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Lipids: Structure, Properties, and Cell Roles

Study Guide — Cell Membrane

Pre-med/IB-style questions on lipid types (fatty acids, triglycerides, phospholipids, steroids), amphipathic behavior, membrane fluidity/permeability, lipid asymmetry and signaling, and classic conceptual traps (cis vs trans, cholesterol effects, detergents).

40 items — Study Guide with Answers

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1 **Which molecule is amphipathic and most likely to self-assemble into a bilayer in water?**

- A Glucose
- B Triacylglycerol (triglyceride)
- C **Phosphatidylcholine** ✓
- D Cholesteryl ester
- E Glycine

▶ **Explanation:** Phosphatidylcholine has a hydrophilic phosphate-containing head and two hydrophobic fatty acid tails, making it amphipathic and ideal for bilayers. Triacylglycerols and cholesteryl esters are largely hydrophobic (storage lipids), and glucose/amino acids are not lipids.

2 **Compared with phospholipids, triacylglycerols are better suited for long-term energy storage mainly because they:**

- A Have charged phosphate heads that make them water-soluble
- B **Are highly reduced and stored without much associated water** ✓
- C Form bilayers that trap energy inside cells
- D Contain peptide bonds that store chemical energy
- E Are catalysts that speed up ATP synthesis

▶ **Explanation:** Triacylglycerols are energy-dense because their carbons are highly reduced (many C–H bonds) and they are hydrophobic, so they can be stored anhydrously. Phospholipids are primarily structural and amphipathic, not optimized for storage.

3 **Two fatty acids are both 18 carbons long. Which change would MOST increase melting point and decrease membrane fluidity at a fixed temperature?**

- A Add one cis double bond (18:0 → 18:1 cis)
- B Convert a cis double bond to a trans double bond
- C **Remove a double bond (18:1 cis → 18:0)** ✓
- D Shorten the chain from 18 carbons to 12 carbons
- E Add a phosphate group to the fatty acid tail

▶ **Explanation:** Removing a double bond makes the chain more saturated and straighter, allowing tighter packing and stronger van der Waals interactions—raising melting point and decreasing fluidity. Cis double bonds (and shorter chains) disrupt packing and increase fluidity.

4 A trans-unsaturated fatty acid behaves more like a saturated fatty acid than a cis-unsaturated fatty acid because trans double bonds:

- A Create large kinks that prevent packing
- B **Make the chain straighter, allowing tighter packing** ✓
- C Make the fatty acid positively charged
- D Turn the fatty acid into a carbohydrate
- E Prevent the fatty acid from being part of membranes

▶ **Explanation:** Cis double bonds introduce a kink that disrupts packing. Trans double bonds keep the chain relatively straight, so packing resembles saturated fats, increasing melting point and decreasing membrane fluidity compared with cis.

5 Which statement BEST describes cholesterol's effect on a mammalian plasma membrane?

- A It always increases membrane fluidity at all temperatures
- B It always decreases membrane fluidity at all temperatures

C **It buffers fluidity: decreases fluidity at high temperature but prevents solidification at low temperature ✓**

D It replaces phospholipids to form the bilayer backbone

E It makes the membrane freely permeable to ions

▶ **Explanation:** Cholesterol acts as a "fluidity buffer." At high temperatures it restrains phospholipid movement (less fluid), while at low temperatures it prevents tight packing/crystallization (more fluid than it would otherwise be). It does not form the membrane backbone or allow ions to diffuse freely.

6 At the same temperature and saturation level, which membrane would generally be MORE fluid?

A **Membrane with shorter fatty acid tails ✓**

B Membrane with longer fatty acid tails

C Membrane with more hydrogen bonding between water molecules

D Membrane made only of triglycerides

E Membrane with more peptide bonds in the bilayer

▶ **Explanation:** Shorter hydrocarbon chains have fewer van der Waals interactions and pack less tightly, increasing fluidity. Longer chains pack more strongly and reduce fluidity. Triglycerides do not form bilayers.

7 A cell is cooled rapidly. Which lipid change would BEST help maintain membrane function in the cold (homeoviscous adaptation)?

A Increase saturated fatty acid content

B Increase trans-unsaturated fatty acid content

C **Increase cis-unsaturated fatty acid content ✓**

D Replace phospholipids with triglycerides

E Increase peptide bond formation in membrane proteins

▶ **Explanation:** Cis-unsaturated tails introduce kinks and prevent tight packing, keeping membranes more fluid at low temperature. Saturated and trans-unsaturated chains pack tightly and make membranes more rigid in the cold.

8 What is the BEST explanation for why phospholipids spontaneously form bilayers in water?

A Phospholipids form covalent bonds with water to stabilize the membrane

B **Water molecules gain entropy when hydrophobic tails are sequestered away from water (hydrophobic effect)** ✓

C Phospholipids are charged and attract each other strongly

D Bilayers form because fatty acid tails hydrogen-bond to each other

E Bilayers form only when ATP is consumed

▶ **Explanation:** The hydrophobic effect is the main driver: arranging hydrophobic tails inward reduces ordered "cages" of water, increasing water's entropy and making bilayer formation energetically favorable without ATP.

9 Why do many detergents form micelles rather than stable bilayers in water?

A Detergents usually have two tails, which favor bilayers

B **Detergents often have a single hydrophobic tail, creating a cone shape that favors micelles** ✓

C Detergents are always fully hydrophobic, so they cannot self-assemble

D Micelles require peptide bonds to form

E Bilayers cannot form in water under any conditions

▶ **Explanation:** Single-tailed amphipathic molecules tend to form micelles because their shape packs well into spheres. Double-tailed phospholipids are more cylindrical and pack well into bilayers.

10 **Which substance would diffuse FASTEST across a pure phospholipid bilayer (no transport proteins)?**

- A O2 ✓
- B Glucose
- C Na^+
- D Cl–
- E Amino acid (charged form)

▶ **Explanation:** Small nonpolar molecules like O2 cross lipid bilayers readily by simple diffusion. Ions and large polar molecules (glucose, charged amino acids) are strongly blocked without channels/transporters.

11 **Ions cross lipid bilayers very poorly mainly because:**

- A Ions are too large to fit between lipid tails
- B **Ions would have to shed their hydration shell to enter the hydrophobic core, which is energetically costly** ✓
- C Ions do not interact with water
- D The membrane core is positively charged and repels all ions
- E Ions immediately form peptide bonds with phospholipids

▶ **Explanation:** The hydrophobic membrane interior is unfavorable for charged, hydrated ions. Removing the hydration shell (and stabilizing charge in a nonpolar environment) costs a lot of energy, so channels/transporters are needed.

12 **A membrane shifts from a more "gel-like" state to a more "fluid" state as temperature rises. Which outcome is most likely as fluidity increases?**

- A **Lateral diffusion of membrane proteins and lipids increases** ✓
- B Peptide bonds in membrane proteins break
- C All ion gradients across the membrane disappear instantly
- D Phospholipids stop being amphipathic
- E The bilayer becomes covalently cross-linked

▶ **Explanation:** Higher fluidity generally increases lateral movement of lipids and many proteins within the plane of the membrane. It does not directly break peptide bonds or instantly erase ion gradients (those require permeability changes or channels).

13 **Which membrane lipid movement is typically the SLOWEST without enzymes?**

- A Rotation of a phospholipid around its axis
- B Flexing of fatty acid tails
- C Lateral diffusion within one leaflet
- D **Flip-flop (movement from one leaflet to the other)** ✓
- E Vibration of bonds in the lipid tails

▶ **Explanation:** Flip-flop is slow because a polar head group would have to pass through the hydrophobic core. Lateral diffusion and rotation/flexing are relatively rapid.

14 **A flippase enzyme in the plasma membrane most directly helps maintain lipid asymmetry by:**

- A **Moving lipids from the outer leaflet to the inner leaflet in a selective way** ✓

- B Moving lipids randomly in both directions equally
- C Breaking phospholipids into fatty acids and glycerol
- D Adding double bonds to fatty acids
- E Making peptide bonds between membrane proteins

▶ **Explanation:** Flippases selectively move specific phospholipids (often inward) to maintain asymmetry. Randomization is more typical of scramblases. Lipases break lipids; desaturases add double bonds.

15 Which enzyme would most directly RANDOMIZE phospholipids between the two leaflets (reducing asymmetry), especially during cell stress?

- A Flippase
- B **Scramblase** ✓
- C ATP synthase
- D DNA polymerase
- E Peptidyl transferase

▶ **Explanation:** Scramblases move lipids in a less selective way and can collapse asymmetry. Flippases and floppases are more selective and often ATP-dependent.

16 Phosphatidylserine (PS) is normally enriched in the inner leaflet of the plasma membrane. Its exposure on the outer leaflet is a key signal for:

- A DNA replication
- B Protein translation
- C **Apoptosis recognition by phagocytes** ✓
- D Glycogen synthesis
- E Microtubule polymerization

▶ **Explanation:** Externalized PS acts as an “eat me” signal for phagocytic cells, helping remove apoptotic cells. It is not a signal for replication or translation.

17 **Glycolipids involved in cell recognition are most commonly located on which side of the plasma membrane?**

- A Cytosolic (inner) leaflet only
- B **Extracellular (outer) leaflet only** ✓
- C Evenly distributed between inner and outer leaflets
- D Only inside the nucleus
- E Only on mitochondrial inner membranes

▶ **Explanation:** Carbohydrate groups of glycolipids typically face the extracellular space, contributing to the glycocalyx and cell recognition. This asymmetry is a key concept.

18 **Lipid rafts are best described as membrane microdomains that are:**

- A Regions lacking cholesterol and rich in polyunsaturated fats
- B **Cholesterol- and sphingolipid-rich regions that are more ordered and often involved in signaling** ✓
- C Areas where phospholipids are covalently cross-linked
- D Nuclear pores made of lipids
- E Permanent holes in membranes for ion diffusion

▶ **Explanation:** Lipid rafts are enriched in cholesterol and sphingolipids, making them relatively ordered. They can concentrate certain proteins and support signaling and trafficking.

19 **A protein is attached to the OUTER surface of the plasma membrane via a GPI anchor. Which statement is most accurate?**

- A The protein is anchored to the cytosolic leaflet by a fatty acid tail
- B **The protein is anchored to the extracellular leaflet by a glycolipid-based anchor ✓**
- C The protein must span the membrane as an ion channel
- D The protein is anchored by a peptide bond to phospholipid heads
- E The protein is stored inside the nucleus until needed

▶ **Explanation:** GPI anchors tether proteins to the extracellular (outer) leaflet through a glycolipid linkage. These proteins do not necessarily span the membrane.

20 **Steroid hormones (e.g., cortisol) can often enter cells without a membrane transporter because they are:**

- A Large, highly charged polymers
- B **Hydrophobic molecules that can diffuse through the lipid bilayer ✓**
- C Ions that pass through lipid tails easily
- D Proteins that use ribosomes as carriers
- E Carbohydrates that cross via simple diffusion

▶ **Explanation:** Steroid hormones are largely nonpolar and can diffuse through lipid membranes. Many then bind intracellular receptors to regulate gene expression. Ions and polar molecules usually need transport proteins.

21 **Eicosanoids (like prostaglandins) are best described as:**

- A Long-term energy storage molecules made of three fatty acids

- B **Local signaling molecules derived from fatty acids ✓**
- C Primary structural components of DNA
- D Enzymes that break peptide bonds
- E Transporters that move ions across membranes

▶ **Explanation:** Eicosanoids are lipid-derived signaling molecules (often from arachidonic acid) that act locally and are involved in processes like inflammation and smooth muscle tone. They are not storage lipids like triglycerides.

22 Why do fats provide more energy per gram than carbohydrates when oxidized?

- A Fats contain more oxygen atoms per carbon
- B **Fats are more reduced (more C–H bonds), yielding more electrons for ATP production ✓**
- C Fats contain peptide bonds that release ATP directly
- D Fats are stored with large amounts of water, increasing mass
- E Carbohydrates cannot be oxidized in cells

▶ **Explanation:** Lipids are highly reduced, so their oxidation releases more high-energy electrons per gram than carbohydrates. Carbohydrates are already partially oxidized (more C–O bonds), yielding less energy per gram.

23 A key reason triglyceride stores are compact compared with glycogen stores is that triglycerides:

- A Must bind water molecules to remain stable
- B **Are hydrophobic and stored without much water, unlike glycogen ✓**
- C Are made of amino acids and fold tightly

- D Are positively charged and repel water
- E Form rigid crystals that occupy less space than liquids

▶ **Explanation:** Glycogen is hydrophilic and associates with a lot of water; triglycerides are hydrophobic and stored in lipid droplets with minimal water, making them more mass- and space-efficient energy stores.

24 Because most lipids are poorly soluble in water, the body transports many lipids in blood primarily as:

- A Free fatty acids dissolved directly in plasma at high concentration
- B **Lipoprotein particles with a hydrophobic core and hydrophilic surface** ✓
- C DNA–lipid complexes formed in the nucleus
- D Peptide-bond polymers called liposomes
- E Pure triglyceride droplets floating freely in plasma

▶ **Explanation:** Lipoproteins package hydrophobic lipids in a core (e.g., triglycerides, cholesteryl esters) with a hydrophilic surface (phospholipids and proteins) to move through watery plasma.

25 Which feature makes a lipoprotein particle soluble in blood plasma?

- A **A surface made mainly of phospholipid heads and apolipoproteins facing water** ✓
- B A surface made mainly of triglyceride tails facing water
- C A surface made mainly of DNA and RNA
- D A surface made mainly of cholesterol esters facing water
- E A surface made mainly of peptide bonds without side chains

▶ **Explanation:** Amphipathic phospholipids and apolipoproteins create a hydrophilic exterior that interacts with water. Hydrophobic molecules (triglycerides, cholesteryl esters) are kept in the core away from water.

26 Which statement correctly contrasts a phospholipid with a triglyceride?

- A Phospholipids have 3 fatty acid tails; triglycerides have 2
- B **Phospholipids are mainly structural membrane molecules; triglycerides are mainly energy-storage molecules** ✓
- C Triglycerides are amphipathic and form bilayers; phospholipids are fully hydrophobic
- D Triglycerides contain nitrogenous bases; phospholipids contain ribose
- E Phospholipids are polymers made by peptide bonds

▶ **Explanation:** Phospholipids are amphipathic (often 2 tails + phosphate head) and form bilayers. Triglycerides (3 tails) are mostly hydrophobic storage molecules and do not form bilayers on their own.

27 Vegetable oils are typically liquid at room temperature mainly because they contain:

- A Many long saturated fatty acids that pack tightly
- B **Many cis-unsaturated fatty acids that pack less tightly** ✓
- C Mostly peptide bonds that prevent crystallization
- D Large amounts of cholesterol, which always solidifies membranes
- E Only single-tailed detergents

▶ **Explanation:** Cis double bonds introduce kinks, preventing tight packing and lowering melting points—so many plant oils remain liquid at room temperature. Saturated fats pack tightly and are often solid.

28 **Partial hydrogenation of vegetable oil tends to make it more solid at room temperature mainly because it:**

- A Adds cis double bonds and increases kinks
- B **Removes some double bonds and can create trans double bonds, increasing packing** ✓
- C Adds phosphate heads, making it water-soluble
- D Breaks triglycerides into amino acids
- E Turns fatty acids into carbohydrates

▶ **Explanation:** Hydrogenation reduces unsaturation and may convert some cis bonds to trans, both of which allow tighter packing and raise melting point, making oils more solid.

29 **Waxes (wax esters) are especially useful for organisms mainly because they:**

- A Are highly polar and dissolve easily in water
- B **Are hydrophobic and form water-resistant protective coatings** ✓
- C Are the main component of ribosomes
- D Form ion channels in membranes
- E Are made of nucleotides and store genetic information

▶ **Explanation:** Waxes are strongly hydrophobic and help prevent water loss and provide protective coatings (e.g., plant cuticle). They are not genetic material or membrane channels.

30 **Which statement BEST distinguishes sphingolipids from many common phospholipids?**

- A **Sphingolipids have a sphingosine backbone instead of a glycerol backbone ✓**
- B Sphingolipids are made of amino acids linked by peptide bonds
- C Sphingolipids are always water-soluble and do not enter membranes
- D Sphingolipids contain ribose sugars as their backbone
- E Sphingolipids cannot contain fatty acid chains

▶ **Explanation:** Many phospholipids are glycerophospholipids (glycerol backbone). Sphingolipids use a sphingosine backbone and are common in membranes (often enriched with cholesterol in rafts).

31 Myelin membranes are particularly lipid-rich. Which composition pattern best supports their insulating role?

- A High triglycerides only, no cholesterol
- B **High cholesterol and sphingolipids, creating a tightly packed, less permeable membrane ✓**
- C High glucose and amino acids forming a gel layer
- D High RNA content for rapid signaling
- E High free ions to accelerate conduction directly through the membrane

▶ **Explanation:** Myelin is enriched in lipids like cholesterol and sphingolipids, producing an insulating, low-permeability sheath that helps electrical signals travel efficiently along axons.

32 Cardiolipin is a distinctive phospholipid found in high amounts in which membrane, supporting energy-related protein complexes?

- A Plasma membrane outer leaflet
- B **Inner mitochondrial membrane ✓**
- C Nuclear envelope outer membrane only

D Golgi lumen

E Ribosome surface

▶ **Explanation:** Cardiolipin is strongly associated with the inner mitochondrial membrane, where it supports the function and organization of respiratory chain complexes involved in ATP production.

33 Archaea often survive extreme environments partly because their membrane lipids commonly contain:

A Ester-linked fatty acids on glycerol (like typical bacteria)

B **Ether-linked isoprenoid chains, which are more chemically stable** ✓

C Peptide bonds linking hydrocarbons

D Cellulose microfibrils embedded in the membrane

E Phosphodiester bonds like DNA

▶ **Explanation:** Archaeal membrane lipids typically use ether linkages and isoprenoid chains, which can increase stability under heat, acidity, or salinity compared with ester-linked fatty acids.

34 Which enzyme class most directly hydrolyzes triglycerides into glycerol and fatty acids?

A Proteases

B **Lipases** ✓

C Kinases

D Polymerases

E Ligases

▶ **Explanation:** Lipases hydrolyze ester bonds in triglycerides to release fatty acids and glycerol. Proteases act on peptide bonds; polymerases copy nucleic acids; kinases add phosphate groups.

35 A signal causes phospholipase C to cleave a membrane phospholipid called PIP2. Which products are formed (concept level)?

- A ATP and ADP
- B DNA and RNA
- C **DAG (diacylglycerol) and IP3 (inositol trisphosphate)** ✓
- D Glycogen and glucose
- E Cholesterol and bile salts

▶ **Explanation:** Phospholipase C cleaves PIP2 into DAG (stays in the membrane) and IP3 (diffuses into the cytosol). This is a classic lipid-based signaling pathway.

36 Why does DAG (diacylglycerol) usually remain in the membrane after being produced from PIP2?

- A DAG is highly charged and attracted to water
- B **DAG is hydrophobic (two fatty acid tails) and partitions into the lipid bilayer** ✓
- C DAG forms covalent bonds to DNA, trapping it in the nucleus
- D DAG is a protein and cannot leave the membrane
- E DAG is pumped into the membrane by ATP synthase

▶ **Explanation:** DAG retains two hydrophobic tails and lacks a strongly hydrophilic head, so it stays embedded in the bilayer, where it can recruit/activate signaling proteins.

37 **A major function of cholesterol in cells is NOT only as a membrane component, but also as a precursor for:**

- A **Steroid hormones ✓**
- B Amino acids
- C DNA nucleotides
- D Cellulose
- E Peptide bonds

▶ **Explanation:** Cholesterol is a steroid lipid and serves as a precursor for steroid hormones (and other steroid-derived molecules). It is not a precursor for amino acids, nucleotides, cellulose, or peptide bonds.

38 **Which statement correctly distinguishes cholesterol from a cholesteryl ester?**

- A Cholesteryl esters are more amphipathic than cholesterol
- B **Cholesteryl esters have a fatty acid attached, making them more hydrophobic and suited for storage/transport in cores ✓**
- C Cholesteryl esters form the polar head group of phospholipids
- D Cholesterol cannot be found in membranes, only cholesteryl esters can
- E Cholesteryl esters are carbohydrates linked to cholesterol

▶ **Explanation:** Esterifying cholesterol's hydroxyl group with a fatty acid removes much of its polarity, making cholesteryl esters highly hydrophobic—ideal for storage and for lipoprotein cores. Free cholesterol is more amphipathic and fits into membranes.

39 **Which explanation best accounts for why cis double bonds increase membrane fluidity?**

- A **They create kinks that reduce tight packing of lipid tails ✓**
- B They add positive charges to fatty acids
- C They increase hydrogen bonding between tails
- D They convert fatty acids into proteins
- E They form covalent crosslinks between phospholipids

▶ **Explanation:** Cis double bonds introduce a bend that prevents close packing, weakening van der Waals interactions and increasing fluidity (lowering melting temperature).

40 A researcher punctures an artificial phospholipid bilayer (liposome) with a fine needle. Why can such bilayers often "self-seal" after small disruptions?

- A Because phospholipids form covalent bonds instantly to repair holes
- B **Because exposed hydrophobic tails are energetically unfavorable in water, driving lipids to rearrange and close the gap ✓**
- C Because ATP-driven pumps pull lipids into place
- D Because DNA repair enzymes fix membrane breaks
- E Because peptide bonds in the membrane tighten like a zipper

▶ **Explanation:** Exposing hydrophobic tails to water is energetically costly. Lipids rearrange to minimize this exposure, which favors resealing. This is a physical-chemical property, not a covalent repair or ATP-driven process in simple liposomes.