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ANSWER BOOK

Artificial selection and selective breeding

Evolution and speciation · Unit B19

OCR A 6.1.2 · CAIE 17.2

15 questions · 53 marks

NAVY EDITION

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SECTION A · Short, 1 to 2 marks

A1 ASB-Q15

B1 wild rice supplied a resistance allele against grassy stunt virus, which was bred into commercial rice varieties, or another correctly named documented case. **B1** such material is stored in seed banks such as the Millennium Seed Bank or the Svalbard Global Seed Vault, which hold seed samples of wild relatives, old local varieties and rare breeds. [2]

SECTION B · Standard, 3 to 5 marks

B1 ASB-Q7

B1 cross the resistant wild plant with the high-yielding commercial variety, so the offspring inherit alleles from both parents. **B1** screen the offspring by deliberately infecting them with the pathogen and keeping only the plants that survive, selecting for the resistance allele. **B1** cross the resistant offspring back to the high-yielding commercial variety, a backcross, and screen again for resistance. **B1** repeat the backcrossing and screening over several generations, so the proportion of the genome matching the commercial variety increases each round while the resistance allele is retained. **B1** select and test the resulting plants over several sites and seasons before releasing a new variety essentially identical to the original commercial variety except for the added resistance. [5]

B2 ASB-Q8

B1 against: fast growth outpaces skeletal and cardiovascular development, causing leg deformities, lameness and heart failure in a high proportion of birds, a direct animal-welfare cost of the selection. **B1** against: birds cannot easily escape this trade-off, since the same genes are often linked to both the growth advantage and the physical strain, so selecting harder for growth tends to worsen the welfare problems. **B1** for: faster growth reduces the feed, land and time needed to produce each bird, lowering the cost of chicken as a food source and reducing the environmental resources used per bird produced. **B1** for: breeders can select simultaneously for growth rate and for leg strength or heart health if both are measured and included in the breeding programme, so the trade-off is not fixed by biology alone. **B1** a judgement: because the welfare cost falls directly and severely on the animal while the benefit is mainly economic, breeding programmes should give more weight to leg and heart health alongside growth rate, which some breeding companies have begun to do by including health traits in their selection targets. [5]

B3 ASB-Q1

B1 identify and select the sheep in the flock that produce the greatest mass of wool. **B1** breed only from those selected sheep, so that only their alleles are passed on. **B1** measure the wool produced by the offspring and select the best of them as the next generation of parents. **B1** repeat the selection and breeding over many generations, so the alleles for high wool yield become more frequent and the mean of the flock rises. [4]

B4 ASB-Q2 **B1** each generation of self-pollination halves the proportion of heterozygotes, so after several generations the line is almost entirely homozygous. **B1** harmful recessive alleles that were masked in heterozygotes are now present in the homozygous state and are expressed, which is inbreeding depression. **B1** crossing two different inbred lines gives offspring that are heterozygous at every locus where the two lines differed, so those harmful recessive alleles are masked again. **B1** the offspring are therefore uniform and vigorous and outyield both parent lines, which is hybrid vigour. [4]

B5 ASB-Q3 **B1** against: the selected shape causes ill health, because the airway is too small for the skull it sits in, so the dogs have difficulty breathing and cooling themselves. **B1** against: breeding within a closed register means matings between close relatives, so inbreeding depression raises the incidence of inherited disease. **B1** for: people value the appearance and temperament of particular breeds, and breeding to a standard is what keeps a breed recognisable and predictable. **B1** a judgement: the welfare cost falls on the animal and the benefit on the owner, so breed standards that reward the extreme should be rewritten and outcrossing allowed, which several kennel clubs have begun to do. [4]

B6 ASB-Q9 **B1** repeated selection has made the alleles favouring high egg number increasingly common in the flock, reducing the genetic variation for the characteristic. **B1** once the favourable alleles are close to fixed, with nearly every bird homozygous for them, very little genetic variation is left for selection to act on, and selection cannot act on variation that is not present. **B1** keeping only a small number of the highest-laying hens and their close relatives as breeding stock over six generations is a form of inbreeding. **B1** this raises homozygosity generally and can produce inbreeding depression, reduced vigour and fertility, which could offset or mask any further genetic gain in egg number even where some variation remains. [4]

B7 ASB-Q10 **M1** the proportion of heterozygotes halves each generation, so after n generations the proportion remaining is $100\% \times (\tfrac{1}{2})^{n}$. **M1** substitute n = 5: $100 \times (\tfrac{1}{2})^{5} = 100 \div 32$. **A1** = **3.125%**, which rounds to 3.1%. **A1** this shows why after six or seven generations of selfing an inbred line is described as almost completely homozygous: well under 5% of loci that started heterozygous remain so. [4]

B8 ASB-Q4 **B1** milk yield cannot be measured in a bull, because bulls do not lactate. **B1** the bull is therefore mated to many cows and the milk yields of his daughters are recorded and compared with the herds they are kept in. **B1** those yields estimate the alleles the bull passes on, so a bull that tests well can then be used on a very large scale through artificial insemination. [3]

B9 ASB-Q5 [3]

B1 the high-yielding variety has been selected from a small number of parents, so its gene pool is narrow and many alleles are absent from it. **B1** wild relatives and old varieties hold alleles the commercial variety has lost, including alleles for resistance to pathogens and for tolerance of drought or cold. **B1** those alleles can be bred into the commercial variety by crossing and backcrossing when a new pathogen or a change in climate arrives, and selection cannot act on variation that is not there.

B10 ASB-Q6 [3]

B1 in both, some individuals contribute more offspring than others, so the frequency of their alleles rises, and neither creates new alleles. **B1** in natural selection the environment decides, and what is favoured raises survival and reproduction, whereas in artificial selection a breeder decides, and what is favoured may reduce an organism's chance of surviving. **B1** artificial selection usually reduces genetic diversity far faster, because a very small number of parents is used deliberately.

B11 ASB-Q11 [3]

B1 close relatives share a higher than average proportion of their alleles, because they have recent common ancestors. **B1** mating between them therefore produces offspring that are more likely to be homozygous at any given locus than offspring of unrelated parents. **B1** harmful recessive alleles that were masked in heterozygous parents are exposed in the homozygous state in these offspring and are expressed, causing the reduced vigour, fertility and disease resistance seen as inbreeding depression.

B12 ASB-Q12 [3]

B1 with natural mating, a single bull or cow can only be the parent of a small number of calves in its lifetime, so an individual of high breeding value contributes only a small proportion of the alleles in the next generation. **B1** artificial insemination lets semen from one high-breeding-value bull be used on very large numbers of cows, including abroad since semen can be frozen and shipped, so his favourable alleles spread through a much larger proportion of the next generation than natural mating would allow. **B1** embryo transfer does the equivalent job on the female side, letting a cow of high breeding value be the genetic mother of many more calves than she could carry and give birth to herself, again spreading her favourable alleles faster through the population.

B13 ASB-Q13 [3]

B1 disbudding causes the calf pain and a wound that could become infected, so an animal born polled avoids the procedure entirely, a direct welfare benefit rather than a cost, unlike breeding decided by appearance or productivity alone. **B1** because polled is dominant, breeding from polled parents raises the frequency of the polled allele in the population, so more calves are born hornless and disbudding becomes unnecessary for them. **B1** a test cross: mate the bull with several homozygous horned cows; if any calf is born horned, the bull must be heterozygous for the polled allele, since a homozygous polled bull could only pass on the polled allele.

B14 ASB-Q14

B1 resistant wheat plants are identified by directly testing them, deliberately infecting offspring with the pathogen and keeping the survivors, whereas milk yield cannot be measured in the animal bred from, a bull, so bulls are instead judged indirectly by progeny testing, recording the yields of their daughters. **B1** a resistant wheat plant is multiplied by repeated crossing, backcrossing and growing seed from selected plants over several generations and seasons, whereas a bull identified as high breeding value is multiplied almost immediately and on a vastly larger scale through artificial insemination of many cows in a single breeding season. **B1** both programmes increase the frequency of favourable alleles by breeding selectively from the individuals carrying them, but a seed-propagated crop and an animal bred by artificial insemination differ greatly in how many offspring one selected individual can have, which is why livestock breeding can change a population's average much faster once an individual's value is known. [3]

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