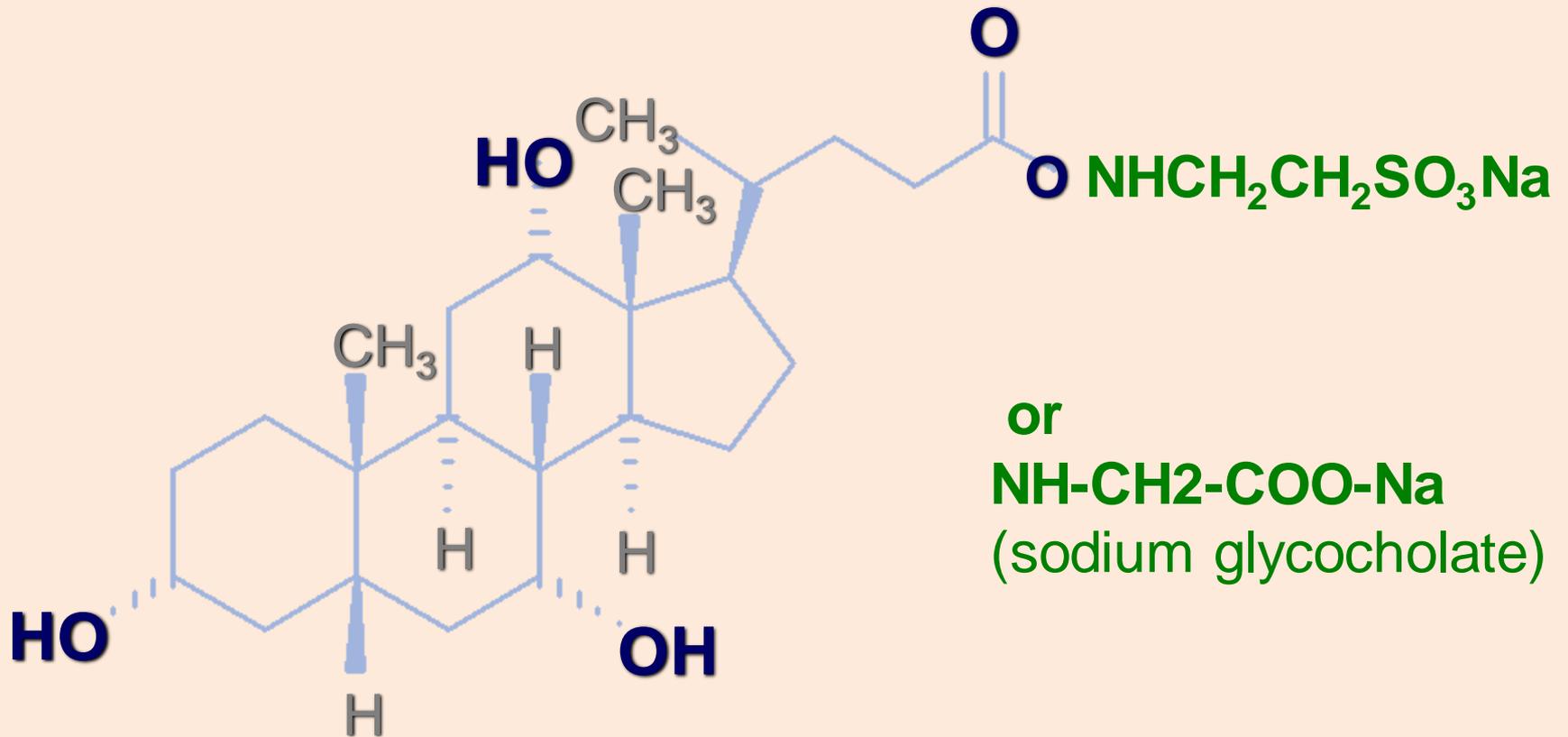
+  
Glycine  
OR  
Taurine



Glycocholic acid Or Taurocholic acid

# Bile salts: Sodium taurocholate

(conjugated bile salt)

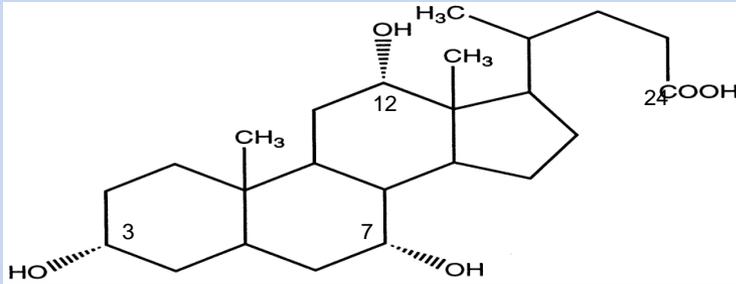


# Biosynthesis of bile acids & Enterohepatic circulation

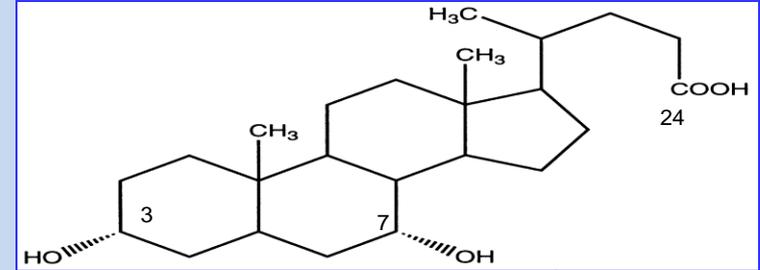
- Bile acid synthesis occurs in **liver cells** which synthesize primary bile acids in humans from **cholesterol**.
- Bile acids are stored in the **gallbladder** and are cycled between the intestines and liver via the enterohepatic circulation.
- When these bile acids are secreted into the lumen of the **intestine**, bacterial partial dehydroxylation forms the secondary bile acids.
- **Cholic acid is converted into deoxycholic acid and chenodeoxycholic acid into lithocholic acid.**
- All these bile acids can be taken back up into the blood stream (~95%), return to the liver, and be re-secreted in a process known as **enterohepatic circulation**. **~5%** are excreted in faeces.

# Primary and secondary bile acids

## Primary Bile Acids



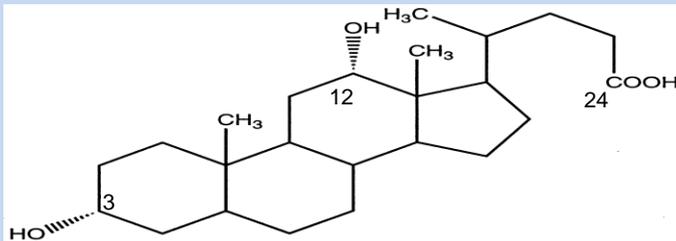
**Cholic acid**  
(3 OH groups)



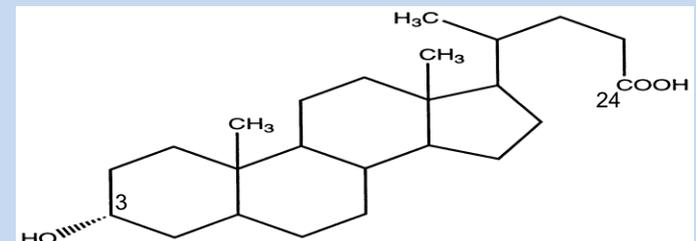
**Chenodeoxycholic acid**  
(2 OH groups)

**7-dehydroxylation  
by gut bacteria**

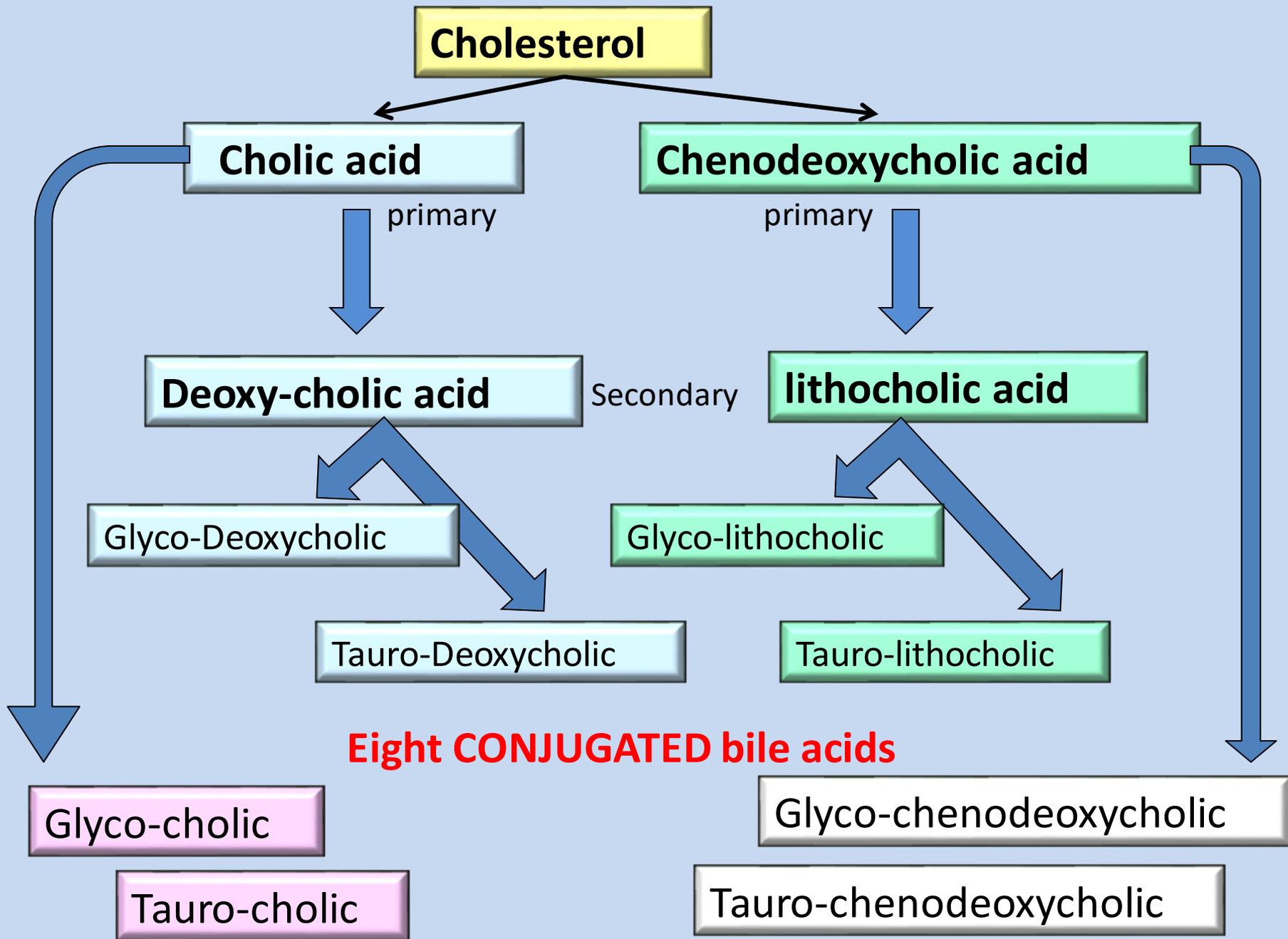
## Secondary Bile Acids



**Deoxycholic acid**  
(2 OH groups)

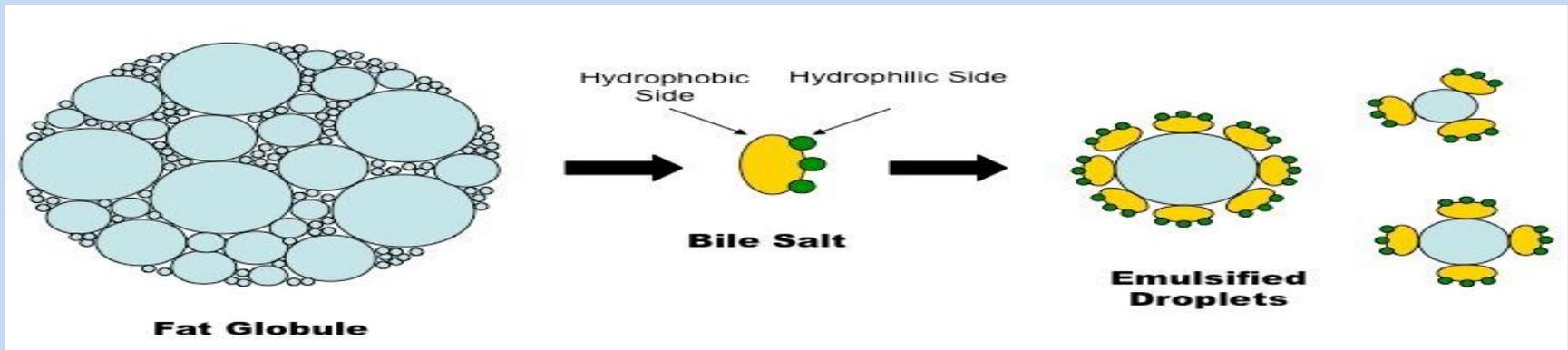


**Lithocholic acid**  
(1 OH group)



# Functions of bile acids/salts

1. The main function of bile acids is to act as **powerful detergents** or **emulsifying agents** in the intestines to aid the **digestion and absorption** of *fatty acids, monoacylglycerols, fat-soluble vitamins* and other fatty products.
- As amphipathic molecules, conjugated bile salts sit at the lipid/water interface to form **micelles** and can **solubilize lipids**.
  - Bile acid-containing micelles aid **lipases** to digest lipids.



# Functions of bile acids/salts

2. Prevent the precipitation of cholesterol in bile.
3. This is the major pathway for the removal of cholesterol from the body as ~ 5% of bile acids is lost into the faeces.
4. bile acids act as signaling molecules.
  - They have an influence on the metabolism of lipids and of glucose.
5. bile acid has inhibitory effects upon apoptosis and is being study for potential beneficial effects in a number of disease states such as Alzheimer's.

# Clinical significance of bile salts

## Hyperlipidemia:

- As bile acids are made from endogenous cholesterol, disruption of the enterohepatic circulation of bile acids will lower cholesterol.
- **Bile acid sequestrants** bind bile acids in the gut, preventing reabsorption. In so doing, more endogenous cholesterol is shunted into the production of bile acids, thereby lowering cholesterol levels. The sequestered bile acids are then excreted in the faeces.

## Cholestasis

- Structural or functional abnormalities of the biliary system result in an increase in bile acids in the blood. Bile acids are related to the itching.

# Clinical significance of bile salts

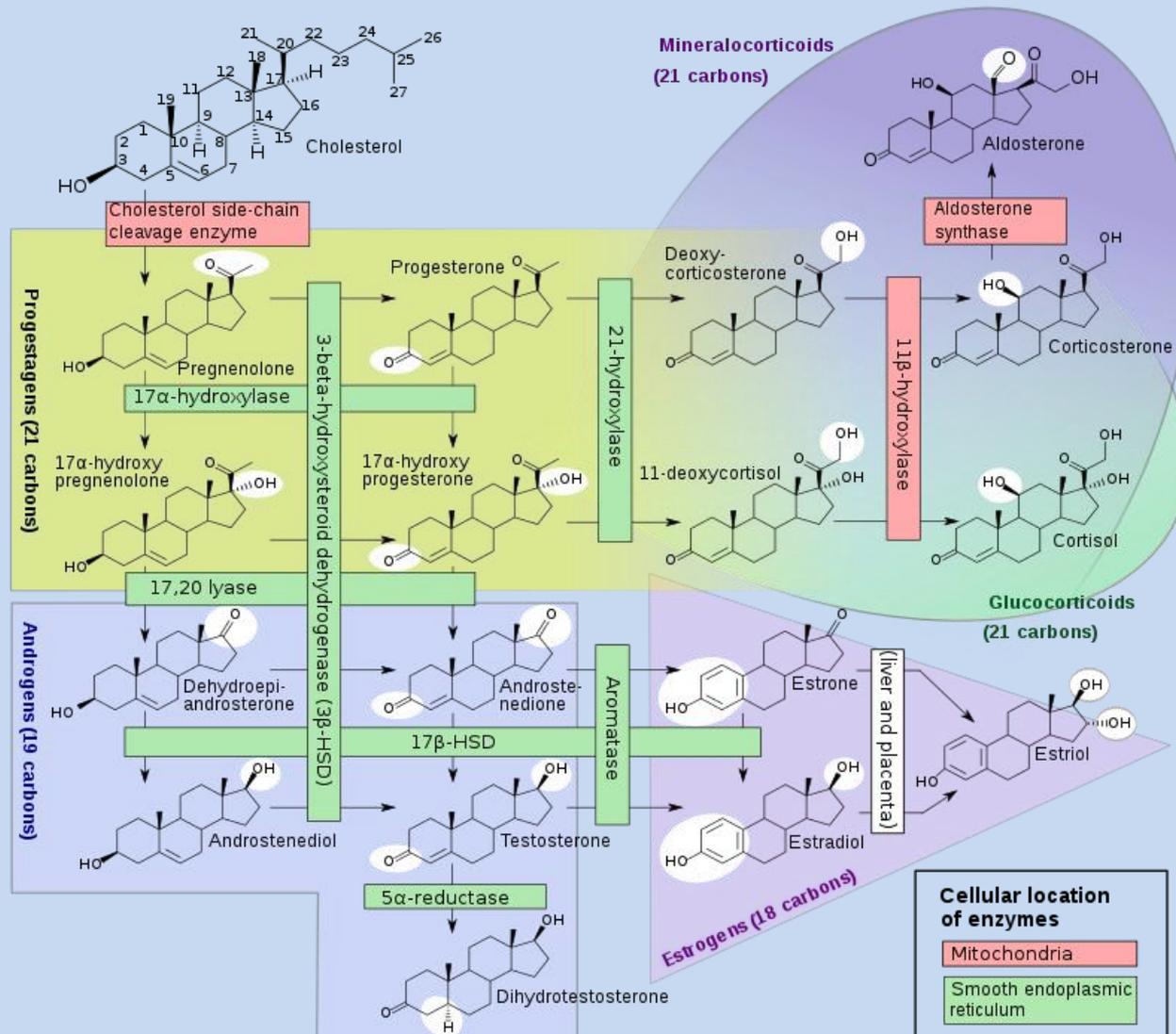
## Colon cancer

- At high concentrations, **bile acids are toxic** and their presence is relevant to colon cancer.

## Gallstones:

- Lower concentrations of Bile acids or Phospholipids in bile reduce cholesterol solubility and lead to microcrystal formation.
- Oral therapy with chenodeoxycholic acid has been used to dissolve cholesterol gallstones.

# Steroid Hormones



# Corticosteroids:



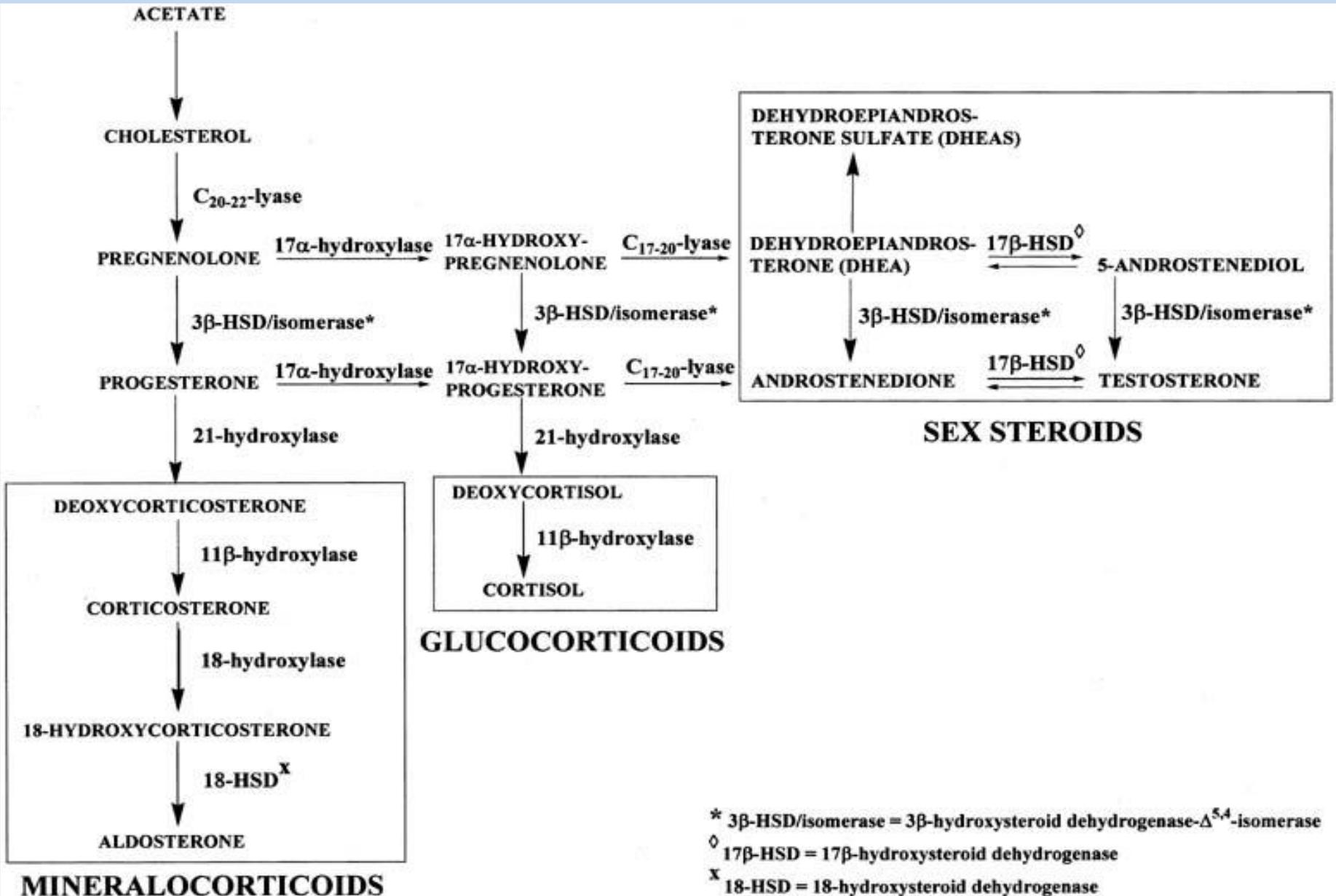
Corticosteroids are a class of steroid hormones that are produced in the adrenal cortex of vertebrates.

Two main classes of corticosteroids, glucocorticoids and mineralocorticoids, are involved in a wide range of physiological processes, including stress response, immune response, and regulation of inflammation, carbohydrate metabolism, protein catabolism, blood electrolyte levels, and behavior.

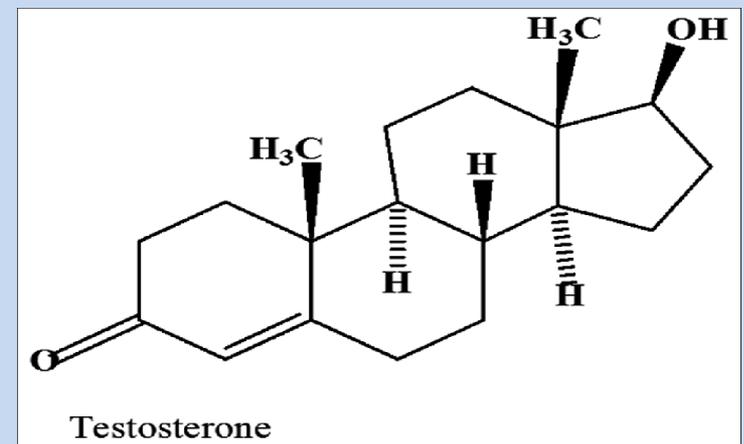
Some common naturally occurring steroid hormones are cortisol, corticosterone, cortisone and aldosterone.

**The main corticosteroids produced by the adrenal cortex are cortisol and aldosterone.**

# Pathway of Corticosteroids biosynthesis



# Male sex hormones: **Testosterone**



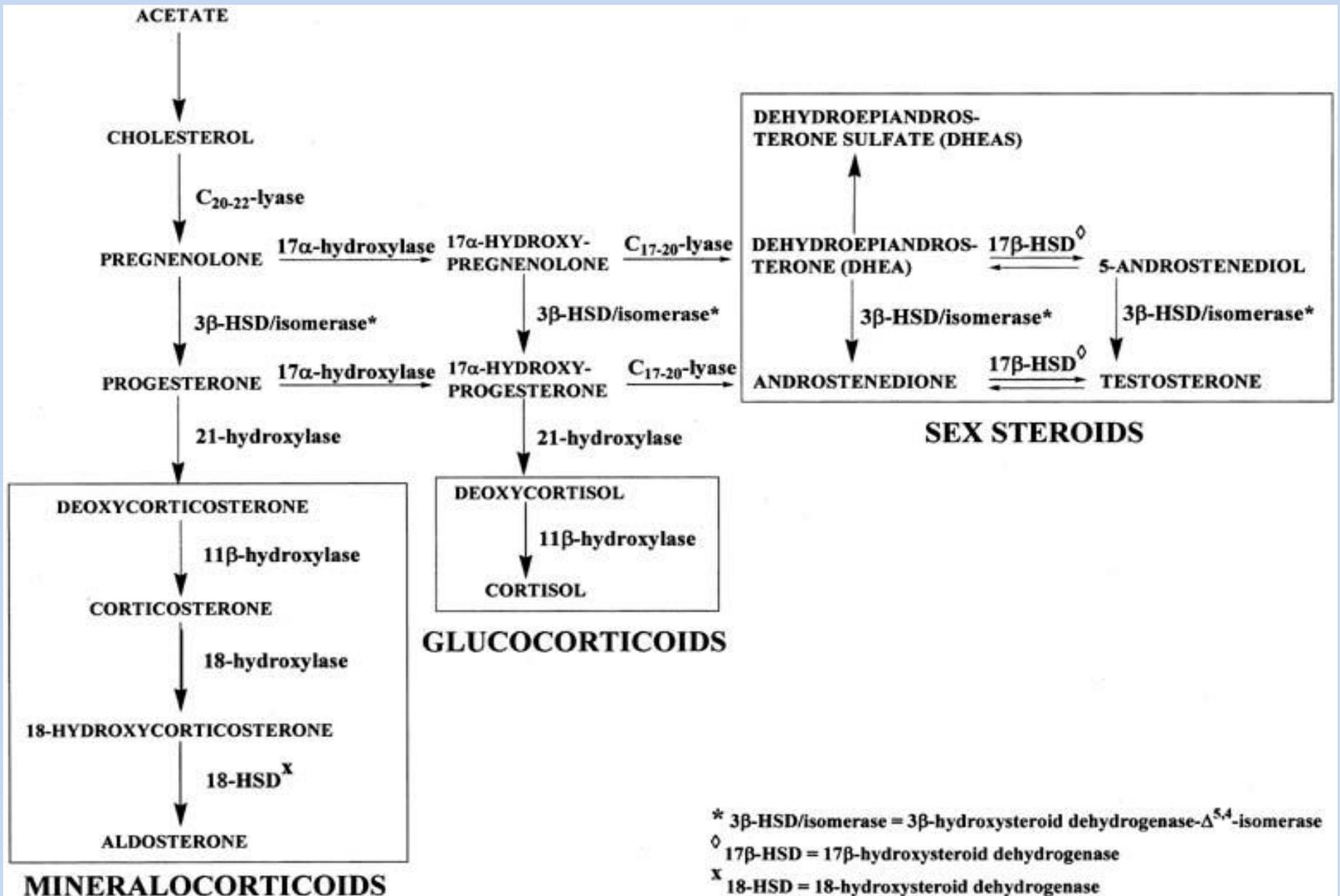
Testosterone is a hormone found in humans, as well as in animals. The testicles primarily make testosterone in men. Women's ovaries also make testosterone, though in much smaller amounts.

The production of testosterone starts to increase significantly during puberty, and begins to dip after age 30 or so.

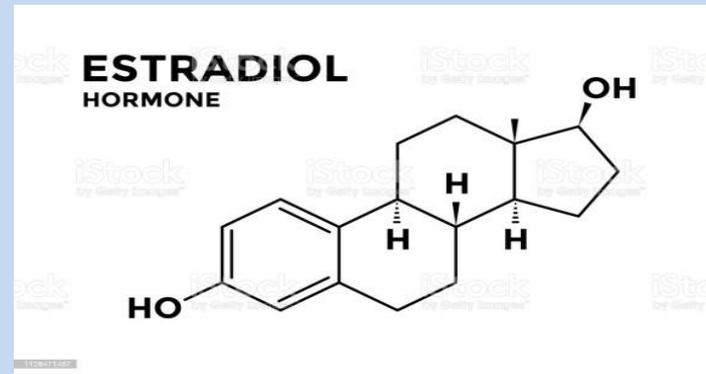
Testosterone is most often associated with sex drive, and plays a vital role in sperm production.

A man's testosterone levels can also affect his mood.

# Pathway of testosterone biosynthesis



# Female sex hormones: **Estradiol**

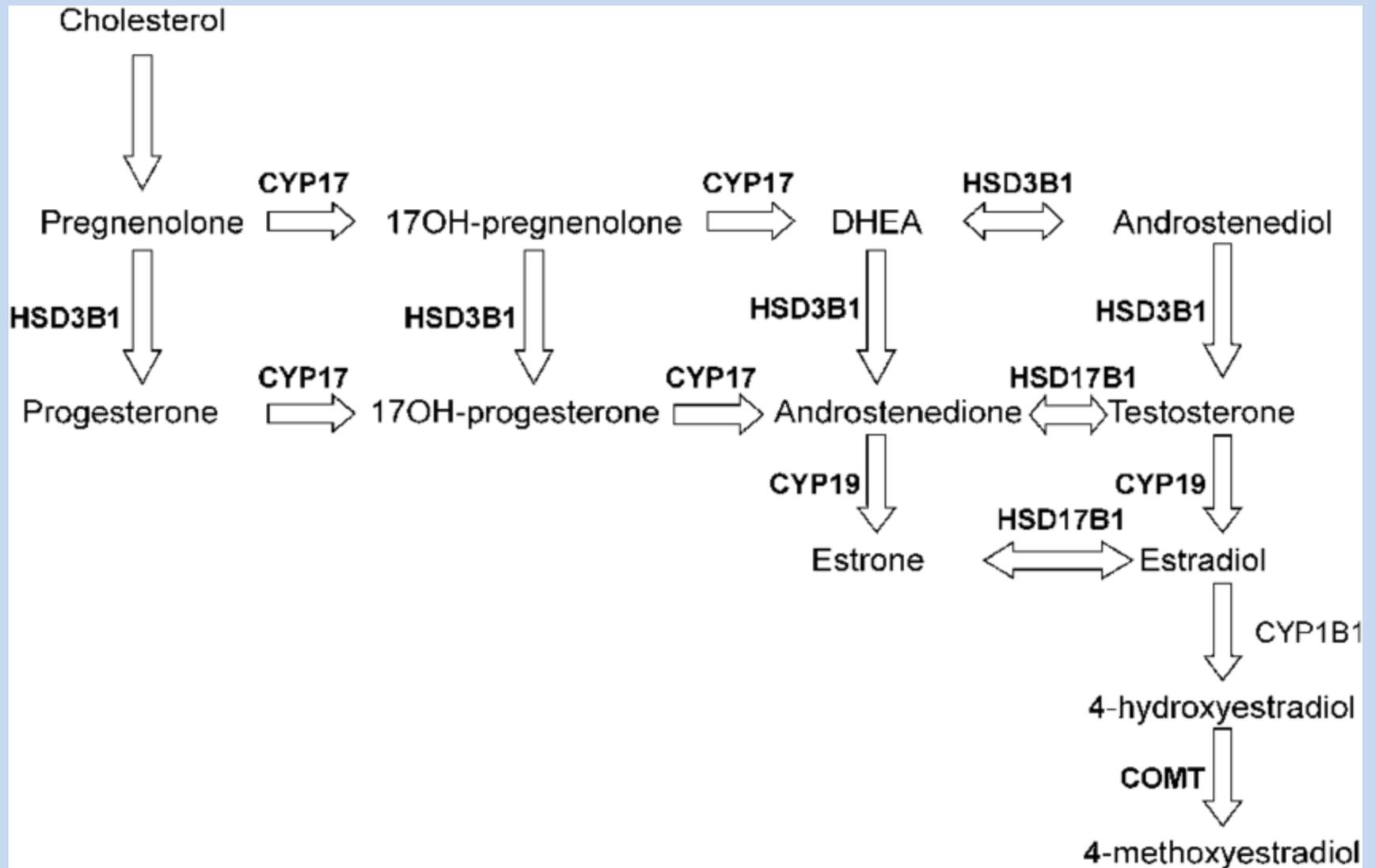


Estradiol , also spelled oestradiol, is an estrogen steroid hormone and the major female sex hormone.

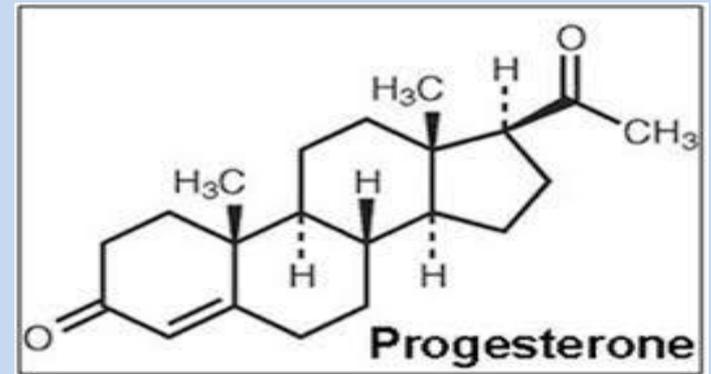
Estradiol is responsible for the development of female secondary sexual characteristics such as the breasts, widening of the hips, and a female-associated pattern of fat distribution

It is important in the development and maintenance of female reproductive tissues such as the mammary glands, uterus, and vagina during puberty, adulthood, and pregnancy.

# Pathway of estradiol biosynthesis



## Female sex hormones: **Progesterone**



**Progesterone is an endogenous steroid and progestogen sex hormone involved in the menstrual cycle, pregnancy, and embryogenesis of humans and other species.**

**Progesterone has a variety of important functions in the body.**

**It is also a crucial metabolic intermediate in the production of other endogenous steroids, including the sex hormones and the corticosteroids, and plays an important role in brain function as a neurosteroid**

