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10th International Biology Olympiad

Theoretical test 1999-07-08

The theoretical test is composed of three parts:

In part A, all questions are multiple choice questions with one and only one correct answer. You always mark the correct answer with a cross (X) on the line in front of it.

In part B, all questions are multiple choice questions, but in each question any number among the answers may be correct. Thus, there may be only one correct answer, or several, or all answers may be correct. You must mark exactly and only those answers that are correct. You always mark the correct answers with a cross (X) on the lines in front of them.

In part C, the questions are constructed in various ways, and you have to read for each question how the answer is to be given. Often you answer by writing one or a few digits or characters, and then these must be distinct and legible, otherwise your answer will not be judged as correct.

Surname

First name

Country

Code number

10th International Biology Olympiad

Theoretical test 1999-07-08

Part A

In this part, all questions are multiple choice questions with one and only one correct answer.

You always mark the correct answer with a cross (X) on the line in front of it.

Cell Biology, Microbiology & Biotechnology

1. Almost all cells in an animal contain the same genes. The cells are different in structure and function because they synthesize different . . .

(1p)

- A. . . . tRNA molecules.
- B. . . . mRNA molecules.
- C. . . . histones.
- D. . . . ribosomes.

2. Vesicles from the smooth endoplasmic reticulum most likely are on their way to the . . .

(1p)

- A. . . . rough endoplasmatic reticulum.
- B. . . . lysosomes.
- C. . . . Golgi apparatus.
- D. . . . plant cell vacuole.

3. In the thylakoid membranes of the chloroplast there are two photosystems, PS I and PS II.

3a. Are both of these photosystems associated with light harvesting pigments?

(1p)

_____ A. Yes both.

_____ B. Only PS I.

_____ C. Only PS II.

3b. The splitting of water results in three products: oxygen, protons and electrons. Which of these are used in the photosynthetic light reaction?

(1p)

_____ A. All three of them.

_____ B. Oxygen and protons.

_____ C. Protons and electrons.

_____ D. Oxygen and electrons.

_____ E. Only electrons.

3c. Some photosynthetic and anaerobic bacteria do not split water but another compound instead. Which compound?

(1p)

_____ A. Hydrogen sulfide, H_2S .

_____ B. Methane, CH_4 .

_____ C. Sodium sulfate, Na_2SO_4 .

_____ D. Ethylene, C_2H_4 .

4. What is cytokinesis?

(1p)

- _____ A. Mitosis.
- _____ B. Division of the cytoplasm.
- _____ C. Cytoplasmic streaming during interphase.
- _____ D. Cell crawling.
- _____ E. Flagellar locomotion of a sperm.

5. In which order do the following processes take place during mitosis in animals and plants?

(1p)

- I The nuclear envelope breaks down.
- II The chromosomes move to the middle ("equator") of the spindle.
- III Microtubules attach to kinetochores.
- IV Daughter chromosomes move apart.

- _____ A: I, II, III, IV
- _____ B: II, III, I, IV
- _____ C: I, III, II, IV
- _____ D: IV, III, II, I

6. In which order do the following events take place during meiosis in animals and plants?

(1p)

- I Formation of synaptonemal complex (SC) and pairing of homologous chromosome regions.
- II Crossing over, i.e. exchange of nonsister chromatid regions.
- III Cessation of pairing of homologous chromosome regions.
- IV Cessation of association between sister chromatid regions. However, association between sister chromatid regions in the centromere region still prevails.
- V Formation of chiasmata.

_____ A: I, II, III, IV, V

_____ B: I, II, III, V, IV

_____ C: I, V, II, III, IV

_____ D: I, III, IV, V, II

7. Myxobacteria are said to be "social" bacteria, because they can aggregate to form multicellular structures. To form these multicellular structures, the bacteria communicate with each other using chemical signals, one of which is cyclic AMP (cAMP). A scientist is cultivating myxobacteria on a semi-solid surface where the bacteria can move. He is applying a gradient of cAMP to the culture vessel, so that the concentration of this compound is much higher at one end of the vessel than at the opposite.

Where does he find the bacteria in the vessel?

(1p)

- A. At the end where the cAMP concentration is highest.
- B. At the end where the cAMP concentration is lowest.
- C. At the middle, where the cAMP concentration is intermediate.
- D. Evenly dispersed all over the vessel.

8. Human superoxide dismutase (hSOD, an enzyme converting the superoxide radical, O_2^- , to peroxide, O_2^{2-}) is a remarkable enzyme: heat resistant, and stable to proteases and detergents. It is of considerable medical interest for its potential in treating various human syndromes caused by oxidation damage. You have access to cDNA encoding this enzyme, and want to clone it for large-scale production. Which of the following vectors (DNA molecule into which to clone your hSOD gene) is the most suitable choice for cloning this gene?

(1p)

- _____ A. A bacterial plasmid providing the cloned gene with a signal sequence causing its export out of the cell.
- _____ B. A bacterial virus that replicates to produce a high number of new virions, and then lyses the cell.
- _____ C. A eukaryotic high-copy-number plasmid (high copy number = the plasmid is present in a very high number in each cell that harbors it).
- _____ D. A eukaryotic plasmid providing the cloned gene with a signal sequence causing its export out of the cell.

Plant Anatomy & Physiology

9. What is the primary cause of the inability of non-halophyte plants to grow in soils of high salt concentration?

(1p)

- A. Mineral ions are poisonous to the plants.
- B. The water potential of the soil is too low.
- C. The oxygen content of the soil is too low.
- D. Salt-loving nematodes feed on the root hairs.
- E. A crust of salt close to the soil surface makes it difficult for young seedlings to penetrate the soil.
- F. Salt crystals form in the stomata and stop the gas exchange.

10. From which layer in a young tree stem do aphids (the insect family Aphididae) obtain their nutrition?

(1p)

- A. The cambium.
- B. The layer outside the cambium.
- C. The layer inside the cambium.
- D. Different layers depending on the age of the plant.
- E. Different layers depending on the aphid's age and stage of development.

11a. What is the plant diplophase called?

(1p)

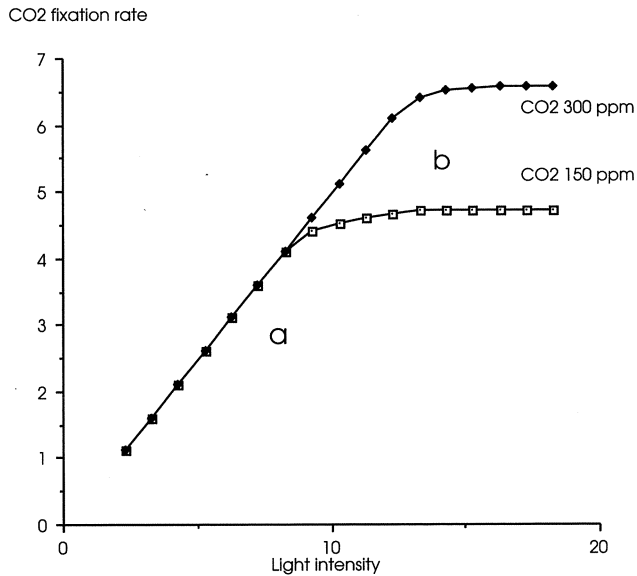
- A. Mesophyte.
- B. Gametophyte.
- C. Endospermatophyte.
- D. Allelophyte.
- E. Sporophyte.
- F. Zygotophyte.
- G. Cormophyte.
- H. Chrocophyte.
- I. Diplophyte.

11b. What is the plant haplophase called?

(1p)

- A. Mesophyte.
- B. Gametophyte.
- C. Endospermatophyte.
- D. Chrocophyte.
- E. Cormophyte.
- F. Haplophyte.
- G. Sporophyte.
- H. Allelophyte.
- I. Egg-plant.

12. This graph shows how the CO₂ fixation rate of a plant varies with light intensity and different CO₂ concentrations in the air:



Which of the following interpretations of the linear portion (a) of the curve is correct? It represents the part where CO₂ fixation rate is limited by . . .

(1p)

- A. . . CO₂.
- B. . . light.
- C. . . CO₂ and light.
- D. . . temperature.

13. The carrot (*Daucus carota*) belongs to a group of plants we call rosette plants, because they grow into a rosette of leaves in the first year and build up a supply of food in their roots. If such a plant is left in the field over the winter, the root and the stem tip will survive, and in the next summer it will grow into a long stem with leaves and flowers and then develop fruits and seeds. Then it will die.

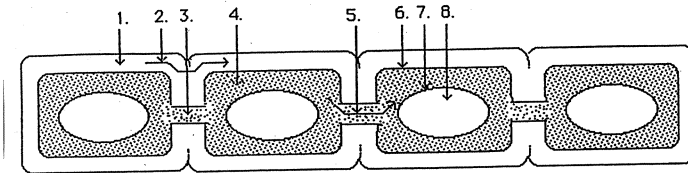
However, it is possible to keep it alive and growing for several years without flowering. What treatment is appropriate?

(1p)

- _____ A. Spray with gibberellin every second month.
- _____ B. Keep it in a glasshouse with a constant temperature of 20 °C.
- _____ C. Plant it in a very poor soil.
- _____ D. Dig it up every autumn and place it in a refrigerator during the winter.
- _____ E. Cut off the leaves before they wilt after the summer.

14. The drawing shows some leaf cells. The arrows (1-8) mark parts of the cells and pathways where water can pass. Which of the statements (A-D) provides a correct explanation of the drawing?

(1p)



- ___ A. 1 = symplast, 2 = symplastic pathway, 3 = plasmodesma, 4 = apoplast,
5 = apoplastic pathway, 6 = plasma membrane, 7 = vacuole membrane,
8 = stoma
- ___ B. 1 = apoplast, 2 = apoplastic pathway, 3 = plasmodesm, 4 = symplast,
5 = symplastic pathway, 6 = vacuole membrane, 7 = plasma membrane,
8 = vacuole
- ___ C. 1 = symplast, 2 = apoplastic pathway, 3 = cytoplasm, 4 = cell wall,
5 = symplastic pathway, 6 = vacuole membrane, 7 = plasma membrane,
8 = stoma
- ___ D. 1 = apoplast, 2 = apoplastic pathway, 3 = plasmodesm, 4 = symplast,
5 = symplastic pathway, 6 = plasma membrane, 7 = vacuole membrane,
8 = vacuole

Animal Anatomy & Physiology

15. The taste quality detected by taste buds located on the posterior third of the human tongue is . . .

(1p)

- A. . . . sweet.
- B. . . . sour.
- C. . . . bitter.
- D. . . . salty.

16. An antidiuretic hormone . . .

(1p)

- A. . . . increases plasma osmolality (solute potential).
- B. . . . decreases sodium reabsorption from the ascending limb of the loop of Henle.
- C. . . . decreases plasma glucose after meals.
- D. . . . decreases urea reabsorption.
- E. . . . increases free-water transfer from the distal tubule and collecting duct to the

capillary blood.

17. Hyperthyroidism is characterized by . . .

(1p)

- A. . . . increased metabolic rate, increased heart rate, weight gain.
- B. . . . increased metabolic rate, increased heat production, weight loss.
- C. . . . increased heat production, increased oxygen consumption, weight gain.
- D. . . . increased heart rate, weight loss, sleepiness.

18. At what stage does implantation into the uterus of a woman occur?

(1p)

- A. Zygote.
- B. Unfertilized egg cell.
- C. Gastrula.
- D. Blastocyst.

19. Deleted

Plant Anatomy & Physiology

20. The spectrum of light reaching the ground under a canopy in a forest differs from the light reaching the ground in an open field.

20a. This difference is mostly due to a certain plant molecule. Which?

(1p)

- A. Rubisco.
- B. Chlorophyll.
- C. Phytochrome.
- D. Cellulose.
- E. Tabasco.

20b. In what respect does the light under a canopy differ from the light in an open field?

(1p)

- A. The ratio of blue to green light is higher.
- B. The ratio of red to far red light is higher.
- C. The ratio of red to green light is higher.
- D. The ratio of far red to red light is higher.

20. (continued)

20c. Plants respond to the composition of light through the action of a certain compound. Which compound?

(1p)

- A. Gibberellin.
- B. Cytokinin.
- C. Phytochrome.
- D. Rhodopsin.
- E. Cytochrome.

20d. In which of the following respects do the plants under a canopy differ from plants of the same species in an open field?

(1p)

- A. They have longer internodes.
- B. They have shorter internodes.
- C. They have thicker stems.
- D. Their anthocyanin content is higher.

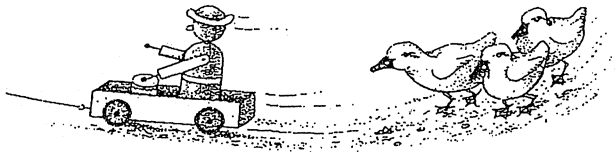
Ethology

21. In the picture you can see a moving toy followed by three goslings (young domestic geese).

What is the most likely explanation for the behaviour of the young birds?

(1p)

- A. It is a displacement activity resulting from the absence of their parents.
- B. Imprinting, i.e. the toy was the first moving object they saw after hatching, and as a result they react to it as if it were their parent.
- C. They have been trained by their keeper to follow this particular object.
- D. Goslings have an innate tendency or instinct to follow any moving object they see.



22. Deleted

23. In certain animal species, such as ants and bees, many or even most individuals abstain from their own reproduction and devote all their energy to nursing and protecting the offspring of other individuals. This may appear paradoxical, since natural selection implies unequal reproductive success and generates organisms maximizing their reproductive output. What is the evolutionary explanation of the presence of large numbers of sterile individuals in an ant colony?

(1p)

- _____ A. Reduced reproductive output guarantees that the demand for food can perpetually be satisfied locally and thus the ant colony safeguards its own long-term persistence by reproductive restraint.
- _____ B. All the ants in the colony are closely related genetically and therefore accrue fitness through the reproductive success of their close kin.
- _____ C. The sex ratio among new-born ants is greatly skewed such that most females do not find males to mate with and therefore inevitably live a sterile life.
- _____ D. Ants reproduce exclusively parthenogenetically.

24. In the practical test, you investigated if female guppies prefer some males over others. A more complicated question is **why** female guppies show such preferences.

24a. For simplicity, assume that most females already have evolved a preference for males with large tail-fins. In that case, what advantage may an individual female get by mating preferentially with males having large tail-fins, instead of mating randomly with any male?

(1p)

- _____ A. By copulating preferentially with males having large tail-fins, a female will experience less competition (from other females) over mating opportunities.
- _____ B. A male with a large tailfin is likely to produce sons with large tailfins as well, and as a result a female which preferentially copulates with such a male will get sons that are attractive to other females, and therefore she is likely to get many grandchildren.
- _____ C. A male with a large tailfin is likely to produce sons with small tailfins, so the sons will not be very attractive to other females, and consequently they have to copulate with their mother and she will get many more offspring.
- _____ D. A male with a large tail-fin is less likely to have copulated with many other females, and therefore a female copulating preferentially with such males has a lower risk of getting infected by venereal diseases.

24. (continued)

24b. Not only females may be choosy about whom to mate with. In a number of species males prefer certain females and ignore or reject others. In some species males are in fact more choosy than females. An alternative experiment therefore could have been to investigate the mating preferences of male guppies, for instance, whether they prefer big or small females.

Suppose you know that males prefer big females. Suppose also that the males on each copulation event deliver a number of sperm that is many times the number needed to fertilize all the ripe eggs carried by the female, while there is a limit to how frequently a male can copulate. What could then be the advantage to the male of being choosy about whom to mate with instead of mating randomly with any female?

(1p)

- A. Larger females produce more eggs, so a male that copulates preferentially with larger females is likely to sire a larger number of offspring.
- B. Larger males produce more sperm, and therefore a male that copulates preferentially with larger females is likely to sire a larger number of offspring.
- C. Larger females use more energy and nutrients for body growth and less for producing young, and therefore a male that copulates preferentially with larger females is likely to sire a smaller number of offspring.
- D. Larger females copulate with a higher number of different males, and therefore the offspring of each male is more genetically diverse if the mother is large than if the mother is small. This increased genetic diversity leads to higher fitness of the offspring, and therefore a male sires more grandchildren if he copulates preferentially with large females.

Genetics & Evolution

25. Tay Sach's disease (TSD) in humans is caused by the inability to synthesize hexosaminidase. This enzyme contributes to the breakdown and turnover of lipids in brain cells. TSD shows monohybrid, autosomal and recessive inheritance. The genotype of an individual with TSD may thus be denoted aa . What is the most likely explanation for an Aa -individual being just as healthy as an AA -individual?

(1p)

- _____ A. The dominant allele A is a transposon. In a heterozygous individual it detaches from its normal position and moves on to the recessive allele a , thus preventing the transcription of a .
- _____ B. The recessive mutant allele is expressed as an inhibitor protein that prevents the transcription of the normal allele A .
- _____ C. In heterozygous embryos a mutates to A . Consequently there are no Aa -adults.
- _____ D. The amount of hexosaminidase produced by an Aa -individual is quite enough for normal breakdown of lipids.

26. Independently of Darwin, another person developed the same theory of natural selection as the chief driving force of evolution. When he informed Darwin about his theory, this precipitated Darwin's publication of "On the Origin of Species". What was the name of this person?

(1p)

- _____ A. Ernst Haeckel
- _____ B. Carl von Linné (Carolus Linnaeus)
- _____ C. Alfred Wallace
- _____ D. Jean-Baptiste de Lamarck
- _____ E. Charles Lyell
- _____ F. Gregor Mendel

27. Of which of the following phenomena do Darwin's observations of the Galapagos finches (fam. Geospizidae) provide a classical example?

(1p)

- _____ A. Hardy-Weinberg equilibrium.
- _____ B. Sympatric speciation.
- _____ C. Adaptive radiation.
- _____ D. Convergent evolution.
- _____ E. Flightlessness.

28. The alleles at the ABO-locus are here denoted I^A , I^B and i , respectively. The genotype of an individual with blood group B is thus either $I^B I^B$ or $I^B i$. The allele frequencies in the population are denoted $p(I^A)$, $q(I^B)$ and $r(i)$, respectively.

When you answer the following questions, assume that individuals mate randomly with respect to their genotype at the ABO-locus.

28a. What is the expected frequency of individuals with blood group B?

(1p)

- A. $2qr^3$
- B. $q^2 + 2qr$
- C. $2qr$
- D. $q + r$
- E. $p + q + r$

In the country Faraway live Eve and Elvis and their two children, Olga and Boris. Eve and Elvis both have blood group B.

28b. What is the probability that Olga has blood group O?

(1p)

- A. r^2
- B. $2qr^3$
- C. $(2qr)^2 \times 1/4$
- D. $(2qr / (q^2 + 2qr))^2 \times 1/4$
- E. $1 - 2qr$

28. (continued)

28c. What is the probability that Olga and her brother Boris **both** have blood group O?

(1p)

- _____ A. r^4
- _____ B. $(2qr)^2 \times 1/4$
- _____ C. $(2qr / (q^2 + 2qr))^2 \times (1/4)^2$
- _____ D. $((2qr / (q^2 + 2qr))^2 \times 1/4)^2$
- _____ E. $(1 - 2qr)^2$

29. On an isolated island live 5 800 people, of which 2 800 are men. 196 of these men are red-green colour-blind. This type of colour blindness is caused by a recessive allele (r) on the X-chromosome. This type of colour blindness does not affect the fitness of an individual.

What is the probability that **at least one** of the **women** on this island is red-green colour-blind?

(1p)

- _____ A. 0.00
- _____ B. 0.08
- _____ C. $1 - 0.9951^{3000}$
- _____ D. $1 - 0.9936^{3000}$
- _____ E. $3000 \times 0.0056 \times 0.9944^{2999}$
- _____ F. 0.0064
- _____ G. 1.00

30. In an island population of an annual, diploid plant species the allele frequencies in 1999 are $p(A) = 0.90$ and $q(a) = 0.10$. Suppose that the population consists of 50 plants in the year of 2000. Then, what is the probability that the allele *a* **has been lost** (i.e. $p(A) = 1$), just by chance, between the year 1999 and 2000?

(1p)

- _____ A. 0.90^{100}
- _____ B. 0.90^{50}
- _____ C. 0.90
- _____ D. 0.10^{100}
- _____ E. 0.10

31. Heterozygosity, i.e. the frequency of individuals that are heterozygous at a certain locus, is a commonly used measure of genetic variation in a population. Assume a population of an annual plant species consisting of about 50 individuals. This year the allele frequencies in one locus are $p(A) = 0.90$ and $q(a) = 0.10$, respectively. Which of the following evolutionary forces might cause an increase of the heterozygosity in the next generation?

(1p)

- _____ A. Genetic drift.
- _____ B. Inbreeding.
- _____ C. Selection against *aa*-plants (*aa* having lower fitness than *AA* and *Aa*).
- _____ D. Immigration from a population where $p(A) = 0.99$ and $q(a) = 0.01$.

32. What features of present day bacteria are likely to prevent their direct evolution into multicellular organisms with differentiated organs?

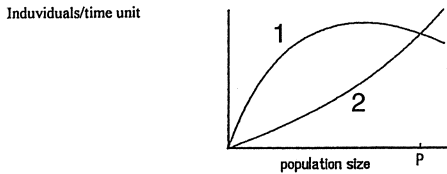
(1p)

- _____ A. They are very successful in the niche they occupy, and therefore do not need to evolve to multicellularity.
- _____ B. They lack a cytoskeleton, and thus cannot develop good communications to adjacent cells.
- _____ C. They have a rigid cell wall, and therefore cannot contact other cells.
- _____ D. Because they have a very versatile metabolism they cannot develop multicellularity.

Ecology

33. In setting harvesting quotas, for instance for whales, graphs are studied that show the relationship between number of births, number of deaths and population size. Inspect the following example:

Individuals/time unit



Which line in the graph shows the number of births, and what does the point P represent?

(1p)

- _____ A. Line 1 shows the number of births, and P represents the maximum population size.
- _____ B. Line 2 shows the number of births, and P represents the maximum population size.
- _____ C. Line 1 shows the number of births, and P represents the carrying capacity.
- _____ D. Line 2 shows the number of births, and P represents the carrying capacity.

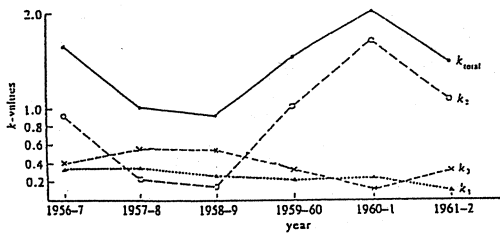
34. The marine pelagial is usually divided into two zones: an upper zone where net primary production takes place, and a lower zone where it does not. What is the critical factor generating this difference?

(1p)

- _____ A. In the upper zone the water is warm enough for algae to grow faster than their primary consumers can eat them.
- _____ B. In the upper zone there is enough light for photosynthesis to produce a surplus of organic matter.
- _____ C. In the upper zone the concentration of nutrients is high enough for photosynthesis to produce a surplus of organic matter.
- _____ D. In the upper zone the intensive stirring of water near the surface gives the water an oxygen concentration high enough for photosynthesis to take place.
- _____ E. In the upper zone the population density of fish is high enough to keep zooplankton at a low density, thereby allowing a high concentration of algae.

35. The population of a particular species of butterfly is affected by three mortality factors (with k -values k_1 , k_2 , k_3). The graph shows the variation of these over several years together with the variation in k_{total} . As k -values increase, butterfly mortality increases.

Use the graph to help you answer these questions:



35a. What is the relationship between k_1 , k_2 , k_3 and k_{total} ?

(1p)

- _____ A. $k_{\text{total}} = k_1 \times k_2 \times k_3$
- _____ B. $k_{\text{total}} = k_1 \times k_2 / k_3$
- _____ C. $k_{\text{total}} = k_1 \times k_3 / k_2$
- _____ D. $k_{\text{total}} = k_1 + k_2 + k_3$
- _____ E. $k_{\text{total}} = k_1 + k_2 - k_3$
- _____ F. $k_{\text{total}} = k_1 + k_3 - k_2$

35. (continued)

35b. Which was the main mortality factor in 1960?

(1p)

_____ A. k_1

_____ B. k_2

_____ C. k_3

35c. In which year did most butterflies survive to breed?

(1p)

_____ A. 1956-57

_____ B. 1957-58

_____ C. 1958-59

_____ D. 1959-60

_____ E. 1960-61

_____ F. 1961-62

36. The number of species in a landscape is often divided into two components called α -diversity and β -diversity. α -diversity is the number of species within a certain biotope in the area, while β -diversity is the degree of difference in the number of species composition between different biotopes in the landscape. Study the following table, which shows the species composition in three different biotopes within three different areas.

Area	1			2			3		
<i>Biotope</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>1</i>	<i>2</i>	<i>3</i>
Species									
1	x			x			x		
2				x					
3	x			x			x		
4	x			x			x		
5	x			x			x		
6	x	x		x	x		x		
7	x	x		x	x		x		
8	x	x		x	x		x		
9	x	x		x	x			x	
10	x	x						x	
11		x	x		x			x	
12		x	x		x	x		x	
13		x	x		x			x	
14						x		x	
15		x	x			x			x
16			x			x			x
17			x			x			x
18			x			x			
19			x			x			x
20						x			x

36. (continued)

36a. Which biotope has on the average the highest α -diversity?

(1p)

_____ A. Biotope 1.

_____ B. Biotope 2.

_____ C. Biotope 3.

36b. In which area is the average α -diversity of the three biotopes highest?

(1p)

_____ A. Area 1.

_____ B. Area 2.

_____ C. Area 3.

36c. In which area is the β -diversity highest?

(1p)

_____ A. Area 1.

_____ B. Area 2.

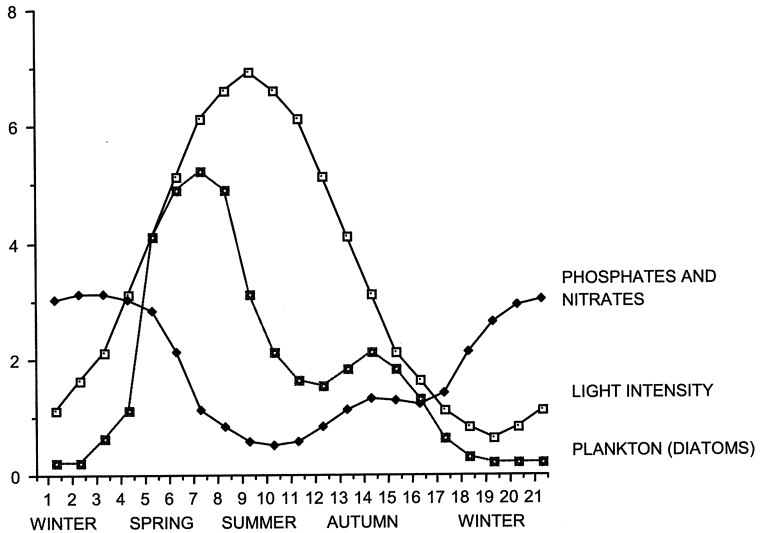
_____ C. Area 3.

37. Deleted

38. Deleted

39. This graph shows the seasonal changes in diatom plankton number and in some abiotic factors in the upper layers of an ocean in the Northern temperate zone:

Arbitrary units



Which of the following interpretations of the graph is correct?

(1p)

- A. The increasing light intensity destroys diatoms.
- B. The increasing amount of diatoms decreases the amount of nutrients.
- C. The increasing light intensity creates upwelling which raises the nutrients to the sea surface.
- D. The increasing light intensity increases the activity of decomposers and as a result of this the amount of nutrients decreases.
- E. The decline of diatoms causes the declines of nutrients.

Systematics

40. In which of the following alternatives (A-D) are the traditional taxonomic categories listed from more inclusive to less inclusive?

(1p)

- A. Order, Genus, Class, Family, Species.
- B. Class, Order, Family, Genus, Species.
- C. Genus, Order, Class, Family, Species.
- D. Family, Genus, Order, Class, Species.

41. Which of the following categories includes all the others?

(1p)

- A. Chordates.
- B. Vertebrates.
- C. Amphibians.
- D. Mammals.

42. When did Dinosaurs become extinct?

(1p)

- _____ A. Ca 2 million years ago.
- _____ B. Ca 65 million years ago.
- _____ C. Ca 200 million years ago.
- _____ D. Ca 400 million years ago.

43. A fish, a dolphin and a penguin have many external features in common, such as a stream-lined body shape. Why?

(1p)

- _____ A. They descend from one and the same recent ancestor and still possess many of this ancestor's traits (phylogenetic inertia); thus the body shape is not an adaptive trait.
- _____ B. They are all swimming animals and have therefore accumulated features making locomotion in water less energy-demanding (convergent evolution).
- _____ C. The similarity between these animals is superficial and reflects neither common history nor evolutionary response to the same environment; in fact, these animals are built along entirely different principles; they live in the same habitat (water) because they have their particular shape, rather than the other way around.

44. The genetic similarities between man and the two chimpanzee species allow us to estimate that the separation of the hominid line and the chimpanzee line occurred:

(1p)

- _____ A. Ca 250 000 years ago.
- _____ B. Ca 100 000 000 years ago.
- _____ C. Ca 6 000 000 years ago.
- _____ D. Ca 6 000 years ago.

45. After the separation of the chimpanzee and hominid lines, the first major trait characterizing the hominid line was . . .

(1p)

- _____ A. . . . brain enlargement.
- _____ B. . . . stereoscopic vision.
- _____ C. . . . tool making.
- _____ D. . . . bipedalism and erect body posture/walking.
- _____ E. . . . homeothermy.
- _____ F. . . . increased sexual size dimorphism.
- _____ G. . . . carnivory (meat-eating).

Surname

First name

Country

Code number

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Part B

In this part, all questions are multiple choice questions, but in each question any number among the answers may be correct. Thus, there may be only one correct answer, or several, or all answers may be correct. You must mark exactly and only those answers that are correct. You always mark the correct answers with a cross (X) on the lines in front of them.

Cell Biology, Microbiology & Biotechnology

46. The *lac* genes of *Escherichia coli* are classic; this is where the operon concept was coined, and investigations of how this operon was regulated rendered its investigators a Nobel prize. The *lac* operon of *E. coli* contains three genes:

- z*, encoding β -galactosidase,
- y*, encoding β -galactoside permease, and
- a*, encoding a transacetylase.

Allolactose is an isomer of lactose that is produced by β -galactosidase as an intermediate in the splitting of lactose to galactose and glucose. It is allolactose, not lactose, that is the natural inducer for the *lac* operon. Allolactose binds to the repressor and thereby opens the operon for transcription. Under which of the following conditions will expression of β -galactoside permease be induced?

(2p)

- _____ A. Addition of lactose to a z^+y^+ mutant.
- _____ B. Addition of allolactose to a z^-y^+ mutant.
- _____ C. Addition of lactose to a z^+y^- mutant.
- _____ D. Addition of allolactose to a z^+y^- mutant.

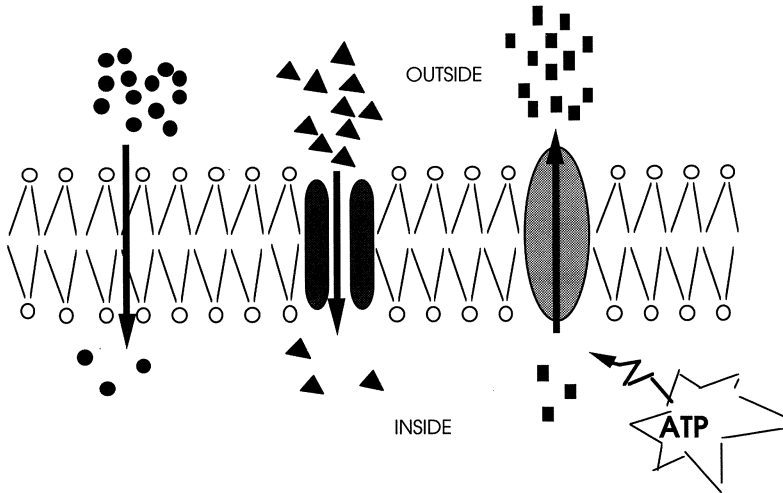
47. Cycloheximide is a drug that prevents protein synthesis in eukaryotic cells; chloramphenicol prevents protein synthesis in bacterial cells. Steroid hormones exert their effect by binding to cellular receptors. The hormone-receptor complex then binds to particular regions of DNA, and thereby regulates transcription. A transcriptional co-activator, TC, has been isolated from human cells. This binds to the steroid receptor, and is necessary for full transcriptional activation by a steroid hormone. The cDNA encoding TC has been cloned in a bacterial plasmid. Cultured human cells were transfected with this plasmid in the presence of cycloheximide or chloramphenicol. In both cases full steroid hormone transcription activation took place. The cDNA clone was subsequently mutated, introducing stop codons in all three reading frames. Upon transfection of human cells, full steroid hormone transcription activation took place.

Which of the following explanations are consistent with these data?

(2p)

- A. The human cells contain translational suppressors that override all the stop codons. Therefore the normal TC product can be made, despite the presence of stop codons in all reading frames.
- B. The gene product of TC necessary to activate transcription is an RNA, not a protein.
- C. The plasmid contained enough TC protein so that no new TC protein synthesis was needed in the human cell upon transfection for maximal transcription activation.
- D. The cDNA itself bound to the steroid receptor and thereby activated transcription.

48. The drawing below shows the transport of different substances through the plasma membrane of a plant cell. The drawing represents a lipid bilayer with a channel protein (middle) and a carrier protein (right). The direction of each transport is shown by an arrow and the number of symbols indicates the concentration of each substance.



Which statements are correct?

(1p)

- A. This substance can be sucrose.
- B. This substance can be oxygen.
- C. This substance can be chloride ions.
- D. This substance can be water.
- E. This substance can be protons.

49. One line of cultured mouse lymphoma cells is quite sensitive to cyclic AMP (cAMP). High internal levels of cAMP cause cell death. The intracellular activity of dibutyryl-cAMP (db-cAMP) and cAMP is the same. Resistant cells can be selected by growing the cells in the presence of db-cAMP. Such cells are resistant not only to cAMP, but also to the prostaglandin PGE1 (which kills sensitive cells by raising their intracellular cAMP level).

A student homogenized db-cAMP-sensitive and db-cAMP-resistant cells so that their cell membranes became disrupted, and then removed all particulate matter (fragments of cell membranes, nuclei and internal membrane systems) so that essentially only the protein-containing cytoplasm was left. She prepared three samples for analysis, as shown below. She then added radioactive cAMP, incubated for a while, and subjected the mixture to gel filtration (a technique that separates molecules according to their size). In both cases she found the radioactivity in two peaks: a complex of cAMP with some protein(-s) (fraction A), and free cAMP (fraction B):

Cell homogenates	fraction radioactive cAMP	
	A: in protein complex	B: free
sensitive	0.5	0.5
resistant	0.1	0.9
equal mixture of sensitive and resistant	0.5	0.5

49. (continued)

Which of the following explanations is/are consistent with the data?

(2 p)

- A. The transport system for cAMP is defective in resistant cells. cAMP binds to this transport protein in homogenates from sensitive cells, and therefore does not bind to anything in homogenates from resistant cells
- B. The regulatory subunit of a protein kinase is defective in resistant cells. cAMP binds to this regulatory subunit in homogenates from sensitive cells, and therefore does not bind to anything in homogenates from resistant cells.
- C. Resistant cells contain a new activity that is capable of modifying cAMP so that it no longer can bind to its receptor. The "free cAMP" in homogenates from resistant cells is really modified cAMP that elutes in approximately the same way as cAMP.

50. In eukaryotes, the majority of the RNA made in the nucleus undergoes three modifications before being transported from the nucleus to the cytoplasm. Which of these modifications help protect the RNA from degradation by nucleases?

(1 p)

- A. A 7-methyl-guanosine cap is added to its 5' end.
- B. A poly-A tail is added to its 3' end.
- C. Introns are spliced out.

51. Which of the features below would permit you to determine whether a cell is eukaryotic or prokaryotic?

(1p)

- A. The genetic material exists as a complex of nucleic acids and proteins.
- B. The genetic material is separated from the rest of the cell by a semipermeable barrier.
- C. There is a cell wall.
- D. The cell is motile.
- E. It can use H_2S as energy source.

52. Which of the following statements is/are true for bacteria?

(1p)

- A. Negative control of gene expression is common.
- B. The processes of transcription and translation are coupled.
- C. Positive control of gene expression is common.
- D. Structural genes average 50 000 base pairs.
- E. Several genes are transcribed into one mRNA molecule.

53. Respiring cells use the citric acid cycle (Krebs cycle) to oxidize their nutrients completely, and obtain NADH that is subsequently oxidized in mitochondria to gain ATP. Fermenting cells (yeast, for instance, and many bacteria) use part of the citric acid cycle, although they cannot oxidize their nutrients completely, and do not gain ATP from the extra NADH it generates. What do fermenting cells gain by operating part of the citric acid cycle?

(1 p)

_____ A. A supply of oxaloacetate, which is a very unstable compound, and therefore needs to be made continuously.

_____ B. Supplies of some of the citric acid cycle intermediates, which are essential precursors for cellular biosynthesis.

_____ C. A supply of succinate, which is needed for acylation of tRNAs. Without acyl- tRNAs, protein synthesis is inhibited.

_____ D. A supply of malate, which is needed for all ATP synthesis.

54. Deleted

55. Deleted

56. A scientist was growing yeast (*Saccharomyces cerevisiae*) in a simple nutrient solution, using ^{14}C -labelled glucose as its only energy source. She noted that for each mole of glucose that was completely oxidized, the cells consumed 6 moles of O_2 , and produced 36 moles of ATP.

56a. The radioactivity of what carbon compound(-s) did she measure to be able to say that the glucose was completely oxidized?

(1p)

- A. CO_2
- B. CH_4
- C. Ethanol
- D. Lactate

56b. What is the name of the process that she was studying?

(1p)

- A. Respiration.
- B. Detoxification.
- C. Fermentation.
- D. Denitrification.
- E. Photosynthesis.

56. (continued)

She then moved her culture to an anaerobic environment, and continued to study what happened to the radioactive glucose. She found that the cells continued to grow, utilizing glucose as energy source. Now, no oxygen was consumed, and the yield of ATP was only 2 moles per mole glucose oxidized.

56c. What is the name of the process that she is now studying?

(1p)

- A. Respiration.
- B. Detoxification.
- C. Fermentation.
- D. Denitrification.
- E. Photosynthesis.

56d. Which compound(-s) will become labelled by ^{14}C under these conditions?

(1p)

- A. CO_2
- B. CH_4
- C. Ethanol.
- D. Lactate.

Plant Anatomy & Physiology

57. Seeds of wheat (*Triticum aestivum*, family Poaceae = Graminae) and lupin (*Lupinus polyphyllus*, family Fabaceae = Leguminosae) were used in the following experiment. Both types of seeds had been harvested about 6 months before. Dry seeds of each species were put together in samples of the same weight and treated as follows:

- a. Wheat seeds were soaked in water for 24 hours
- b. Wheat seeds were soaked in a solution of 1 M mannitol for 24 hours
(mannitol is a sugar alcohol not taken up by plants)
- c. Lupin seeds were soaked in water for 24 hours
- d. Lupin seeds were dipped in boiling water for a few seconds and then soaked in water for 24 hours.

All samples were kept in darkness for 24 hours and then weighed and placed on wet filter papers in Petri dishes for a germination test. The table below shows the approximate percent increase in weight during the different treatments, and the percent germination.

57. (continued)

Treatment	Percent increase	Percent
	In weight	germinating seeds
a. Wheat soaked in water	98	100
b. Wheat soaked in mannitol solution	12	0
c. Lupin seeds soaked in water	11	0
d. Lupin seed dipped in hot water before soaking	110	80

Which explanations to the results are probable?

(2p)

- _____ A. In water-soaked seeds respiration starts so that water can be taken up.
- _____ B. The difference in weight between dry seeds and water-soaked seed is due to water uptake.
- _____ C. The mannitol enters the cell wall and makes it impermeable to oxygen and water.
- _____ D. The mannitol inhibits certain steps in the citric acid cycle (Krebs cycle).
- _____ E. The high concentration of mannitol hinders the uptake of water.
- _____ F. Mannitol makes a very tight slime around the wheat seeds which squeezes them so they cannot grow.
- _____ G. Fresh lupin seeds have seed coats with a very low permeability to water.
- _____ H. When heated the dry lupin seeds are stressed and produce a lot of new proteins so that their weight increases.
- _____ I. The heating of lupin seeds makes the seed coat more permeable to water.
- _____ J. The heating of lupin seeds destroys the cell membranes so that water goes in.

58. The Calvin cycle . . .

(1p)

- A. . . . proceeds during the night.
- B. . . . produces phosphoglyceraldehyde.
- C. . . . needs ATP.
- D. . . . releases carbon dioxide.

59. What are the benefits to the plant of C4 photosynthesis as compared to C3 photosynthesis?

(1p)

- A. C4 photosynthesis needs fewer light quanta to fix one mole of CO_2 .
- B. C4 photosynthesis can proceed at much lower CO_2 concentrations than C3 photosynthesis.
- C. Plants with C4 photosynthesis are more economic in water use.
- D. Plants with C4 photosynthesis require fewer types of minerals.

Animal Anatomy & Physiology

60. The absorption in the small intestine in humans is impaired if the liver stops producing bile.

The absorption of which of the compounds A-E would be severely reduced without bile?

(1p)

- A. Dipeptides.
- B. Fat-soluble vitamins.
- C. Starch.
- D. Glucose.
- E. Amino acids.

61. Which of the following compounds are transported in intestinal epithelial cells by a sodium ion- (Na^+) dependent cotransport process?

(1p)

- A. Glucose.
- B. Galactose.
- C. Fructose.
- D. Amino acids.
- E. Dipeptides.

62. Which of the following structures, features and processes are necessary for gas exchange in all animals?

(2p)

- A. Hemoglobin or another respiratory pigment.
- B. Thin and wet surface.
- C. Diffusion.
- D. Red blood cells.
- E. Lungs or tracheae.
- F. Oxygenated water or air.

63. Which of the following compounds normally appear in the glomerular filtrate of mammals?

(1p)

- A. Urea.
- B. Glucose.
- C. Amino acids.
- D. Plasma proteins.
- E. Mineral salts.

64. Which of the following substance(s) are essential for blood coagulation in the human body?

(1p)

_____ A. Prothrombin.

_____ B. Potassium.

_____ C. Heparin.

_____ D. Fibrinogen.

_____ E. Calcium.

65. The following measurements were obtained in a male patient:

Heart rate = 70 beats/min

Pulmonary vein contains 0.24 ml O₂/ml

Pulmonary artery contains 0.16 ml O₂/ml

Whole body O₂ consumption = 500 ml/min

What is the patient's cardiac output?

(2p)

_____ A. 1.65 L/min.

_____ B. 4.55 L/min.

_____ C. 5.0 L/min.

_____ D. 6.25 L/min.

_____ E. 8.0 L/min.

66. Two types of muscle participate in the locomotion of earthworms (*Lumbricus*, Annelida). When moving forward, an earthworm first squeezes the front segments into a long tube (I) and then drags its back part (II). Which muscles are contracted (c) and relaxed (r) in I and II, respectively?

(2p)

	I	II
	Longitudinal muscles/circular muscles	Longitudinal muscles/circular muscles
_____ A.	r/c	r/c
_____ B.	r/c	c/r
_____ C.	c/r	c/r
_____ D.	c/r	r/c
_____ E.	c/c	r/r

Genetics & Evolution

67. The wild type eye colour of the fruit fly *Drosophila melanogaster* is brick red. In such an eye there are two types of pigments: bright red and brown pigments.

A young student has as a hobby to collect mutants of *D. melanogaster* with bright red eyes. He has received some such strains from a Drosophila Stock Centre, e.g. *cinnabar*, *scarlet* and *vermilion*, all of which have bright red eyes. In the compost bucket in his kitchen he was happy to find a mutant with bright red eye colour. From this compost mutant he produced a true-breeding strain with bright red eyes that he calls "Uppsala". His girl-friend has given him "Wik", which is another true-breeding strain with bright red eyes. Crosses between some true-breeding strains gave the results presented in the table below. Each F_1 consisted of hundreds of flies. The number of F_2 individuals are given in the table. Wild type is denoted by "+", and the mutants with bright red eye colour by "m".

67. (continued)

Parent strains (P)			Phenotypes in F ₁		Phenotypes in F ₂	
Females	x	Males	Females	Males	Females	Males
<i>cinnabar</i>	x	+	+	+	762 + 242 m	757 + 239 m
<i>scarlet</i>	x	+	+	+	312 + 101 m	301 + 99 m
<i>scarlet</i>	x	<i>cinnabar</i>	+	+	908 + 699 m	901 + 692 m
<i>vermilion</i>	x	+	+	m	114 + 104 m	111 + 102 m
Uppsala	x	+	+	+	612 + 199 m	601 + 182 m
Uppsala	x	<i>cinnabar</i>	m	m	216 m	203 m
Wik	x	+	+	m	160 + 151 m	155 + 149 m
Wik	x	<i>vermilion</i>	+	m	203 + 197 m	4 + 396 m

67. (continued)

67a. In which of these strains does mutant bright eye colour show autosomal, monohybrid and recessive inheritance in relation to wild type?

(2p)

- _____ A. *cinnabar*
- _____ B. *scarlet*
- _____ C. *vermilion*
- _____ D. Uppsala
- _____ E. Wik

67b. Which mutant strains carry mutant genes in linked but separate loci?

(2p)

- _____ A. *cinnabar* and *scarlet*
- _____ B. *cinnabar* and *vermilion*
- _____ C. *vermilion* and Uppsala
- _____ D. Uppsala and Wik
- _____ E. *vermilion* and Wik

67. (continued)

67c. What is the distance between these two linked loci?

(2p)

- _____ A. 1 cM (cM = centimorgan)
- _____ B. 2 cM
- _____ C. 4 cM
- _____ D. 8 cM
- _____ E. 10 cM
- _____ F. 12 cM
- _____ G. 20 cM
- _____ H. 80 cM

68. Which of the following cell structures are homologous, i.e. derived from a common ancestor?

(1p)

- _____ A. The cell wall of bacteria and the cell wall of plants.
- _____ B. The flagellum of a bacterium and the flagellum of an animal cell, e.g. a sperm.
- _____ C. The nucleosomes in plants and the nucleosomes in animals.
- _____ D. The mitochondria in plants and the mitochondria in animals.

69. Some mutations in mitochondrial DNA can cause a disease in humans called Leber's hereditary optic neuropathy (LHON). This is characterized by a sudden onset of blindness in adults. Which of the following statements are true?

(1 p)

- A. Only women (not men) can develop LHON.
- B. Both men and women can develop LHON.
- C. A person will develop LHON only if both its mother's and its father's mitochondria carry the mutation.
- D. A person will develop LHON if its father has the disease but its mother is healthy.
- E. A person will develop LHON if its mother has the disease but its father is healthy.

70. Which of the following statements about speciation in animals is/are true?

(2p)

- _____ A. Species always arise momentarily as a result of major sudden mutations.
- _____ B. The number of species usually multiplies as a result of one population becoming divided into two (or more), which subsequently evolve in divergent directions.
- _____ C. A species may undergo changes over time and eventually become different enough to be regarded and named as a new species.
- _____ D. Speciation invariably proceeds at a fixed pace. Speciation events can therefore be accurately dated using the molecular clock.
- _____ E. According to the biological species definition a species consists of the total set of individual organisms having identical genomes.
- _____ F. On inspection of external features, it should be possible to identify each individual in a species. Otherwise the species delimitations are erroneous and have to be revised.
- _____ G. All traits distinguishing two species must have evolved by natural selection.
- _____ H. Artificial selection can in principle lead to the generation of new species.

Ethology

71. A flock of sparrows is feeding at a bird table in a garden. Suddenly one of the sparrows gives an alarm call, all the birds fly off and hide in nearby bushes, and a second later a hawk flies past. How can the sparrow that first spotted the hawk gain fitness by calling instead of flying off silently?

(2p)

- _____ A. By giving the alarm call the caller will attract the attention of the predator in order to sacrifice itself for the benefit of its species.
- _____ B. Predators that realize they have lost their chance of a surprise attack often give up hunting, so by giving the alarm call the caller signals to the hawk that it had been discovered, and the caller thereby will reduce its own risk of being attacked.
- _____ C. By giving the alarm call the caller will save a number of flock members, many of which are its own relatives. In other words, the habit of giving an alarm call can be explained in terms of kin selection.
- _____ D. Alarm calling is an instinctive response always produced in the presence of a predator.

Ecology

72. The reproductive life history of an individual is defined by the number, time distribution and size of its reproductive investments.

Which of the following variables are elements in an individual's reproductive life history as defined above:

(1p)

- A. Reproduction several times or only once.
- B. Number and size of offspring per litter/clutch.
- C. Age at first reproduction.
- D. Discontinuation of reproduction beyond a certain age.
- E. Aerobic versus anaerobic metabolism.
- F. Vulnerability to interspecific competition.
- G. Variation in immunocompetence.

73. An ecological pyramid may describe the number of individuals, the biomass, or the rate of energy flow, at different trophic levels within an ecosystem. Usually the values at a higher trophic level are lower than those at a lower level within the same pyramid. Otherwise the pyramid may be called inverted. What circumstances may lead to inverted pyramids?

(1p)

- _____ A. A pyramid of biomass, in which the producers have a very short lifecycle compared to the consumers.
- _____ B. A pyramid of biomass, in which the consumers have a very short lifecycle compared to the producers.
- _____ C. A pyramid of numbers of individuals, in which the individual bodymass of producers is several orders of magnitude larger than the individual bodymass of consumers.
- _____ D. A pyramid of numbers of individuals, in which the primary consumer level is strongly dominated by one abundant species.
- _____ E. Extremely hot climate promotes inverted pyramids.
- _____ F. Extremely cold climate promotes inverted pyramids.
- _____ G. Mountainous areas with high UV-radiation have inverted pyramids.

74. Which of the following statements is / are correct in relation to the carrying capacity of an area for a particular species?

(1p)

- A. The carrying capacity of an area is determined by the availability of resources.
- B. When a population that inhabits an area is larger than its carrying capacity, the population is likely to decrease
- C. The carrying capacity of an area can vary as a result of the environmental conditions.
- D. The carrying capacity of an area can be zero.
- E. The carrying capacity is always the same for all populations of a species throughout its range.

75. Which of the following interactions may plausibly generate coevolutionary change?

(1p)

- A. Interspecific competition.
- B. Mutualism (Symbiosis).
- C. Predation.
- D. Commensalism.
- E. Parasitism.

76. A metapopulation is a set of local populations, where sometimes a population becomes extinct and sometimes a new population is "born" by emigrants from some population colonizing an empty habitat patch (that is "a population of populations"). In a population, the number of individuals is determined by the balance between birth rate (+ immigration) and death rate (+ emigration). Correspondingly, in a metapopulation the number of populations is determined by the balance between extinction rate and colonization rate. Which of the following statements about metapopulations are correct?

(2p)

- A. If there are many habitat patches and colonizations of empty patches occur frequently, then the metapopulation may persist for a very long time even if all local populations are short-lived.
- B. If the extinction rate of local populations exceeds a certain rate the whole metapopulation will go extinct.
- C. Species that require a habitat that is patchily distributed are more likely to function as metapopulations than species that are habitat generalists.
- D. Species in which every individual moves several times per day between different resource patches are more likely to function as metapopulations than species which only seldom make movements between the resource patches.
- E. A metapopulation can persist only if some dispersal between the habitat patches is possible.
- F. In a metapopulation, no single population persists longer than the lifespan of one individual.

Systematics

77. Which of the following statements is / are true?

(1p)

- A. The human species, *Homo sapiens*, is a very old species which has been around since late Cretaceous.
- B. Orangutans are the closest relatives of humans.
- C. The human species arose in Africa, from where humans spread over the world.
- D. The human species is the only species manufacturing tools for defined purposes.
- E. The genetic variation among populations in the human species is small compared to that in most species.

78. Deleted

79. Which of the following plants is / are monocotyledons?

(1p)

- _____ A. Potato (*Solanum*).
- _____ B. Apple (*Malus*).
- _____ C. Wheat (*Triticum*).
- _____ D. Carrot (*Daucus*).
- _____ E. Maize (*Zea*).
- _____ F. Onion (*Allium*).

80. Which of the following statements about Carolus Linnaeus (Carl von Linné) are true?

(2p)

- _____ A. Linnaeus introduced the concept of hierarchical systematics with ever more exclusive groups from kingdom down to species.
- _____ B. Linnaeus invented the binomial system of nomenclature giving each species a genus name and a species name, for example *Homo sapiens* for humans.
- _____ C. According to the rules of taxonomy a name given by Linnaeus to a species of animal or plant can never be changed.
- _____ D. Darwin explicitly benefited from the Linnean hierarchical systematic system ("clusters within clusters") for the elaboration of his theory of descent with modification.
- _____ E. Linnaeus' binomial nomenclature is still used in botany but not in zoology.
- _____ F. Linnaeus classified humans as a species belonging to the class of Mammalia and the order of Primates.
- _____ G. In his life Linnaeus scientifically defined and described more than 100 000 species of plants and animals.

Surname

First name

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Part C

In this part, the questions are constructed in various ways, and you have to read for each question how the answer is to be given. Often you answer by writing one or a few digits or characters, and then these must be distinct and legible, otherwise your answer will not be judged as correct. You must use Arabic numerals (1,2,3..).

Cell Biology, Microbiology & Biotechnology

81. It is possible to fuse somatic cells of different origin to each other, producing somatic cell hybrids. The hybrid cells usually retain only some of the chromosomes contributed by each fusion partner, different in each hybrid cell. Cells lacking hypoxanthine-guanine phosphoribosyltransferase (HGPRT) are resistant to 8-azaguanine (8-azaG), while cells lacking thymidine kinase (TK) are resistant to 5-bromodeoxyuridine (BudR). Neither HGPRT nor TK is essential for cell growth under ordinary circumstances. In order to map positions of human genes, a scientist wanted to fuse human cells capable of encoding HGPRT but not TK to mouse cells lacking HGPRT-coding capacity but capable of encoding TK.

81a. What would she need to add to the growth medium to select hybrid cells incapable of making either HGPRT or TK?

(1p)

- A. 8-azaG.
- B. BudR.
- C. Both 8-azaG and BudR.
- D. Neither azaG nor BudR.
- E. HGPRT.
- F. TK.
- G. HGPRT and TK.
- H. Neither HGPRT nor TK.

81. (continued)

Having obtained the fused cells, she then analyzed the presence (+) or absence (-) of five human enzymes in five different hybrid cell lines. She also tested the presence or absence of four particular human chromosomes in these hybrid cell lines. The results are shown in the table below:

		Hybrid cell lines				
		A	B	C	D	E
Human enzymes	I	-	+	-	+	-
	II	-	-	-	-	-
	III	+	-	-	+	-
	IV	+	+	+	+	+
	V	+	-	-	+	-
Human chromosomes	1	-	+	-	+	-
	3	+	-	-	+	-
	8	-	-	-	+	+
	17	+	+	+	+	+

81b. Write on the dotted line for each chromosome which of the enzymes I-V it encodes.

(1p)

Chromosome 1:

Chromosome 3:

Chromosome 8:

Chromosome 17:

82. The chromatin of human cells contains 1.08 mg histone and 0.7 mg non-histone protein per mg of DNA. Assume that a mole of an average gene contains 10^6 g DNA, and that the average molecular weights of histones and non-histone chromatin proteins are 12000 and 17000 daltons, respectively.

82a. How many molecules of chromosomal protein are complexed with an average gene? Write your answers on the dotted lines.

(1p)

No. histone molecules:

No. non-histone protein molecules:

82b. If an average human cell contains 10^{13} daltons of DNA, how many molecules of chromosomal proteins are complexed with it? Write your answer on the dotted line.

(1p)

..... molecules

82c. According to one model for how eukaryotic gene expression is regulated, certain chromatin proteins function as activators, turning on large sets of genes. Assume such an activator induces the expression of 1000 genes. If one molecule of activator is required per gene, and the cells are diploid, what percentage of total chromatin proteins would this represent? Write your answer on the dotted line.

(1p)

.....%

83. The following table contains a list of cell constituents in plant and animal cells. Mark with a cross (X) in appropriate boxes of the table the statements that apply to each constituent. Compare only plant and animal cells.

(2p)

Constituent	Only in Plant cells	Only in animal cells	Contains DNA	Forms starch	Is photo- synthetic	Is coloured
Chloroplast						
Ribosome						
Proplastid						
Endoplasmatic reticulum						
Microfilament						
Mitochondrion						
Nucleus						
Cell wall						
Golgi apparatus						

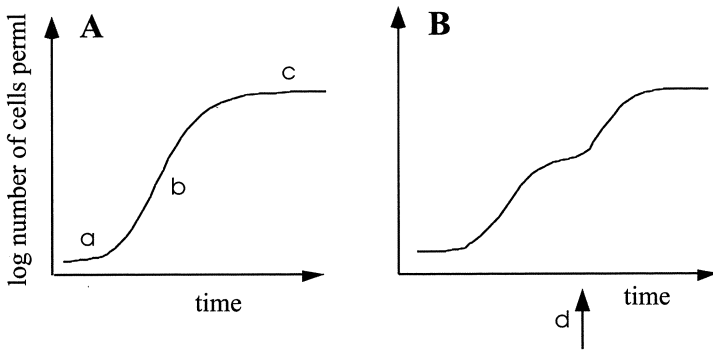
84. Mitochondria are organelles surrounded by membranes. It is possible to prepare pure mitochondria, and treat them in various ways. What happens when you expose purified mitochondria, kept at 37 °C in an isotonic buffer, to the following treatments?

Several treatments may result in the same effect, and some effects are not obtained by any treatment. Mark with a cross (X) in appropriate boxes of the table which effect the different treatments have. Mark only one box for each treatment.

(2p)

Effect	Treatment							
	Temperature raised by 30°	Temperature reduced by 30°	Detergent added	Lysozyme added	Protease added	Cyanide added	ATP added	Pyruvate added
The membranes are destroyed								
The membranes become more solid								
Electron transport starts running "backwards" so that ATP is consumed								
Electron transport to oxygen is blocked								
The compound is taken up and oxidized								
Nothing happens								

85. The figure below shows two growth curves obtained with *Escherichia coli*. For both, the cells were kept in a simple mineral-salts medium with no nutrients added. For fig A, 0.2 g glucose was added per 100 ml culture at the start of the experiment. For fig B, 0.05 g glucose was added per 100 ml at the start of the experiment.



85a. What are the correct names of the growth phases designated a - c in fig A?

Choose among the names 1-4, and write the number of the correct name on the appropriate line.

(2p)

1 = death phase

2 = exponential phase

3 = lag phase

4 = stationary phase

Phase a is _____

Phase b is _____

Phase c is _____

85. (continued)

85b. In fig. B, which addition(-s) at time d would result in the growth curve illustrated?

(1p)

- _____ A. 0.05 g potassium cyanide.
- _____ B. 0.05 g glucose.
- _____ C. 0.05 g lactose.
- _____ D. 0.05 g sodium pyruvate.
- _____ E. 0.05 g sodium azide.

86. In which order do the processes A-F take place in a eukaryotic cell?

(2p)

- A. Peptidyl transfer
- B. Ribosome binding to RNA
- C. RNA polymerase binding to DNA
- D. Splicing
- E. Transcription
- F. Folding of the polypeptide chain

Write the letters A-F in the correct order here:

87. Suppose you want to clone a human gene that is expressed in liver and is suspected to be involved in a genetic disease.

87a. Which of the following would be the best starting material?

(1p)

- _____ A. A human genomic DNA library. ___ C. Human cellular DNA
_____ B. A human liver cDNA library. ___ D. A human tRNA library

87b. Regardless of your preference in question 87a, you are forced to use a human genomic library, available as phage clones (no other material is available). You have identified a particular phage clone carrying the gene you are interested in, in a stretch of human DNA including at least 10 other genes of no interest to you. What is the logical order of subsequent steps in order to produce a clone that carries just the gene that you are interested in? The procedure outlined will not permit you to identify your clone, just produce it.

- A. cleave DNA with a restriction endonuclease D. transform *Escherichia coli* cells
B. treat with DNA ligase E. mix library DNA with vector (plasmid) DNA
C. extract DNA from starting material F. heat mixture to inactivate enzyme

Write here the letters A-F in the order these steps should be performed. You may need to perform one or more steps more than once.

(2p)

Plant Anatomy & Physiology

88. What are the effects of these different plant hormones? Mark the correct alternatives with a cross (X). Mark only one hormone for each effect.

(2p)

	Auxin	Gibberellin	Abscissic acid	Ethylene	Cytokinin
Delays the breakdown of chlorophyll					
Closes stomata					
Is active in phototropic responses					
Can make long-day plant flower during short days					
Makes bananas yellow					

89 Only some of the processes 1-7 below occur in extant plants. Name these processes correctly by writing the number of the process on the appropriate line.

(2 p)

- | | |
|------------------|------------------|
| 1. DNA → RNA | 5. RNA → protein |
| 2. DNA → protein | 6. Protein → DNA |
| 3. RNA → DNA | 7. Protein → RNA |
| 4. DNA → DNA | |

Replication is process no.

Reverse transcription is process no.

Transcription is process no.

Translation is process no.

Animal Anatomy & Physiology

90. Match each of the following elements, listed below, with its corresponding mass percentage in the human body.

(2p)

elements C - H - N - O - P mass percentages 1 - 3 - 10 - 18 - 65

- C%
- H%
- N%
- O%
- P%

91. Compare marine fish to freshwater fish with respect to the following statements! Mark with a cross (X) the correct fish type for each statement.

(2p)

	Marine fish	Freshwater fish
Higher water intake		
Excrete salts across their gills		
Absorb salts through specialized cells in their gills		
Have relatively dilute urine		

92. Deleted

Genetics & Evolution

93. A human disease was shown to be due to a recessive mutant allele, denoted a . Children with genotype aa all die before the age of 10. AA - and Aa -individuals have the same fitness. In one generation (generation G_0) of an isolated population, the frequency of the allele a was 0.0100 among adults.

93a. If no new mutations arise, what is the frequency of heterozygous carriers (Aa) among newborn babies in the next generation (generation G_1)? Give your answer to four places of decimals.

(1p)

Answer:

93b. What is the frequency of the allele a among adults in the next generation (generation G_1)?

Give your answer to four places of decimals.

(1p)

Answer:

94. An archaeologist discovered a sample of mammoth flesh frozen in ice in the Siberian taiga. She wanted to test how similar DNA from this flesh was to DNA from present-day Indian elephants. Choose among the following techniques those appropriate for this task, and list the techniques you have chosen, in the correct order of performing the analysis.

- A. Carry out DNA electrophoresis.
- B. Transform mammoth DNA into elephant cells.
- C. Subject the mammoth specimen to amniocentesis.
- D. Use the polymerase chain reaction on mammoth and elephant DNA.
- E. Carry out restriction enzyme digestion of DNA.
- F. Hydrolyze mammoth and elephant DNA with acid.
- G. Analyse the karyotype of the mammoth specimen.

Write the letters designating the appropriate techniques in the correct order on the dotted line.

(2p)

Correct order:

95. The sex determination system in the insect order Hymenoptera (ants, bees and wasps) is such that males are haploid (n) and females (queens and workers) are diploid (2n).

Microsatellites are short tandem repeats of one to six nucleotides. The number of repeats often varies from one individual to another, and a given number of repeats constitutes an allele of that particular microsatellite locus. Microsatellites are common throughout most eukaryotic genomes.

In an experiment, microsatellite DNA fragments from 10 ant workers (numbered 1-10 below), all from the same mound of *Formica sp.*, were tested. In this species there is only one queen per mound, but she can mate with one or more males.

Two microsatellite loci were amplified separately by means of PCR, using primers complementary to regions outside the microsatellite itself. The amplified DNA was radioactively labelled. The fragments were then separated by means of electrophoresis in a polyacrylamide gel. Under these conditions DNA will move towards the anode, the faster the smaller it is. After concluding the electrophoresis, a photographic film was placed on top of the gel. The film then darkened at places where there were radioactive DNA fragments. The results are shown below.

Individual:	1	2	3	4	5	6	7	8	9	10
Locus 1:	-	-	-	-	-	-	-	-	-	-
	-		-	-	-		-	-	-	-

Individual:	1	2	3	4	5	6	7	8	9	10
Locus 2:		-	-			-	-	-		
	-			-	-		-		-	-
	-	-			-	-			-	

95. (continued)

95a. How many alleles are there at each of the two loci?

(1p)

Locus 1:

Locus 2:

95b. What is the minimum number of males with whom this queen has mated, judging from the results of amplification of locus 1?

(1p)

Answer:

95c. What is the minimum number of males with whom this queen has mated, judging from the results of amplification of locus 2?

(1p)

Answer:

96. For what pioneering contributions are the geneticists A-F known? (In brackets the year when their respective discovery was presented, at a meeting and / or in a printed publication.) After each of the descriptions I-VI, write the letter (A-F) of the person(s) known for this advance.

(2p)

- A Gregor Mendel (1865/1866)
 - B Thomas H Morgan (1910)
 - C Herman J Muller (1927)
 - D Oswald T Avery, Colin M MacLeod & Maclyn McCarty (1944)
 - E Barbara McClintock (1950)
 - F James Watson & Frances Crick (1953)
- I Studied the X-ray diffraction pattern of DNA and concluded that DNA has a double-stranded and helical structure.

Answer:

- II Showed that X-rays induce mutations.

Answer:

- III From studies of unstable loci in maize (*Zea mays*), concluded that some genetic elements, now called transposons, are mobile in the genome.

Answer:

96. (continued)

IV From experiments with *Streptococcus* (at that time called *Pneumococcus*) concluded that genes are made of DNA.

Answer:

V From experiments with the garden pea (*Pisum sativum*), concluded that the hereditary "factors" are derived in pairs from the parents and are segregated unchanged to the germ cells. The hereditary "factors" do not blend. Coined these terms: dominant and recessive.

Answer:

VI Discovered X-linked inheritance in the fruit fly (*Drosophila melanogaster*). One of his students, Calvin Bridges, later demonstrated that genes are contained in the chromosomes. Another of his students, Alfred H Sturtevant ("that young Sturtevant!") was able to interpret experimental data that were due to linkage of genes in a chromosome. Sturtevant used these data for gene mapping.

Answer:

Ecology

97. A student wished to estimate the size of a population of woodlice (terrestrial Isopoda) under a log. She captured 40 woodlice, marked and then released them and allowed them to thoroughly mix with the rest of the population. After 24 hours, once again she captured 40 woodlice. Of the newly captured woodlice, only 16 were marked. Assume that no woodlice were born, died, immigrated to or emigrated from the population during the past 24 hours. Estimate the number of woodlice in the population.

(2p)

The number of woodlice in the population is estimated to be

98. According to the equilibrium theory of island biogeography, the number of species on an island is determined by the balance between frequency of extinctions on the island and frequency of new species colonizing the island. The theory says that the larger an island is, the more seldom will species go extinct. It also says that the closer an island is to the mainland from which new colonists may come, the more often will colonizers arrive at the island. As a result the number of species will be at or near an equilibrium level where extinctions and colonizations take place equally often. But there will also be a change of the particular species which are found on the island at a given time. This change is called species turnover, and turnover rate is the sum of extinction rate and colonization rate.

Of four islands differing in size and distance to mainland, which will have high and low species number and which will have high and low species turnover rate? Write on the dotted lines the digit (I-IV) of the appropriate description.

(2p)

- I. most species, intermediate turnover rate
- II. intermediate species number, lowest turnover rate
- III. fewest species, intermediate turnover rate
- IV. intermediate species number, highest turnover rate

- a) A large island close to the mainland has.....
- b) A large island far away from the mainland has
- c) A small island close to the mainland has
- d) A small island far away from the mainland has

Systematics

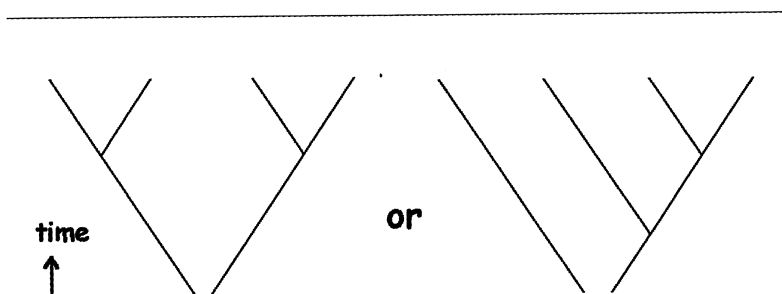
99. Systematists use the so called cladistic method to find evolutionary relationships. Organisms are first described in terms of specific characters, as shown in the table below.

Character	frog (A)	bat (B)	duck (C)	anteater (D)
1 mammary glands	—	+	—	+
2 wings	—	+	+	—
3 fingers and toes	+	+	+	+
4 sticky tongue	+	—	—	+
5 three ear ossicles	—	+	—	+
6 endothermy	—	+	+	+
7 diaphragm	—	+	+	+
8 placenta	—	+	—	+

You will see that some characters are shared by two or more organisms, which indicates that these organisms may be related. However, shared similarities may also be the result of convergent

evolution, and be misleading when we try to reconstruct the evolutionary relationships of a group of organisms. Only similarities that are due to common descent can be true indicators of relationship. Shared similarities may also be the result of common descent from an ancestor having the property in question. Such characters say nothing about the pattern of evolutionary branching from this ancestor. In order to distinguish primitive characters from those that have evolved more recently, cladistic analysis uses a concept called outgroup comparison. An outgroup is a species or group that is relatively closely related to the group studied, but clearly not as closely related as the study-group members are to each other.

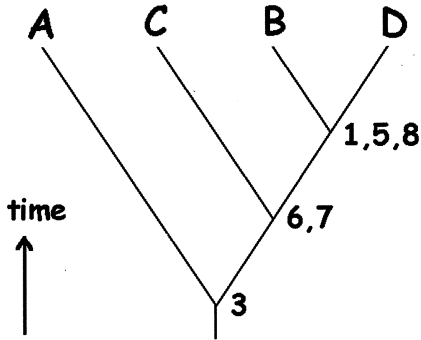
The organisms are then grouped together on simple branched trees called cladograms. With four groups of organisms the shape of the cladogram may be:



The best cladogram is the one in which the pattern of branches most closely reflects the character distribution among the organisms. In most cases, the criterion used is **parsimony**, meaning that the simplest explanation is preferred. This results in a cladogram showing the fewest number of independent changes.

Characters are mapped onto the cladogram at the base of the group of organisms that share that character.

In this case the best cladogram out of 15 possibilities is:



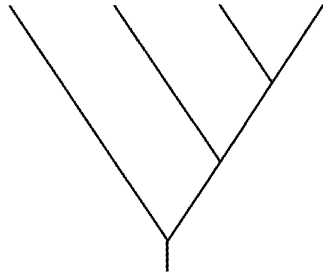
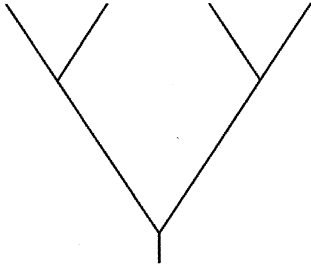
Using this knowledge you have to find the appropriate cladogram that fits to four species indicated by P, Q, R and S, which have the following similarities:

- 1 only P and Q are abundant in the desert
- 2 only R and S produce seeds
- 3 all four have chlorophyll
- 4 only P and Q have spores
- 5 all have vascular tissues with the exception of P
- 6 only R and S produce flowers
- 7 only in Q, R and S is the sporophyte the dominant generation
- 8 only P does not have roots

The task is to choose the cladogram with the correct shape, to fill out P, Q, R and S at the end of the correct branches, and to indicate the correct similarities at the start of the branches.

Now fill out your answer below:

(3p)



10th International Biology Olympiad

1999-07-04--11

Answer key to the theoretical test

Part A

- | | |
|---------------|---------------|
| 1. B | 24a. B |
| 2. C | 24b. A |
| 3a. A | 25. D |
| 3b. C | 26. C |
| 3c. A | 27. C |
| 4. B | 28a. B |
| 5. C | 28b. D |
| 6. B | 28c. C |
| 7. A | 29. C |
| 8. D | 30. A |
| 9. B | 31. A |
| 10. B | 32. (deleted) |
| 11a. E | 33. C |
| 11b. B | 34. B |
| 12. B | 35a. D |
| 13. B | 35b. B |
| 14. D | 35c. C |
| 15. C | 36a. A |
| 16. E | 36b. A |
| 17. B | 36c. C |
| 18. D | 37. (deleted) |
| 19. (deleted) | 38. (deleted) |
| 20a. B | 39. B |
| 20b. D | 40. B |
| 20c. C | 41. A |
| 20d. A | 42. B |
| 21. B | 43. B |
| 22. (deleted) | 44. C |
| 23. B | 45. D |

Part B

- | | |
|------------------|----------------|
| 46. B | 56a. A |
| 47. B | 56b. A |
| 48. B, C, E | 56c. C |
| 49. B | 56d. A, C |
| 50. A, B | 57. B, E, G, I |
| 51. B, E | 58. B, C |
| 52. A, B, (C), E | 59. B, C |
| 53. B | 60. B |
| 54. (deleted) | 61. A, D |
| 55. (deleted) | 62. B, C, F |

- 63. A, B, C, E
- 64. A, D, E
- 65. D
- 66. B
- 67a. A, B, D
- 67b. E
- 67c. B
- 68. C, D
- 69. B, E
- 70. B, C, H

- 71. B, C, (D)
- 72. A, B, C, D
- 73. A, C
- 74. A, B, C, D
- 75. A, B, C, E
- 76. A, B, C, E
- 77. C, E
- 78. (deleted)
- 79. C, E, F
- 80. A, B, D, F

Avdelning C

81a.C C = 1p, C + an other = 1p

81b. Chromosome 1: I
Chromosome 3: III, V
Chromosome 8:
Chromosome 17: IV

82a. No. histone molecules: 90

No. non-histone molecules: 41

82b. $1,31 \times 10^9$

82c. 0,00015%

Constituent	Only in plant cells	Only in animal cells	Contains DNA	Forms Starch	Is photo-synthetic	Is coloured
Chloroplast	x		X	X	x	x
Ribosome						
Proplastid	x		X			
Endoplasmatic Reticulum						
Microfilament						
Mitochondrion			X			
Nucleus			X			
Cell wall	x					
Golgi apparatus						

9-10 R = 2p 5-8 R = 1p 1-2 F = -1p Several faults 0

84.

Effect	Treatment							
	Temperature raised by 30°	Temperature reduced by 30°	Detergent Added	Lysozyme Added	Protease added	Cyanide added	ATP added	Pyruvate added
The membranes Are destroyed	x		X					
The membranes Solidify		x						
Electron transport Starts running "backwards" so that ATP is consumed								
Electron transport to Oxygen is blocked						x		
The compound is Taken up and Oxidized								x
Nothing happens				X	x		x	

85a. Phases a is 3

Phases b is 2

Phases c is 4

85b. B, C, D

86. C E D B A F

87a) B

87b). C, E, A, F, B, (F), D

88.

Auxin	Gibberellin	Abscissic acid	Ethylene	Cytokinin
-------	-------------	----------------	----------	-----------

Delays the breakdown of chlorophyll					x
Closes stomata			x		
Is active in phototropic responses	x				
Can make long-day plant flower During short days		X			
Makes bananas yellow				x	

5R = 2p

3-4 R = 1p

89. Replication is process nr 4
 (Reverse transcription is process nr 3)
 Transcription is process nr 1
 Translation is process nr 5

3

90. C 18%
 H 10%
 N 3%
 O 65%
 P 1%

91.

	Marine fish	Freshwater fish
Higher water intake	X	
Excrete salts across their gills	x	
Absorb salts through specialized cells in their gills		X
Have relatively dilute urine		X

4R = 2p 2 - 3 R = 1p

92 (deleted)

c) IV

d) III

93a. 0.0198

4R = 2p 2-3R = 1p

99. Exakt svar enligt figuren

Allt R = 3p

93b. 0.0099

)

94. D E A **DEA = 2p**

95a. Locus 1: 2

Locus 2: **3 R = 1p**

95b. 2 **R = 1p**

95c. 3 **R = 1p**

96. I F

II C

III E

IV D

V A

VI B

6R = 2p

4-5R = 1p

97. 100

R = 2p

98. a) I

b) II