Choose the best single answer to multiple-choice and true-false questions.

**A. Thermohaline Circulation (5 questions, 10 pts.)**

1. Mediterranean Intermediate Water is the saltiest and densest water mass in the world ocean.
   A. true  
   B. false

2. Antarctic Bottom Water is the coldest and densest water mass in the world ocean.
   A. true  
   B. false

3. North Atlantic Deep Water formation:
   A. occurs in the subantarctic Atlantic from the cooling of relatively salty water derived from the Southern Ocean  
   B. is unimportant in the ocean's thermohaline circulation  
   C. may be enhanced by ice melting in higher latitudes  
   D. may play a role in future anthropogenic climate change as previous reductions in its intensity have been linked to transitions from interglacial to glacial conditions.  
   E. none of the above.

4. Heinrch events:
   A. are recognized in deep-sea cores from the North Atlantic as distinctive clay layers  
   B. are correlated with warming events during the last ice age  
   C. are associated with an intensification of North Atlantic Deep Water formation  
   D. all of the above  
   E. none of the above

5. Nutrient concentrations are higher in the deep waters of the Pacific Ocean than in the deep waters of the North Atlantic.
   A. true  
   B. false
B. Wind-Driven Circulation and the El Nino/Southern Oscillation (8 questions, 16 points)

6. Coriolis force:
   A. arises from the earth’s rotation
   B. accounts for the counter-clockwise rotation of the subtropical gyres in the Northern Hemisphere
   C. accounts for the clockwise rotation of the subtropical gyres in the Northern Hemisphere
   D. A and B are correct
   E. A and C are correct

7. Cyclonic circulation is:
   A. clockwise in the Northern Hemisphere
   B. counter-clockwise in the Northern Hemisphere
   C. associated with high pressure cells
   D. never in geostrophic balance
   E. A and C are correct

8. In the atmosphere, air rises at the equator, descends at mid-latitudes, rises at the polar front, and descends at the poles.
   A. true
   B. false

9. Ekman transport is always 45° to the left of the wind in the Southern Hemisphere.
   A. true
   B. false

10. The Ekman spiral:
    A. is maintained by a balance of Coriolis and gravitational forces
    B. is maintained by a balance of Coriolis, wind shear, and viscous (frictional) forces
    C. leads to a surface current 45° to the right of the wind in the Northern Hemisphere
    D. A and C are correct
    E. B and C are correct
11. During typical (non-El Nino/Southern Oscillation) years:
   A. a pronounced atmospheric low pressure system forms over the eastern tropical Pacific
   B. a pronounced atmospheric low pressure system forms over Hawaii
   C. a distinctive "warm pool" of water forms in eastern tropical Pacific
   D. all of the above
   E. none of the above

12. During El Nino/Southern Oscillation years, global weather patterns are altered, including:
   A. more fires and droughts in Indonesia and Australia
   B. weaker coastal upwelling of cold, nutrient-rich water off Peru
   C. more winter storms and rainfall in southern California
   D. all of the above
   E. none of the above

   A. true
   B. false

C. Global Climate Change (8 questions, 16 points)

14. The impacts of global warming, due to the burning of fossil fuels, an increase in atmospheric carbon dioxide concentration, and the subsequent greenhouse effect, are well known and not controversial.
   A. true
   B. false

15. Most of solar radiation reaching the earth’s surface is in which part of the electromagnetic spectrum?
   A. ultraviolet
   B. visible
   C. infrared
   D. microwave
   E. none of the above
16. Greenhouse gases include:
   A. carbon dioxide
   B. ozone
   C. water vapor
   D. none of the above
   E. answers A and C

17. Measurements showing an increase in atmospheric carbon dioxide concentration have been collected at Mauna Loa, Hawaii since the late 1950’s.
   A. true
   B. false

18. The Intergovernmental Panel on Climate Change (IPCC) has concluded that there is evidence for a human impact on mean global temperature during the past century.
   A. true
   B. false

19. The Kyoto Accord on international carbon dioxide emission standards was supported by Al Gore and has been strongly supported by the current US administration.
   A. true
   B. false

20. As the video we saw in class pointed out, if we had the political willpower, renewable energy sources, such as wind and solar power, could provide all of the world’s current and future energy needs without requiring any fundamental changes in either the lifestyles of people in the developed world or the aspirations of people in the developing world.
   A. true
   B. false

21. Global warming:
   A. will be greatest at higher latitudes
   B. will likely influence global patterns of precipitation and drought
   C. will likely affect the distribution and health of coral reefs
   D. will likely have dramatic effects during your lifetime
   E. all of the above
D. The Biological Pump and Global Patterns of Primary Productivity (6 questions, 12 points)

22. The depth in the water column at which the respiration and photosynthetic rate are equal at any given instant in time is called the compensation depth.
   A. true
   B. false

23. The following areas are high nutrient, low chlorophyll regions of the world ocean:
   A. the Subarctic Atlantic Ocean
   B. the Subarctic Pacific Ocean
   C. the Southern Ocean
   D. the Equatorial Pacific Ocean
   E. answers B, C and D are correct

24. The spring bloom of phytoplankton in the surface waters of high latitude oceans occurs when:
   A. the mixed layer depth becomes shallower than the critical depth
   B. nutrients are regenerated rapidly by zooplankton grazers
   C. increased wind mixing injects nutrients into the surface waters
   D. zooplankton grazing declines as large copepods go into diapause
   E. answers B and C are correct

25. Primary production in these high nutrient, low chlorophyll regions of the world ocean:
   A. is often or always iron limited.
   B. is usually light limited for much of the summer.
   C. is usually phosphate limited.
   D. is always nitrogen limited during peak upwelling season.
   E. answers A and D are correct.

26. In the surface waters of high latitude oceans, the winter is characterized by:
   A. high phytoplankton abundance
   B. strong thermal stratification
   C. low zooplankton abundance
   D. low light availability
   E. answers C and D are correct.
27. On an area basis (production of organic carbon/m² • year), primary production is highest in:
   A. coastal upwelling ecosystems  
   B. open ocean ecosystems  
   C. the Antarctic (or Southern Ocean) ecosystem  
   D. typical coastal ecosystems  
   E. answers A and D are correct

E. Secondary Production, Marine Food Chains, and the Microbial Loop (7 questions, 14 points)

28. The longest marine food chains typically are found in:
   A. coastal upwelling ecosystems  
   B. open ocean ecosystems  
   C. the Antarctic (or Southern Ocean) ecosystem  
   D. typical coastal ecosystems  
   E. answers A and D are correct

29. The marine food chain concept:
   A. is a conceptual simplification of the complex trophic interactions in the ocean  
   B. can be used to make simple estimates of energy transfer through marine ecosystems  
   C. in its traditional form, involves the transfer of energy from phytoplankton to zooplankton to fish  
   D. all of the above.  
   E. answers B and C are correct.

30. The food chain of a coastal ecosystem has a mean primary production of 100,000 tons C/yr, a food chain efficiency of 10%, and a 3-link food chain of:
   **phytoplankton => zooplankton => planktivorous fish => top predator**

   A reasonable prediction of top predator production for this ecosystem is:
   A. 1 ton C/yr  
   B. 10 tons C/yr  
   C. 100 tons C/yr  
   D. 1,000 tons C/yr  
   E. 10,000 tons C/yr
31. The food chain of an upwelling ecosystem has a mean primary production of 1,000,000 tons C/yr, a food chain efficiency of 10%, and a 2-link food chain of:

\textbf{phytoplankton} \Rightarrow \textbf{planktivorous fish} \Rightarrow \textbf{top predator}

Top predator production is two orders of magnitude higher (100x) in this upwelling ecosystem relative to the coastal ecosystem in the previous question due in equal parts to higher primary production and a shorter food chain.

A. true
B. false

32. A substantial fraction of the ocean’s primary producers has only been discovered during the last few decades thanks to the advent of new microscopic and staining techniques enabling us to quantify smaller organisms.

A. true
B. false

33. In low-nutrient, open-ocean ecosystems, small phytoplankton and protozoan grazers predominate, and the microbial loop provides an important source of nutrient recycling.

A. true
B. false

34. Heterotrophic microzooplankton are small “animal plankton” that gain all of their nutritional requirements by ingesting small living or non-living particles of organic matter.

A. true
B. false

F. Life on Rocky Shores (6 questions, 12 points)

35. Of the three types of hydrodynamic forces affecting intertidal organisms, drag is a function of the organism’s surface area and displacement volume.

A. true
B. false

36. Organisms that ingest sediments and extract their food from the organic material on or between the sediment particles are called deposit feeders.

A. true
B. false
37. Organisms that undergo a life cycle with a larval stage and metamorphosis to a juvenile stage exhibit direct development.
   A. true
   B. false

38. In the Far Side cartoon shown above, the husband, Bill, tells his wife, "Well, we'll never want for food, Doris… This rock is absolutely encrusted with oysters and mussels all the way to the top!" This cartoon is funny because:
   A. everybody knows that you cannot live for very long eating oysters and mussels
   B. there is obviously no freshwater to drink
   C. Bill and Doris are in for a rude shock when the tide comes in
   D. Doris is allergic to oysters
   E. with no trees for shade, Bill and Doris will get terribly sunburned

39. The starfish *Pisaster* is the classic Keystone Predator of the rocky intertidal.
   A. true
   B. false
40. The Intermediate Disturbance Hypothesis states that:
   A. the highest species diversity is found at the lowest levels of physical disturbance
   B. the lowest species diversity is found at intermediate levels of physical disturbance
   C. the highest species diversity is found at the highest levels of physical disturbance
   D. all of the above
   E. none of the above

G. Coral Reefs, Bleaching and Marine Diseases (10 questions, 20 points)

41. Coral bleaching involves:
   A. whitening of the coral skeleton from solar UV radiation
   B. the loss of coral tissue in competitive interactions with benthic algae
   C. the loss of coral tissue due to the feeding by fish
   D. the loss of symbiotic algae, called zooxanthellae, by the coral due to heat stress
   E. the loss of zoobots by the coral

42. An interesting aspect of the fungal pathogen attacking sea fans in the Caribbean Sea is its terrestrial origin; it is not an exclusively marine species.
   A. true
   B. false

43. Global warming may increase the incidence of diseases in the ocean by:
   A. by stressing and thereby reducing the resistance of hosts
   B. enhancing the virulence of pathogens
   C. expanding the range of pathogens
   D. all of the above
   E. none of the above.

44. Diseases of sea urchins have had a large effect on coral reef communities in the Caribbean.
   A. true
   B. false

45. The Caribbean Sea and Mediterranean Sea are the two centers of coral reef species diversity.
   A. true
   B. false
46. Between now and 2050, the largest threat to coral reefs worldwide is oil pollution.
   A. true
   B. false

47. Hermatypic corals of coral reef ecosystems:
   A. are dependent on symbiotic algae for most of their nutritional needs
   B. are dependent on chemosynthesis as a major source of nutrition
   C. require relatively shallow (< 100 m), sunlit waters
   D. all of the above
   E. answers A and C are correct

48. Coral reefs grow well:
   A. in tropical oceanic waters between 20 - 30 degrees Centigrade
   B. near the discharge of major rivers
   C. in turbid waters shallower than 30 meters
   D. all of the above
   E. none of the above

49. The Caribbean-wide die-off of sea urchins had little effect on Caribbean coral reefs since sea otters had already kept these important grazers of kelp in check.
   A. true
   B. false

50. Massive coral bleaching events:
   A. have been observed for much of recorded history
   B. are often associated with El Nino/Southern Oscillation events
   C. were first observed in the 1970’s
   D. answers A and B are correct
   E. answers B and C are correct