

Multiple choice. Circle the letter corresponding to the single most correct answer for each of the following. [2 points each]

1) *Water potential* is properly defined as:

- a) the potential for water to dissolve nutrient ions
- b) the saturated water concentration at a particular temperature
- c) the difference in osmotic pressure between two points in space
- d) the free energy of water relative to that of pure water at standard conditions
- e) the energy required to vaporize liquid water

2) The equation or law describing the flow rate of liquid water through a plant in relation to the pressure gradient in the xylem and the xylem conductivity is:

- a) Newton's law of cooling
- b) Darcy's law
- c) van't Hoff's equation
- d) Steffan Boltzman law
- e) Poiseuille's law

3) The correct mathematical expression for the relationship referenced in question #2, above, for the flow rate of water from roots to leaves in a plant (where J is flow rate in $\text{m}^3 \text{s}^{-1}$, Ψ_{roots} is the water potential of the roots in MPa, Ψ_{leaves} is the water potential of leaves in the plant in MPa, and k is the hydraulic conductivity from roots to leaves in $\text{m}^3 \text{s}^{-1} \text{MPa}^{-1}$) is:

- a) $J = (\Psi_{\text{roots}} - \Psi_{\text{leaves}}) \times k$
- b) $J = (\Psi_{\text{roots}} + \Psi_{\text{leaves}}) \times k$
- c) $J = (\Psi_{\text{roots}} / \Psi_{\text{leaves}}) - k$
- d) $J = k / \Psi_{\text{roots}} + k / \Psi_{\text{leaves}}$
- e) $J = (\Psi_{\text{roots}} - \Psi_{\text{leaves}}) / k$

4) The water flow rate through a plant, J (in $\text{m}^3 \text{s}^{-1}$), from roots to leaves, when Ψ_{roots} is -0.1 MPa, Ψ_{leaves} is -1.2 MPa, and k is $0.04 \text{ m}^3 \text{ s}^{-1} \text{MPa}^{-1}$ is:

- a) 27.5
- b) -0.052
- c) 0.0433
- d) -32.5
- e) 0.0440

5) The equation or law describing the osmotic potential of a solution in relation to the solute concentration and temperature is:

- a) Newton's law of cooling
- b) Darcy's law
- c) van't Hoff's equation
- d) Steffan Boltzman law
- e) Poiseuille's law

6) The correct mathematical expression for the relationship referenced in question #5, above, for the osmotic potential of a solution (where Ψ_o is the solution osmotic potential in MPa, R is the universal gas constant [8.3134 J K⁻¹ mol⁻¹], T is temperature in kelvins, and c is solute concentration in mols m⁻³) is:

- a) $\Psi_o = (-R / Tc) \times 10^{-6}$
- b) $\Psi_o = (RTc) \times 10^{-6}$
- c) $\Psi_o = (R - Tc) \times 10^{-6}$
- d) $\Psi_o = (c / (R - T)) \times 10^{-6}$
- e) $\Psi_o = (-RTc) \times 10^{-6}$

7) The osmotic potential of a solution, Ψ_o (in MPa), when temperature, T , is 289 kelvins and solute concentration, c , is 450 mols m⁻³ is:

- a) -1.60×10^{-6}
- b) 1.08
- c) -1.08
- d) -0.13
- e) -1.29×10^{-5}

8) A plant with an internal water status that remains relatively constant despite large changes in the moisture content of its surroundings is termed a _____ plant.

- a) phreatophytic
- b) heliotropic
- c) poikilohydric
- d) hydrophilic
- e) homeohydric

9) The equation or law describing the rate of longwave radiation emitted by a leaf in relation to leaf temperature is:

- a) Newton's law of cooling
- b) Darcy's law
- c) van't Hoff's equation
- d) Steffan Boltzman law
- e) Poiseuille's law

10) The correct mathematical expression for the relationship referenced in question #9, above, for the longwave radiation emitted by one side of a leaf in $W m^{-2}$ (where ϵ is emissivity [=0.97 for plant leaves], σ is a constant [$5.67 \times 10^{-8} W m^{-2} K^{-4}$] and T is temperature in kelvins) is:

- a) $LR_{em} = \epsilon\sigma T^4$
- b) $LR_{em} = \epsilon\sigma / T^4$
- c) $LR_{em} = \epsilon - \sigma T$
- d) $LR_{em} = \epsilon^4 / \sigma T$
- e) $LR_{em} = \epsilon\sigma T$

11) The longwave radiation emitted by one side of a leaf, LR_{em} (in $W m^{-2}$), when leaf temperature is 275 kelvins is:

- a) 0.97
- b) 1.5×10^{-5}
- c) 9.6×10^{-18}
- d) 4.3×10^9
- e) 314.5

12) The law describing the rate of convective heat loss from a leaf in relation to the leaf temperature, air temperature and boundary layer thickness is:

- a) Newton's law of cooling
- b) Darcy's law
- c) van't Hoff's equation
- d) Steffan Boltzman law
- e) Poiseuille's law

13) The thickness of the air boundary layer over a leaf is related to these two parameters:

- a) wind speed and leaf width
- b) solar radiation and leaf color
- c) leaf color and wind speed
- d) leaf volume and solar radiation
- e) leaf width and leaf volume

14) Of the total amount of energy absorbed by plants from solar radiation, approximately what proportion is absorbed from 0.7 to 3.0 micrometers wavelength?

- a) 8%
- b) 15%
- c) 25%
- d) 40%
- e) 60%

15) The term **field capacity** as used to describe soil moisture refers to:

- a) the mass of dry soil divided by its saturated water content
- b) the permanent wilting point minus the osmotic potential
- c) the total amount of soil water held by matric forces minus at the permanent wilting point
- d) the water content of soil after complete wetting and gravitational drainage
- e) the osmotic potential of soil at standard temperature and pressure conditions

16) A **nurse plant** is one that:

- a) can repair photo-oxidative damage caused by excess sunlight under chilling temperatures
- b) facilitates establishment of seedlings beneath its canopy through its moderating effect on the harsh microclimate
- c) releases chelators into the soil solution to improve uptake of nutrients
- d) avoids direct shortwave radiation by leaf movements
- e) develops a high root to shoot ratio under drought conditions

17) Forced convection refers to:

- a) heat dissipation from turbulent movement of air over a surface induced by wind
- b) strong adhesive forces between water and cell surfaces driving water movement
- c) heat dissipation from vaporization of water at leaf surfaces
- d) active transport of water through a plant

18) A plant that establishes a deep root system to tap into the local groundwater table is a:

- a) phreatophyte
- b) epiphyte
- c) periphyte
- d) halophyte
- e) periphyte

19) The stunted and shrubby form that trees take on at upper tree line at high altitude is referred to as the _____ growth form.

- a) tussock
- b) giant rosette
- c) Krumholz
- d) cushion

20) The soil water potential at which a plant can no longer absorb water and suffers damage is often termed the:

- a) soil water holding capacity
- b) soil osmotic potential
- c) permanent wilting point
- d) available soil water
- e) soil matric potential

21) Chilling temperatures (between 0 and 10°C) can be very detrimental to some plant species because of cell membrane impairment. Why are cell membranes so sensitive to chilling temperatures? Provide a detailed chemical explanation. **[6 points]**

22) Describe the mechanism causing cavitation in tracheids and vessels of plant xylem during a freeze-thaw event. Now explain why there is a trade-off between vulnerability to freeze-thaw cavitation and hydraulic conductance through a plant. **[6 points]**

23) Describe *three* (3) adaptations in sagebrush (*Artemisia tridentata*) that allow this beautiful shrub to survive the hot, dry summers on western rangelands. **DO NOT** just **LIST** these adaptations. Rather **describe** each one in enough detail to show that you know why these adaptations are important for sagebrush. **[9 points]**

24) The tree growth form is not found in high elevation environments where mid-summer temperatures average less than about 10°C. Why? What is the ecophysiological explanation for this observation? **[6 points]**

25) Explain one physiological mechanism in roots allowing plants to take up calcium ions (Ca^+) from the soil solution *against* a Ca^+ concentration gradient from soil to root. **[6 points]**

26) What evidence was presented in lecture to suggest that above ground net primary production (ANPP) in ecosystems of arid and semiarid areas is likely to be MORE sensitive to changes in precipitation amount than in ecosystems of wetter areas? Clearly describe this evidence. **[9 points]**

27) Describe, do not just list, four (4) mechanisms or characteristics that allow plants to survive in the alpine environment at high elevation. **[8 points]**

28) The figure below is taken from the lecture slides. It shows the relationship for phosphorus (open symbols) and potassium (filled symbols) uptake rates per unit root mass (y axis) across a range of root length densities (x axis). First, why do the uptake rates per unit root mass **DECLINE** with increases in root length density? Second, why is the decline more pronounced for potassium than for phosphorus? **[10 points]**

