

ISC Class 12 Biology Specimen Paper 1

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Maximum Marks: 70 | Time Allowed: Three hours | Reading Time: 15 minutes

Paper 1 (Theory) carries 70 marks. Sections A and B are compulsory. Attempt any three questions from Section C.

General Instructions

Write your answers on the separate answer paper provided. The first 15 minutes are for reading the paper, and you may not write during that time. Section A and Section B are compulsory, and from Section C you must attempt any three of the four questions. Marks for each question, or part of a question, are shown in brackets. No diagrams are printed in this paper. Where a question asks you to draw and label a structure you are expected to draw it yourself in pencil, draw it large enough to be read, and label it with straight lines that do not cross one another. Scientific names must be written in the correct form, with the genus beginning with a capital letter. All working for numerical questions must be shown on the same sheet as the answer. This paper carries 70 of the 100 marks for the subject, the remaining 30 being for the practical work, the project and the practical file.

SECTION A (14 Marks)

Attempt all parts of Question 1.

Question 1 [14]

Each part carries 1 mark. For the parts that offer four choices, write only the option you choose. For the rest, answer in a single sentence or give the single word, name or value asked for.

- (i) The layer of the anther wall which nourishes the developing pollen grains is:
(a) the epidermis (b) the endothecium
(c) the middle layer (d) the tapetum
- (ii) Name the process by which a diploid megaspore mother cell in the ovule gives rise to megaspores.
- (iii) The hormone whose sharp rise at about the middle of the menstrual cycle brings about ovulation is:
(a) luteinising hormone (b) follicle stimulating hormone
(c) progesterone (d) human chorionic gonadotropin
- (iv) Give the full form of ZIFT and state the part of the body into which the material is placed.
- (v) Mendel's law of independent assortment holds good for two genes which are:
(a) closely linked on one chromosome (b) carried on two different pairs of homologous chromosomes
(c) both carried on the X chromosome (d) carried on the Y chromosome
- (vi) Name the human disorder caused by the trisomy of chromosome 21 and give the total number of chromosomes in an affected person.
- (vii) The spread of antibiotic resistance through a bacterial population kept under the pressure of an antibiotic is an example of:
(a) stabilising selection (b) disruptive selection
(c) directional selection (d) genetic drift
- (viii) Name the species of Plasmodium which causes malignant malaria in human beings.
- (ix) The fungus used in the industrial manufacture of citric acid is:
(a) Saccharomyces cerevisiae (b) Aspergillus niger
(c) Penicillium notatum (d) Monascus purpureus
- (x) Name the two gases which make up the greater part of biogas.

- (xi) The gene transferred into cotton to protect the crop against bollworm is:
(a) nif H (b) the gene for adenosine deaminase
(c) the gene for beta galactosidase (d) cry IAc
- (xii) Name the soil bacterium whose plasmid is used as a natural vector to carry genes into dicotyledonous plants.
- (xiii) In a tree ecosystem the pyramid of numbers is:
(a) inverted (b) upright
(c) spindle shaped (d) a straight vertical line
- (xiv) Give the term for the orderly and predictable replacement of one biotic community by another at the same site.

SECTION B (26 Marks)

Attempt all parts of Question 2. Each part carries 2 marks.

Question 2 [26]

- (i) Draw and label a diagram of a mature anatropous ovule, showing the funicle, the integuments, the micropyle, the nucellus and the embryo sac. [2]
- (ii) Distinguish between geitonogamy and xenogamy, and state which of the two brings about genetic recombination. [2]
- (iii) Define apomixis and state one reason why a plant breeder finds it useful. [2]
- (iv) Give the function of the Leydig cells and the function of the Sertoli cells in the human testis. [2]
- (v) In the garden pea, tall (T) is dominant over dwarf (t). A heterozygous tall plant is self pollinated and 480 seeds are obtained, all of which germinate. Work out the number of tall and the number of dwarf plants expected, and give the genotypic ratio of the offspring. [2]
- (vi) State what is meant by a test cross and state what a breeder is able to find out by making one. [2]
- (vii) In a large population which is in Hardy-Weinberg equilibrium for a single pair of alleles, the frequency of individuals homozygous for the recessive allele is 0.09. Calculate the frequency of the recessive allele and the frequency of the heterozygotes. [2]
- (viii) Distinguish between homologous and analogous organs, giving one example of each. [2]
- (ix) Name the causative organism of amoebic dysentery and state how the infection is passed from one person to another. [2]
- (x) Explain what is meant by biofortification and give one example of a biofortified crop with the nutrient it has been improved for. [2]
- (xi) Name the two polypeptide chains of human insulin, and explain the difficulty which had to be overcome before insulin could be made by recombinant DNA technology. [2]
- (xii) A population of 1000 rodents is growing exponentially, and its intrinsic rate of natural increase is 0.2 per year. Calculate the size of the population at the end of 10 years. (Take $e^2 = 7.389$.) [2]
- (xiii) Distinguish between gross primary productivity and net primary productivity, and write the relationship between the two. [2]

SECTION C (30 Marks)

Attempt any three questions from this Section. Each question carries 10 marks.

Question 3 [10]

- (a) Describe double fertilisation as it occurs in a flowering plant, naming the two fusions involved, the product of each fusion and the ploidy of each product. [3]

- (b) Draw and label a diagram of the human female reproductive system, showing the ovary, the fallopian tube, the uterus, the cervix and the vagina. [3]
- (c) (1) Name the hormone secreted in quantity by the corpus luteum and state its function in the uterus. (2) State what becomes of the corpus luteum when fertilisation does not take place, and the event which follows in the uterus. (3) Name two barrier methods of contraception. (4) Give the full form of IUCD and name one copper releasing device of this kind. [4]

Question 4 [10]

- (a) A plant of the genotype AaBb is crossed with a plant of the genotype aabb, the two genes lying on different pairs of chromosomes. Write the kinds of gamete produced by each parent and work out the phenotypic ratio of the offspring. [3]
- (b) Explain what is meant by linkage and by recombination, name the organism in which Morgan established linkage, and define a map unit. [3]
- (c) In a population of 1000 plants in Hardy-Weinberg equilibrium, 160 plants show the recessive phenotype for a single pair of alleles. Calculate the frequency of the recessive allele, the frequency of the dominant allele, the number of heterozygous plants and the number of plants homozygous for the dominant allele. [4]

Question 5 [10]

- (a) For each of typhoid, ringworm and filariasis, name the causative organism, give one symptom and state the mode of transmission. [3]
- (b) Explain what is meant by biological control of pests and diseases, and state how Trichoderma and the baculoviruses are used for this purpose. [3]
- (c) (1) Name the microorganism used in the industrial production of ethanol. (2) Name the organism which yields cyclosporin A and state what the drug is used for. (3) Name the organism which yields the statins and state how they act. (4) Explain the part played by the methanogens in a biogas plant. [4]

Question 6 [10]

- (a) The producers of a grassland fix 20000 kJ of energy. Using the ten per cent law, calculate the energy available at the herbivore level, at the secondary consumer level and at the tertiary consumer level, and state the law. [3]
- (b) Define ecological succession, distinguish between primary and secondary succession, and name the pioneer community on a bare rock. [3]
- (c) (1) Explain what RNA interference is and how it has been used to protect tobacco from the nematode *Meloidogyne incognita*. (2) Name the enzyme which is absent in adenosine deaminase deficiency and state two ways in which the disorder is treated. (3) Explain what is meant by biopiracy and give one example. [4]

ANSWER KEY AND MARKING SCHEME

Full working is given for every numerical. Marks shown in italics are the step marks an examiner would award. Accept any correct alternative wording which carries the same biology, accept a correctly drawn and labelled diagram in any reasonable style, and accept a scientific name written without underlining provided the genus carries a capital letter.

Question 1 [14]

- (i) (d) the tapetum. It is the innermost layer of the anther wall, its cells are rich in food and it is used up as the pollen grains mature.

Correct option 1.

- (ii) Megasporogenesis. The megaspore mother cell divides by meiosis to give four haploid megaspores, of which only one usually survives to form the embryo sac.

Correct answer 1.

- (iii) (a) luteinising hormone. The rapid rise in its level near the middle of the cycle is the LH surge, and it causes the Graafian follicle to rupture and release the ovum.

Correct option 1.

- (iv) ZIFT stands for zygote intra fallopian transfer. The zygote, or an early embryo of up to eight blastomeres, is placed in the fallopian tube.

Full form with the fallopian tube named 1.

- (v) (b) carried on two different pairs of homologous chromosomes. Only then do the two pairs of alleles separate into gametes without any reference to one another.

Correct option 1.

- (vi) Down's syndrome, and the affected person has 47 chromosomes.

Disorder named with 47 chromosomes 1.

- (vii) (c) directional selection. The mean of the population is pushed steadily towards one extreme, in this case greater resistance, because only the resistant cells leave offspring.

Correct option 1.

- (viii) Plasmodium falciparum.

Correct answer 1.

- (ix) (b) Aspergillus niger.

Correct option 1.

- (x) Methane and carbon dioxide. Methane is the larger fraction and is the gas which burns.

Both gases named 1.

- (xi) (d) cry IAc. The protein it codes for is laid down in the plant as an inactive crystalline protoxin and is activated by the alkaline gut of the insect.

Correct option 1.

- (xii) Agrobacterium tumefaciens, whose Ti plasmid carries the foreign gene into the plant cell.

Correct answer 1.

- (xiii) (a) inverted. A single tree supports a very large number of herbivorous insects, which in turn support a smaller number of birds, so the base of the pyramid is the narrowest level.

Correct option 1.

- (xiv) Ecological succession.

Correct answer 1.

Question 2 [26]

- (i) The drawing should show a stalk, the funicle, attaching the ovule to the placenta, and the point at which the funicle joins the body of the ovule marked as the hilum. The body is covered by one or two integuments which leave a narrow opening at one end, the micropyle, and the integuments meet the funicle at the chalaza. In an anatropous ovule the body is bent through about 180 degrees so that the micropyle lies alongside the funicle.

Inside the integuments is the nucellus, a mass of nutritive tissue, and embedded in it is the embryo sac, which should be drawn as an oval sac with the egg cell and two synergids at the micropylar end, three antipodal cells at the chalazal end and the large central cell holding the two polar nuclei.

Outline with funicle, integuments and micropyle correctly placed, and the body shown bent 1. Nucellus and embryo sac labelled, with the embryo sac contents shown 1.

- (ii) Geitonogamy is the transfer of pollen from the anther of one flower to the stigma of another flower borne on the same plant. A pollinating agent is needed, but since both flowers carry the same genes the result is functionally self pollination. Xenogamy is the transfer of pollen to the stigma of a flower on a different plant of the same species. Xenogamy is the one which brings about genetic recombination, because the two gametes that meet come from two different parent plants.

Both terms correctly distinguished 1. Xenogamy named as the one giving recombination, with the reason 1.

- (iii) Apomixis is the production of seed without fertilisation, so that the embryo is formed from a cell of the parent sporophyte and the seedling is genetically identical with the parent plant. It is useful to a breeder because the characters of a valuable hybrid can be fixed and multiplied through seed without the segregation that would follow sexual reproduction, so hybrid seed need not be produced afresh every season.

Apomixis defined as seed set without fertilisation 1. Use to the breeder, that the hybrid character is held without segregation 1.

- (iv) The Leydig cells, also called the interstitial cells, lie in the spaces between the seminiferous tubules and secrete the androgens, chiefly testosterone, which bring about the development of the male secondary sexual characters and support spermatogenesis. The Sertoli cells lie inside the seminiferous tubules, where they are attached to the wall and project towards the lumen. They nourish the developing spermatids and provide them with mechanical support.

Leydig cells and the secretion of androgens 1. Sertoli cells and the nourishment of the developing sperm 1.

- (v) The cross is $Tt \times Tt$. The gametes T and t are formed in equal numbers by each parent, so the offspring are TT, Tt, Tt and tt in equal numbers. Three quarters carry at least one T and are tall, one quarter are tt and are dwarf. Tall plants = $480 \times \frac{3}{4} = 360$. Dwarf plants = $480 \times \frac{1}{4} = 120$. The genotypic ratio is 1 TT : 2 Tt : 1 tt, which in numbers is 120 : 240 : 120.

Tall 360 and dwarf 120 1. Genotypic ratio 1 : 2 : 1 1.

- (vi) A test cross is a cross in which an individual showing the dominant phenotype, and whose genotype is not known, is crossed with the homozygous recessive. If the unknown parent is homozygous dominant every offspring shows the dominant phenotype. If it is heterozygous, half the offspring show the dominant and half the recessive phenotype, a ratio of 1 : 1. The breeder is therefore able to find out whether the parent in question is homozygous or heterozygous, that is to find out its genotype from the phenotypes of its offspring.

Cross with the homozygous recessive described 1. Purpose, to tell a homozygote from a heterozygote, with the 1 : 1 result 1.

- (vii) Let the frequency of the recessive allele be q and that of the dominant allele be p. The frequency of the homozygous recessive is $q^2 = 0.09$, so $q = 0.3$. Since $p + q = 1$, $p = 0.7$. The frequency of the heterozygotes is $2pq = 2 \times 0.7 \times 0.3 = 0.42$, that is 42 per cent of the population.

Recessive allele frequency q = 0.3 1. Heterozygote frequency 2pq = 0.42 1.

- (viii) Homologous organs have the same basic plan of structure and the same embryonic origin, but have come to serve different functions in different animals because they have been remodelled for different ways of life. The forelimb of a whale, of a bat and of a horse are homologous, all being built on the same bone for bone pattern. Homology points to divergent evolution from a common ancestor. Analogous organs are quite different in structure and in origin but perform the same function, because unrelated animals living in the same way have met the same need in the same way. The wing of a bird and the wing of an insect are analogous. Analogy points to convergent evolution.

Homologous organs defined with a correct example 1. Analogous organs defined with a correct example 1.

- (ix) The causative organism is Entamoeba histolytica, a protozoan parasite which lives in the large intestine. The mature cysts are passed out in the faeces of an infected person, and the infection reaches a new host through food and drinking water contaminated with those faeces. Houseflies act as mechanical carriers, picking up the

cysts and leaving them on uncovered food.

Entamoeba histolytica named 1. Transmission through faecally contaminated food and water, with houseflies as carriers 1.

- (x) Biofortification is the breeding of crop plants with a higher content of vitamins, minerals, proteins or healthier fats, so that the nutrition of the people who eat them is improved through the crop itself rather than through a supplement. The wheat variety Atlas 66 has been used as a donor because of its high protein content, and the maize hybrids bred for twice the amount of the amino acids lysine and tryptophan are a further example. Iron fortified rice, which carries over five times as much iron as the common varieties, and the carrot, spinach and pumpkin bred for a higher content of vitamin A are also accepted.

Biofortification correctly defined 1. One correct example with the nutrient named 1.

- (xi) Human insulin is made of two short polypeptide chains, chain A and chain B, which are held together by disulphide bridges. In the human body insulin is first made as a single longer prohormone, proinsulin, which carries an extra stretch called the C peptide between the two chains, and this peptide is cut out before the hormone becomes mature and active. The difficulty was therefore that a bacterium given the gene would make the inactive precursor and could not carry out that processing step. It was met by preparing the two chains separately in *Escherichia coli*, using two sequences coding for chain A and chain B, and then joining the purified chains through their disulphide bonds outside the cell to give mature human insulin.

Chains A and B named 1. The difficulty of the extra C peptide of proinsulin, met by making the two chains separately and joining them 1.

- (xii) Exponential growth follows $N_t = N_0 e^{rt}$. Here $N_0 = 1000$, $r = 0.2$ per year and $t = 10$ years, so $rt = 0.2 \times 10 = 2$.
 $N_t = 1000 \times e^2 = 1000 \times 7.389 = 7389$ rodents.

Correct use of $N_t = N_0 e^{rt}$ with $rt = 2$ 1. Population 7389 1.

- (xiii) Gross primary productivity is the total rate at which the producers of an ecosystem build up organic matter by photosynthesis, counted before anything is spent. A large part of it is at once used up by the producers themselves in respiration. Net primary productivity is what is left after that respiratory loss, and it is the rate at which organic matter is actually added to the standing crop of the producers, so it is the amount which is available to the herbivores and the decomposers. The relationship is $NPP = GPP - R$, where R is the respiratory loss of the producers. Both are expressed as mass of organic matter, or as energy, per unit area per unit time.

Both terms correctly defined, with NPP shown as the amount available to consumers 1. Relationship $NPP = GPP - R$ 1.

Question 3 [10]

- (a) The pollen tube enters the ovule through the micropyle, pushes into the embryo sac and bursts, releasing two male gametes. Both of them fuse, which is why the process is called double fertilisation. In the first fusion, syngamy, one male gamete fuses with the egg cell to give the zygote. The egg is haploid and the gamete is haploid, so the zygote is diploid, and it grows into the embryo. In the second fusion, triple fusion, the other male gamete fuses with the two polar nuclei of the central cell. Three haploid nuclei are involved, so the product, the primary endosperm nucleus, is triploid, and it divides to give the endosperm which feeds the embryo. Double fertilisation of this kind is found only in the angiosperms.

Two male gametes released into the embryo sac, with the term double fertilisation 1. Syngamy giving the diploid zygote 1. Triple fusion giving the triploid primary endosperm nucleus 1.

- (b) The drawing should show a pair of ovaries, one on either side, each a small oval body lying in the pelvis and attached to the uterus by a ligament. From each ovary a fallopian tube runs towards the uterus, and its ovarian end should be drawn as a funnel, the infundibulum, fringed with finger like fimbriae. The two tubes open into the upper corners of the uterus, which should be drawn as a thick walled inverted pear shaped organ with its cavity shown. The narrow lower end of the uterus is the cervix, and below the cervix the canal widens into the vagina, which opens to the outside. The five labels asked for are the ovary, the fallopian tube, the uterus, the cervix and the vagina. The fimbriae and the three layers of the uterine wall, the perimetrium, the myometrium and the endometrium, may be added.

Ovary and fallopian tube correctly drawn and placed 1. Uterus correctly drawn with the cervix below it 1. Vagina shown continuous with the cervix, and all five labels given 1.

- (c) (1) The corpus luteum secretes large amounts of progesterone. In the uterus progesterone makes the endometrium thick, glandular and well supplied with blood, so that it is able to receive and maintain an implanted embryo, and it also keeps the muscle of the uterine wall quiet. (2) If fertilisation does not take place the corpus luteum is not maintained, and it degenerates into a small mass of white scar tissue called the corpus albicans. The level of progesterone therefore falls sharply, the endometrium can no longer be held, and it breaks down and is shed as the menstrual flow. (3) Two barrier methods are the condom and the diaphragm. The cervical cap and the vault are also accepted. (4) IUCD stands for intra uterine contraceptive device. A copper releasing device of this kind is the copper T, and the copper 7 and Multiload 375 are also accepted.

Progesterone named with its action on the endometrium 1. Degeneration into the corpus albicans, with menstruation following 1. Two barrier methods 1. Full form of IUCD with one copper releasing device named 1.

Question 4 [10]

- (a) The parent AaBb is heterozygous at both loci, and since the two genes lie on different pairs of chromosomes they assort independently, so this parent forms four kinds of gamete in equal numbers, AB, Ab, aB and ab. The parent aabb is homozygous recessive at both loci and forms only one kind of gamete, ab. Each of the four gametes of the first parent meets ab, giving AaBb, Aabb, aaBb and aabb in equal numbers. In phenotype these are dominant for both characters, dominant for the first and recessive for the second, recessive for the first and dominant for the second, and recessive for both. The phenotypic ratio is therefore 1 : 1 : 1 : 1. This is the dihybrid test cross, and the equality of the four classes is itself the proof that the two pairs of alleles have assorted independently.

Four gametes AB, Ab, aB, ab from the first parent and ab alone from the second 1. The four offspring genotypes written out 1. Phenotypic ratio 1 : 1 : 1 : 1 1.

- (b) Linkage is the tendency of two or more genes which lie on the same chromosome to be inherited together, so that the parental combinations appear among the offspring far more often than independent assortment would allow. The closer together the two genes lie, the stronger the linkage. Recombination is the appearance of new combinations of those genes among the offspring, and it is brought about by crossing over between the homologous chromosomes at the pachytene stage of meiosis, when non sister chromatids exchange corresponding segments. Morgan established linkage by his work on the fruit fly, *Drosophila melanogaster*. A map unit, also called a centimorgan, is the distance between two genes which gives a recombination frequency of one per cent, and it is used to place genes in order along a chromosome.

*Linkage defined, with the parental combinations in excess 1. Recombination traced to crossing over in meiosis 1. *Drosophila melanogaster* named and the map unit defined as one per cent recombination 1.*

- (c) The recessive phenotype is shown only by the homozygous recessive, so $q^2 = 160/1000 = 0.16$, and $q = \sqrt{0.16} = 0.4$. Since $p + q = 1$, $p = 1 - 0.4 = 0.6$. Heterozygotes have the frequency $2pq = 2 \times 0.6 \times 0.4 = 0.48$, so their number is $0.48 \times 1000 = 480$. Homozygous dominants have the frequency $p^2 = 0.6 \times 0.6 = 0.36$, so their number is $0.36 \times 1000 = 360$. As a check, $360 + 480 + 160 = 1000$, which is the whole population.

$q^2 = 0.16$ giving $q = 0.4$ 1. $p = 0.6$ 1. Heterozygotes 480 1. Homozygous dominants 360, with the three classes adding to 1000 1.

Question 5 [10]

- (a) Typhoid is caused by the bacterium *Salmonella typhi*. A sustained high fever, often with headache, loss of appetite and pain in the abdomen, is a symptom, and in a severe untreated case the intestinal wall may be perforated. The organism is taken in with food and drinking water contaminated by the faeces or urine of a patient or a carrier. Ringworm is caused by fungi of the genera *Microsporum*, *Trichophyton* and *Epidermophyton*. Dry, scaly lesions with intense itching appear on the skin, most often in the groin, between the toes or on the scalp. It spreads by contact with an infected person or with shared towels, combs and clothing, and from soil. Filariasis is caused by the nematode worms *Wuchereria bancrofti* and *Wuchereria malayi*. The worms block the lymphatic vessels, which leads to a gross and lasting swelling of the affected part, the condition called elephantiasis. It is spread by the bite of an infected female *Culex* mosquito.

Typhoid complete with organism, symptom and transmission 1. Ringworm complete 1. Filariasis complete 1.

- (b) Biological control is the control of a pest or a plant disease by using its natural enemies, that is another living organism which preys upon it, parasitises it or competes with it, in place of a chemical pesticide. Because the agent chosen attacks only its own target, the useful organisms of the field are spared, no residue is left in the crop or the soil and the pest does not build up resistance as it does to a chemical. Trichoderma is a genus of free living fungi which are common in the soil of the root region. They grow fast, crowd out and attack a number of fungal pathogens of plants, and are used widely to treat soil and seed against root and wilt diseases. The baculoviruses are viruses which attack insects and other arthropods, and the ones used belong to the genus Nucleopolyhedrovirus. They are very narrow in their host range, often attacking a single pest species, so they leave pollinators, natural predators and vertebrates untouched, and they are valuable where a pest is to be removed from a mixed population of insects.

Biological control defined, with one advantage over a chemical pesticide 1. Trichoderma as a soil fungus used against fungal plant pathogens 1. Baculoviruses of the genus Nucleopolyhedrovirus named as narrow spectrum insect pathogens 1.

- (c) (1) The yeast *Saccharomyces cerevisiae*, known as brewer's yeast, which ferments the sugars of the malted grain or the molasses to ethanol and carbon dioxide. (2) Cyclosporin A is obtained from the fungus *Trichoderma polysporum*. It is an immunosuppressant, and is given to patients who have received a transplanted organ so that the graft is not rejected. (3) The statins are obtained from the yeast *Monascus purpureus*. They lower the level of cholesterol in the blood, acting as competitive inhibitors of the enzyme HMG-CoA reductase, which is the enzyme the body needs in order to make cholesterol. (4) The methanogens, such as *Methanobacterium*, are anaerobic bacteria which are found in the rumen of cattle and therefore in cattle dung. In the closed tank of a biogas plant they act on the products left by the other bacteria which have already broken down the cellulose of the dung, and from these they produce methane along with carbon dioxide and a little hydrogen. The gas mixture is biogas, and the spent slurry that remains is used as manure.

Saccharomyces cerevisiae 1. Trichoderma polysporum with the use as an immunosuppressant 1. Monascus purpureus with cholesterol lowering by inhibition of HMG-CoA reductase 1. Methanogens producing methane from the dung in anaerobic conditions 1.

Question 6 [10]

- (a) By the ten per cent law only about a tenth of the energy held at one trophic level passes into the next. Energy fixed by the producers = 20000 kJ. At the herbivore level, that is the first order consumers, 10 per cent of 20000 = 2000 kJ. At the secondary consumer level, 10 per cent of 2000 = 200 kJ. At the tertiary consumer level, 10 per cent of 200 = 20 kJ. The law states that when energy passes from one trophic level to the next in a food chain only about ten per cent of it is stored as body material in the level above, the remaining ninety per cent being lost mainly as heat in respiration and in the work of living. This is why a food chain can rarely carry more than four or five links.

Herbivore level 2000 kJ 1. Secondary 200 kJ and tertiary 20 kJ 1. Law correctly stated with the loss as heat 1.

- (b) Ecological succession is the orderly and more or less predictable sequence in which the communities of plants and animals at a site replace one another through time, each community altering the conditions in a way that suits the next, until a stable community is reached which is in balance with the climate. That final community is the climax. Primary succession begins on a bare area where no community has lived before, such as a newly cooled lava flow, a bare rock or a newly formed pond, so that soil has first to be made. It is therefore very slow and may take thousands of years. Secondary succession begins where a community has been destroyed, as by fire, flood or the abandoning of cultivated land. The soil is already present with its nutrients, seeds and spores, so the sequence runs far faster. On a bare rock the pioneer community is made up of lichens, which are able to live on an almost dry surface and whose acids slowly etch the rock into the first thin soil. Mosses follow them, then herbs, shrubs and trees.

Succession defined, with the climax community named 1. Primary succession distinguished from secondary, with the presence of soil as the reason for the difference in speed 1. Lichens named as the pioneers on bare rock 1.

- (c) (1) RNA interference is a natural defence of the cell in which a double stranded RNA molecule brings about the silencing of a particular gene. A short complementary RNA binds to the messenger RNA of that gene, so the messenger is destroyed or cannot be translated, and no protein is made from it. Tobacco plants have been protected from the root nematode *Meloidogyne incognita* by this route. A nematode specific gene was introduced into the plant using an *Agrobacterium* vector, and it was arranged so that both the sense and the antisense RNA were made. The two strands pair to form double stranded RNA, which silences the corresponding messenger of the parasite. The nematode can no longer make the protein it needs, so it cannot survive in the transgenic root and the plant is left unharmed. (2) The missing enzyme is adenosine deaminase, which the body needs for the normal working of the lymphocytes, and its absence leaves the child without an effective immune system. The disorder is treated by a bone marrow transplant, which can cure it, and by the injection of the functional enzyme, which is not a permanent remedy because the enzyme has to be given again and again. The third approach is gene therapy, in which lymphocytes carrying a functional ADA gene are returned to the patient, though these cells are not immortal and the treatment must be repeated. (3) Biopiracy is the use of the bioresources or the traditional knowledge of a country or community by an outside organisation, usually a company of another country, without proper authorisation and without any payment or share of the benefit to the country or community from which they were taken. The patent granted on basmati rice is an example, and the patents taken out on turmeric and on neem are also accepted.

RNA interference explained as silencing by double stranded RNA 1. Use of sense and antisense RNA against Meloidogyne incognita, delivered by Agrobacterium 1. Adenosine deaminase named with two correct treatments 1. Biopiracy defined with one correct example 1.