Biology: Organisms and Evolution (Advanced Higher)

The **Mandatory Course key areas** are from the *Course Assessment Specification*. Activities in the **Suggested learning activities** are not mandatory. This offers examples of suggested activities, from which you could select a range of suitable activities. It is not expected that all will be covered. Centres may also devise their own learning activities. **Exemplification of key areas** is not mandatory. It provides an outline of the level of demand and detail of the key areas.

In the **Suggested learning activities**, there are references to the use of case studies. These should be seen as a suggested approach to teaching and learning and not confused with the use of case study as a method of Course assessment. These case studies should make learning active, challenging and enjoyable and identify for the learner the Course content and skills that will be developed. Case studies should be developed in such a way that learners have the opportunity to select activities, where appropriate, and present the opportunity to pursue further study. Case studies need not necessarily be restricted to one Unit but could include biology drawn from different Units.

Mandatory Course key areas	Suggested learning activities	Exemplification of key areas
1 Field techniques for biologists (a) Health and safety.	Discuss standard rules for fieldwork safety.	Fieldwork may involve a wider range of hazards compared with working in the laboratory. Hazards and risks associated with terrain, weather conditions and isolation must be assessed.
(b) Sampling of wild organisms Sampling should be carried out in a manner that minimises impact on wild species and habitats. Consideration must be given to rare and vulnerable species and habitats, which are protected by legislation. The chosen technique such as point count,	Participate in fieldwork. Identification of sample using guides and keys. Awareness of protected species in Scotland.	

transect or remote detection must be appropriate to the species being sampled. Quadrats of suitable size and shape are used for sessile and slow-moving organisms; capture techniques for mobile species. Elusive species can be sampled directly using camera traps or an indirect method such as scat sampling.		
(c) Identification and taxonomy Identification of a sample can be made using classification guides, biological keys or analysis of DNA or protein. Familiarity with taxonomic groupings allows predictions and inferences to be made between the biology of an organism and better-known (model) organisms. Genetic evidence reveals relatedness obscured by divergent or convergent evolution. Life is classified into three domains, the archaea, bacteria and eukaryota. The plant kingdom has major divisions such as mosses, liverworts, ferns, conifers and flowering plants. The animal kingdom is divided into phyla, which include the Chordata (sea squirts and vertebrates), Arthropoda (joint-legged invertebrates: segmented body typically with paired appendages), Nematoda (round worms: very diverse, many parasitic),	In the context of fieldwork, sample the organisms from a variety of habitats and attempt to classify and catalogue them using keys and other materials. Visit a botanic garden to learn more about the major divisions of plants. Visit a zoological park to learn more about the animal phyla. Undertake fieldwork to study the invertebrate phyla commonly found on the shore, in a river or in woodland.	The classification of life according to relatedness is central to biological understanding.

Platyhelminthes (flatworms: bilateral symmetry, internal organs but no body cavity, many parasitic) and Mollusca (molluscs: diverse, many with shells). Model organisms from within all taxonomic groups are used to obtain information that can be applied to species that are more difficult to study directly. Model organism that have been very important in the advancement of modern biology include the bacterium *E. coli*; the flowering plant *Arabidopsis thaliana;* the nematode *C. elegans*; the arthropod *Drosophila melanogaster* and mice, rats and zebrafish which are chordates.		
(d) Monitoring populations Presence, absence or abundance of indicator species can give information of environmental qualities, such as presence of pollutant. Mark and recapture is a method for estimating population size. A sample of the population is captured and marked (M) and released. After an interval of time, a second sample is captured (C). If some of the individuals in this second sample are recaptures (R) then the total population N = (MC)/R, assuming that all individuals have an equal chance of capture and that there is no immigration or emigration.	Identify relevant indicator species to classify a habitat using the British National Vegetation Classification. Carry out a mark and recapture experiment using a wild species or, alternatively, with learners to estimate the total roll.	Classification of vegetation types is based on indicator species within the community structure.

Methods of marking include banding, tagging, surgical implantation, painting and hair clipping. The method of marking and subsequent observation must minimise the impact on the study species.		
(e) Measuring and recording animal behaviour An ethogram of the behaviours shown by a species in a wild context allows the construction of time budgets. Measurements such as latency, frequency and duration. The importance of avoiding anthropomorphism.	Use an ethogram and time sampling to compare the behaviour of different individuals of a species.	
2 Organisms Evolution (a) Drift and selection Evolution is the change over time in the proportion of individuals in a population differing in one or more inherited traits. Evolution can occur through the random processes of genetic drift or the non-random processes of natural selection and sexual selection. Genetic drift is more important in small populations, as alleles are more likely to be lost from the gene pool. Variation in traits arises as a result of mutation. Mutation is the original source of new sequences of DNA. These new		Fitness can be defined in absolute or relative terms. As organisms produce more offspring than the environment can support, those individuals with variations that best fit their environment are the ones most likely to

sequences can be novel alleles. Most mutations are harmful or neutral but in rare cases they may be beneficial to the fitness of an individual. Absolute fitness is the ratio of frequencies of a particular genotype from one generation to the next. Relative fitness is the ratio of surviving offspring of one genotype compared with other genotypes. As organisms produce more offspring than the environment can support, those individuals with variations that best fit their environment are the ones most likely to survive and breed. Through inheritance, these favoured traits are therefore likely to become more frequent in subsequent generations.		survive and breed. Through inheritance, these favoured traits are therefore likely to become more frequent in subsequent generations.
(b) Rate of evolution Where selection pressures are high, the rate of evolution can be rapid. The rate of evolution can be increased by factors such as shorter generation times, warmer environments, the sharing of beneficial DNA sequences between different lineages through sexual reproduction and horizontal gene transfer.	Comparison of cladograms of MRSA and primate evolution to compare the effect of generation time on rates of evolution. Investigate horizontal gene transfer using X-bacteria.	

(c) Co-evolution and the Red Queen Hypothesis Co-evolution is frequently seen in pairs of species that interact frequently or closely. Examples include herbivores and plants, pollinators and plants, predators and their prey, and parasites and their hosts. In co-evolution, a change in the traits of one species acts as a selection pressure on the other species. The ongoing co-evolution between a parasite and host, as exemplified in the Red Queen hypothesis. Hosts better able to resist and tolerate parasitism have greater fitness. Parasites better able to feed, reproduce and find new hosts have greater fitness.	Read excerpts from Matt Ridley's book *The Red Queen*. Case study on HIV and CD4 variability or evolution of *Plasmodium falciparum* and *P. vivax* with reference to primate evolution.	Red Queen hypothesis states that both organisms must 'keep running in order to stay still'.
3 Variation and sexual reproduction (a) Costs and benefits of sexual and asexual reproduction Comparison of the costs and benefits of sexual and asexual reproduction Disadvantages of sexual reproduction: males unable to produce offspring; only half of each parent's genome passed onto offspring disrupting successful parental genomes. Benefits outweigh disadvantages due to increase in genetic variation in the	Consider how the evolutionary importance of sexual reproduction influences experimental design in the life sciences: the natural variation generated means that biologists have to take care when sampling a population and analysing data to make sure that they can distinguish this 'noise' from any experimental result or 'signal'.	The paradox of the existence of males.

population. This genetic variation provides the raw material required to keep running in the Red Queen’s arms race between parasites and their hosts. Asexual reproduction can be a successful reproductive strategy, particularly in very narrow stable niches or when recolonising disturbed habitats. In eukaryotes, examples of asexual reproduction include vegetative cloning in plants and parthenogenic animals that lack fertilisation. Parthenogensis is more common in cooler climates that are disadvantageous to parasites or regions of low parasite density/diversity. Organisms that reproduce principally by asexual reproduction often have mechanisms for horizontal gene transfer between individuals, such as the plasmids of bacteria and yeast.	Examine reproduction in a parthenogenic organism such as the laboratory stick insect *Carausias morosus* (in which offspring are female) and compare with the Komodo dragon (in which offspring are male).	
(b) Meiosis forms variable gametes Homologous chromosomes are pairs of chromosomes of the same size, same centromere position and with the same genes at the same loci. Mechanism by which variation is increased through the production of haploid gametes by meiosis in gamete mother cells.	Use microscopy to examine gamete formation or gametes in plants or invertebrates.	

Meiosis I including: pairing of homologous chromosomes; random crossing over at chiasmata resulting in exchange of DNA between homologous pairs and recombination of alleles of linked genes; independent assortment and separation of parental chromosomes irrespective of their maternal and paternal origin. Meiosis II including: including separation of sister chromatids/chromosomes; gamete formation. In many organisms, gametes are formed directly from the cells produced by meiosis. In other groups, mitosis may occur after meiosis to form a haploid organism; gametes form later by differentiation.	Breed model organisms in the laboratory (eg *Drosophila* or rapid-cycling *Brassica*) to demonstrate independent assortment or, if possible, recombination.	
(c) Sex determination Many species are hermaphroditic. For some species environmental rather than genetic factors determine sex and sex ratio. Sex can change within individuals of some species as a result of size, competition or parasitic infection. Sex chromosomes, such as XY in live-bearing mammals and some insects including *Drosophila*. In many of the mammals a gene on the Y chromosome	Examine data on sex determination in a variety of organisms. Research sex-ratio manipulation in red deer. Compare the flowers of hermaphroditic and unisexual plants. Use *Drosophila* to investigate sex-linked inheritance patterns. Examine data on inheritance patterns of tortoiseshell cats.	Environmental sex determination in reptiles controlled by environmental temperature of egg incubation. In some species the sex ratio of offspring can be adjusted in response to resource availability.

determines development of maleness. In live-bearing mammals, the heterogametic (XY) male lacks homologous alleles on the smaller (Y) chromosome. This can result in sex-linked patterns of inheritance as seen with carrier females (XBXb) and affected males (XbY). In the females, the portions of the X chromosome that are lacking on the Y chromosome are randomly inactivated in one of the homologous X chromosomes in each cell. This effect prevents a double-dose of gene products, which could be harmful to cells. Carriers are less likely to be affected by any deleterious mutations on these X chromosomes as the X-chromosome inactivation is random, half of the cells in any tissue will have a working copy of the gene in question.	Case study on X linked agammaglobulinemia and colour vision defect.	
4 Sex and behaviour (a) Parental investment Comparison of sperm and egg production in relation to number and energy store; greater investment by females. Problem and solutions of sex for sessile organisms. Costs and benefits of external and internal fertilisation. Parental investment is costly but increases the probability of production and survival of	Investigate foraging/pollinating behaviour of insects at flowers. Investigate a range of reproductive strategies using examples such as naked mole rats.	Simplistic classification of parental investment into discrete r-selected and K-selected organisms does not reflect continuous range of life history strategies. Optimal reproduction in terms of the number and quality of current offspring versus potential future offspring.

young. Classification of r-selected and K-selected organisms. Various reproductive strategies have evolved ranging from polygamy to monogamy.		
(b) Courtship Sexual dimorphism as a product of sexual selection. Male–male rivalry: large size or weaponry increases access to females through conflict. Alternatively some males are successful by acting as sneakers. Females generally inconspicuous; males have more conspicuous markings, structures and behaviours. Female choice: involves females assessing honest signals of the fitness of males. Fitness can be in terms of good genes and low parasite burden. In lekking species, alternative successful strategies of dominant and satellite males. Reversed sexual dimorphism in some species. Successful courtship behaviour in birds and fish can be a result of species-specific sign stimuli and fixed action pattern responses. Imprinting: irreversible developmental processes that occur during a critical time period in young birds may influence mate choice later in life.	Courtship in the field: create an ethogram observing the ritualised courtship displays of water birds such as grebes or ducks. Courtship in the laboratory: observe stickleback or *Drosophila* courtship; investigate sexual selection in different *Drosophila* varieties. Research honest signalling in lekking species.	

5 Parasitism (a) The parasite niche A parasite is a symbiont that gains benefit in terms of nutrients at the expense of its host. Unlike in a predator–prey relationship, the reproductive potential of the parasite is greater than that of the host. An ecological niche is a multidimensional summary of tolerances and requirements of a species. Parasites tend to have a narrow niche as they are very host specific. As the host provides so many of the parasite's needs, many parasites are degenerate, lacking in structures and organs found in other organisms. An ectoparasite lives on the surface of its host, whereas an endoparasite lives within the host. The organism on or in which the parasite reaches sexual maturity is the definitive host. Intermediate hosts may also be required for the parasite to complete its life cycle. A vector plays an active role in the transmission of the parasite and may also be a host. A species has a fundamental niche that it occupies in the absence of any interspecific competing influences. A realised niche is occupied in response to interspecific competition. As a result of interspecific competition, competitive exclusion can occur where the niches of	Research the niche of *C. difficile* and the use of fecal transplants.	At least half of all species are parasitic, and all free-living species are thought to host parasites.

two species are so similar that one declines to local extinction. Where the realised niches are sufficiently different, potential competitors can co-exist by resource partitioning.		
(b) Transmission and virulence Transmission is the spread of a parasite to a host. Virulence is the harm caused to a host species by a parasite. Factors that increase transmission rates: the overcrowding of hosts at high density; mechanisms that allow the parasite to spread even when infected hosts are incapacitated, such as vectors and waterborne dispersal stages. Host behaviour is often exploited and modified by parasites to maximise transmission. Through the alteration of host foraging, movement, sexual behaviour, habitat choice or anti-predator behaviour, the host behaviour becomes part of the extended phenotype of the parasite. Parasites also often suppress the host immune system and modify host size and reproductive rate in ways that benefit the parasite growth reproduction or transmission. The distribution of parasites is not uniform across hosts. Sexual and asexual phases	Investigate the spread of a plant pathogen in a variety of planting densities and humidities. Consider the potential socioeconomic impact of plant pathogens, such as blight.	The most successful parasites have efficient modes of transmission and rapid rates of evolution.

allow rapid evolution and rapid build-up of parasite population.		
(c) Immune response to parasites Non-specific defences of mammals: physical barriers, chemical secretions, inflammatory response, phagocytes and natural killer cells destroying abnormal cells. Specific cellular defence in mammals involves immune surveillance by white blood cells, clonal selection of T lymphocytes, T lymphocytes targeting immune response and destroying infected cells by inducing apoptosis, phagocytes presenting antigens to lymphocytes, the clonal selection of B lymphocytes, production of specific antibody by B lymphocyte clones, long term survival of some members of T and B lymphocyte clones to act as immunological memory cells. Epidemiology is the study of the outbreak and spread of infectious disease. The herd immunity threshold is the density of resistant hosts in the population required to prevent an epidemic. Endoparasites mimic host antigens to evade detection by the immune system,	Use a statistical test to confirm or refute the significance of results of an epidemiological study into disease.	

and modify host-immune response to reduce their chances of destruction. Antigenic variation in some parasites allows them to evolve faster than the host immune system can respond to the new antigens.		
(d) Parasitic life cycles Common parasites include protists, platyhelminths, nematodes, arthropods, bacteria and viruses. Many parasites require more than one host to complete their life cycle, eg *Plasmodium spp*. which causes the human disease malaria and the platyhelminth, *Schistosoma spp.,* which causes schistosomiasis in humans. Ectoparasites and endoparasites of the main body cavities, such as the gut, are generally transmitted through direct contact or by consumption of secondary hosts. Endoparasites of the body tissues are often transmitted by vectors. Other parasites can complete their life cycle within one host, eg some endoparasitic amoebas and ectoparasitic arthropods, bacteria and viruses. Human diseases include tuberculosis, caused by bacteria, and influenza and HIV caused by viruses. Viruses are infectious agents that can only replicate inside a host cell. Viruses contain genetic material in the form of DNA or	Consider the ecology, evolution, reproduction and physiology of a selected human parasite. Consider how attempts to disrupt the lifecycle of *Plasmodium* in the control of malaria have resulted in the loss of apex predators due to bio-magnification of the organochloride insecticide DDT. Investigate the effects of a phage virus on bacterial growth.	Some viruses have a lipid membrane surround derived from host cell materials. Most of the genome of most eukaryotic

RNA, packaged in a protective protein coat. The outer surface of a virus contains antigens that a host cell may or may not be able to detect as foreign. RNA retroviruses use the enzyme reverse transcriptase to form DNA, which is then inserted into the genome of the host cell. This virus gene forms new viral particles when transcribed.		species consists of mobile or defunct retrotransposons, which are thought to have arisen from retroviruses. Active retrotransposons form new copies of themselves to be inserted elsewhere in the same genome. The genes responsible for the variability of vertebrate antibodies are thought to have evolved from transposons.
(e) Challenges in treatment and control Some parasites are difficult to culture in the laboratory. Rapid antigen change has to be reflected in the design of vaccines. The similarities between host and parasite metabolism makes it difficult to find drug compounds that only target the parasite. Civil engineering projects to improve sanitation combined with coordinated vector control may often be the only practical control strategies. Challenges arise where parasites spread most rapidly as a result of overcrowding or tropical climates. Improvements in parasite control reduce child mortality and result in population-wide improvements in child development and intelligence as individuals have more resources for growth and development.	Case study on parasitism and childhood. Research impact of parasitism on child mortality rates in developed and developing countries. Consider benefits of intervention programmes in terms of childhood development and intelligence. Research the decline of effectiveness of chemical treatments over time.	There are many challenges to overcome in the successful treatment and control of parasites. Parasites spread most rapidly in those conditions where coordinated treatment and control programs are most difficult to achieve. Overcrowding can occur in, eg refugee camps that result from war or natural disaster or rapidly growing cities in LEDCs.