

AS and A LEVEL

Delivery Guide

BIOLOGY A

H020/H420

For first teaching in 2015

Classification and evolution 4.2.2

Version 2

AS and A LEVEL BIOLOGY A

Delivery guides are designed to represent a body of knowledge about teaching a particular topic and contain:

- Content: A clear outline of the content covered by the delivery guide;
- Thinking Conceptually: Expert guidance on the key concepts involved, common difficulties students may have, approaches to teaching that can help students understand these concepts and how this topic links conceptually to other areas of the subject;
- Thinking Contextually: A range of suggested teaching activities using a variety of themes so that different activities can be selected which best suit particular classes, learning styles or teaching approaches.

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Curriculum Content	Page 3	
Activities	Page 5	
Thinking Conceptually	Page 7	
Activities	Page 8	
Thinking Contextually	Page 9	
Activities	Page 10	
Teacher Resources	Page 11	

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4.2.2 Classification and evolution

- (a) the biological classification of species
- To include the taxonomic hierarchy of kingdom, phylum, class, order, family, genus and species
- AND**
- domain.
- HSW1, HSW5, HSW6, HSW7
- (b) the binomial system of naming species and the advantage of such a system
- (c) (i) the features used to classify organisms into the five kingdoms: Prokaryotae, Protoctista, Fungi, Plantae, Animalia
- To include the use of similarities in observable features in original classification.
- (ii) the evidence that has led to new classification systems, such as the three domains of life, which clarifies relationships
- To include the more recent use of similarities in biological molecules and other genetic evidence
- AND**
- details of the three domains and a comparison of the kingdom and domain classification systems.
- HSW1, HSW5, HSW6, HSW7, HSW11, HSW12
- (d) the relationship between classification and phylogeny
- Cladistics and the phylogenetic definition of species are not covered at AS Level.
- HSW5, HSW7
- (e) the evidence for the theory of evolution by natural selection
- To include the contributions of Darwin and Wallace in formulating the theory of evolution by natural selection
- AND**
- fossil, DNA (only genomic DNA at AS level) and molecular evidence.
- HSW1, HSW2, HSW5, HSW6, HSW7

- (f) the different types of variation
- To include intraspecific and interspecific variation
- AND**
- the differences between continuous and discontinuous variation, using examples of a range of characteristics found in plants, animals and microorganisms
- AND**
- both genetic and environmental causes of variation.
- An opportunity to use standard deviation to measure the spread of a set of data
- and/or**
- Student's t-test to compare means of data values of two populations
- and/or**
- Spearman's rank correlation coefficient to consider the relationship of the data.
- M1.2, M1.3, M1.6, M1.7, M1.10*
- HSW4
- (g) the different types of adaptations of organisms to their environment
- Anatomical, physiological and behavioural adaptations
- AND**
- why organisms from different taxonomic groups may show similar anatomical features, including the marsupial mole and placental mole.
- HSW5

(h) the mechanism by which natural selection can affect the characteristics of a population over time	To include an appreciation that genetic variation, selection pressure and reproductive success (or failure) result in an increased proportion of the population possessing the advantageous characteristic(s). <i>M0.3</i> HSW8
(i) how evolution in some species has implications for human populations.	To include the evolution of pesticide resistance in insects and drug resistance in microorganisms. HSW8, HSW9, HSW12

Classification can, at first glance, seem a somewhat dry and dusty topic to some students, a little akin to stamp collecting. However, it can be exactly the opposite, and delivering it effectively can unlock areas of understanding that enhance students' abilities in other areas of biology.

- Considering the classification of individual organisms can provide students with contextual examples that facilitate their understanding of other topics, such as biodiversity
- Exploring the diversity of living organisms can enthuse students with the wonder of biology and its wider global importance
- Study of classification exemplifies the effect evolution has had on living organisms and, as such, emphasises the importance in biology of understanding evolution.

Students are likely to have studied some classification and variation at Key Stage 3 and should be aware of the process of natural selection from GCSE.

This topic provides an opportunity for students to encounter some of the statistical tests referenced in the mathematical skills requirements in section 5e of the Biology A specifications.

Activity 1**Taxonomic hierarchy 4.2.2(a)**

Students can create mnemonics to remember the order of taxa, for example “*King Phillip Can Only Find Green Slippers*”.

A game based on *Play Your Cards Right* can also be played. Cards with taxon names are placed face down (or leaning on a whiteboard). The teacher turns the first one over to reveal a name, such as ‘family’. A student is then asked to predict if the next card will be a higher or lower group than family.

Activity 2**The binomial system of classification (BBC) 4.2.2(b)**

<https://www.bbc.co.uk/programmes/p011mv7c>

This short video explains the binomial system and its advantages.

Having learned the basics, students can then be asked to comment on media mistakes in using the binomial system, such as *Homo reptilia* being used as a name for intelligent lizards in the TV series *Doctor Who*.

Activity 3**The five kingdoms 4.2.2(c)(i)**

Students can transfer textual information from any textbook or appropriate website and present it as a table with column headings for features, such as ‘presence of nucleus’ or ‘mode of nutrition’.

Characteristics of Kingdoms (Maths and Science Activity Center)

http://www.edinformatics.com/math_science/living_kingdom_classifications.htm

This site contains characteristics for each kingdom (six kingdom system) and an outline table such as the one described above.

Students can be given cards with kingdom names, written in large letters. They then hold up the correct card in response to a series of “What kingdom am I?” questions generated by the teacher (see [Teacher Resource 1](#)).

Activity 4**Re-classified: The three domains 4.2.2(c)(ii)**

Students can research individual examples of species that have been reclassified in the light of molecular evidence, such as chimpanzees, giant pandas, whales or elephants.

African elephants really two wildly different species? (National Geographic)

<http://news.nationalgeographic.com/news/2010/12/101222-african-elephants-two-species-new-science/>

This article describes the news that the African elephant, previously thought of as one species, *Loxodonta africana*, is in fact two.

Having considered examples of individual species reclassification, students can then be introduced to the idea of the 3-domain classification system. Students can debate the pros and cons of the 3-domain system versus the original 5-kingdom system.

Considering these changes to classification provides an opportunity to cover some of the How Science Works statements listed in the specification: HSW1, HSW5, HSW6, HSW7, HSW11 and HSW12.

Activity 5**The theory of evolution by natural selection 4.2.2(e)**

Students can categorise evidence into groups: fossil evidence, molecular evidence, evolution around us (such as MRSA), the plausible inevitability of natural selection itself and ‘other’ types of evidence such as comparative anatomy and embryology.

There are some great websites out there on the theory of evolution by natural selection, Darwin and Wallace. For example:

<http://darwin200.christs.cam.ac.uk/> A useful website for information on Charles Darwin and the theory of evolution by natural selection.

<http://darwin-online.org.uk/>

Fantastic online resource on Charles Darwin, including an e-version of ‘On the Origin of Species’.

<http://wallace-online.org/>

Comprehensive collection of the work of Alfred Russel Wallace.

Activity 6**Variation 4.2.2(f)**

Students can collect data from classmates (with due consideration of sensitive issues – HSW4). These can then be represented as frequency graphs (*M1.3*) with continuous or categoric x-axes. The continuous variation graph could be used to illustrate standard deviation (*M1.10*). Alternatively students can use plant or animal examples from which to gather data, e.g. leaf size, number of petals etc.

Having generated data from two groups, e.g. boys and girls, students could then use the Student's t-test to compare means (*M1.2, M1.6, M1.9, M1.10*) of, for example, height or hair length.

A scatter graph of a correlation between two variables, such as height and shoe size, could be used to calculate a Spearman's rank correlation coefficient (*M1.7, M1.9*).

Adaptation, natural selection and winged fruits (SAPS)

<http://www.saps.org.uk/secondary/science-club-activities/694-adaptation-natural-selection-and-winged-fruits-stem-science-club-activity>

This website provides a worksheet and instructions for a practical activity that covers many of the above points.

Activity 7**Adaptations 4.2.2(g)**

<https://www.bbc.co.uk/bitesize/topics/zb44jxs/resources/1>

This BBC Nature Wildlife webpage on Animal and Plant Adaptations and Behaviours has many good examples.

Students can also be asked to research examples of convergent evolution. For example the eye in humans and squid, wings in bats and birds; and at the whole organism level, the marsupial mole and placental mole, or sharks and dolphins.

Activity 8**Natural selection in context 4.2.2(h)**

Students can be provided with cards on which are the generic steps in the process of natural selection, e.g. 'pre-existing genetic variation'. Students sequence the cards into the correct order. The teacher then provides a series of example scenarios, e.g. 'the evolution of white fur-colour in polar bears', to which students apply these general steps in context.

Alternatively, students can produce storyboards illustrating a particular example of natural selection.

Activity 9**Evolution now 4.2.2(i)**

Students can research individual examples given by the teacher. The use of a list of essential criteria for each presentation would allow students to demonstrate understanding of other learning objectives.

Approaches to teaching the content

Students have some prior knowledge and understanding of the topic from Key Stage 3 or GCSE. It is possible, therefore, to teach the topic from the top down, beginning with an interesting species and visiting all the learning outcomes in context. This can be engaging and interesting for students and can help them relate the learning outcomes to a wider context. However, this approach is likely to be inappropriate for some students who struggle to understand some of the concepts being exemplified. It is more appropriate in most cases to give students a fundamental understanding of the key concepts before letting them explore individual examples.

Common misconceptions or difficulties students may have

The common misconceptions in this topic tend to be rather specific. Many students find it difficult to appreciate or understand the place of kingdoms within the 3-domain classification system. It is therefore important to emphasise that domains do not replace kingdoms; they merely provide an extra tier of classification taxon, above that of kingdom. The other major misconception is that selection pressures cause mutations, in particular that antibiotics cause mutations in bacteria.

Another difficulty, and one shared with section 4.2.1, arises from students' lack of familiarity with any species other than *Homo sapiens*. This can make the understanding of contextual examples difficult, and contextual examples are a key feature of this topic. This lack of knowledge is particularly evident when discussing plant-based examples of variation or natural selection.

Conceptual links to other areas of the specification – useful ways to approach this topic to set students up for topics later in the course

When individual species or adaptations are considered, there are links to many learning outcomes. However, understanding of some of the key concepts is underpinned by an understanding of the nature of nucleic acids, 2.1.3(d), and proteins, 2.1.2(m), and the relationship between the two, 2.1.3(f-g). There is an opportunity to incorporate practical skills from 1.1.3 in relation to variation (4.2.2(f)). The implications of 4.2.2(i) are best understood in the light of 4.1.1(a) and 4.1.1(m-n). Future topics with significant contextual links are 6.1.2 (Patterns of inheritance) in its entirety and 6.1.1(c) (development) and 6.1.3(a-b) (DNA sequencing).

When referring to the concept of selection pressures or adaptations, obvious links can be made with the biodiversity topic (4.2.1), in particular learning outcomes (f), (g) and (i).

Mutations are likely to have already been covered in 2.1.3(e) (DNA replication). Natural selection provides an opportunity to recap mutations and their random nature. The fact that mutations are not *caused* by selection pressures can be discussed in this context. For example, penicillin weakens bacterial cell walls; it does not disrupt DNA replication.

Diagrammatic representations of classification systems available on the internet are, literally, wonderful and can be very useful for enthusing students; however many are very complex, which can hinder understanding.

Learner Activity 1**Modern Classification Systems (Open Curriculum) 4.2.2(c)(ii)**

<http://www.opencurriculum.org/5366/modern-classification-systems/> (link does not work in Internet Explorer)

This text-based website provides useful information about the development of various recent classification systems and contains a simple cladistics diagram that shows clearly the relationship between kingdoms and domains.

Contexts

The classification topic is almost inevitably taught in context. Indeed the ideas contained in most of the learning outcomes make little sense outside a specific context: the taxonomic hierarchy makes much more sense when seen in the context of an example; examples illustrate the binomial naming system and its advantages. The process of natural selection is made much more 'real' for students as a 'story' about how a particular adaptation arose – examples are needed at all stages.

Old, or current, textbooks are awash with examples to use for all learning points.

In order to contextualise natural selection, students can write a narrative about the evolution of a particular species or adaptation in the style of a fairy tale, or a story in the style of a Rudyard Kipling 'Just So' story.

An interesting starting point for more holistic individual student research is that of two similarly adapted but unrelated species, such as the marsupial mole and the placental mole. Students can then research each species as an example of each of the learning points. For example, their classification, their binomial name, the variation shown by key adaptations, how natural selection resulted in the development of key adaptations, etc.

There is an almost infinite list of paired examples to choose from but some websites are a useful starting point. See the next page for examples.

Learner Activity 1**Convergent Evolution (Eric Pianka) 4.2.2(g)**

<http://www.zo.utexas.edu/courses/THOC/Convergence.html>

A text-based website which explains convergent evolution and contains lots of examples.

If the research activity described on the previous page is carried out at the end of teaching of 4.2.1 and 4.2.2, the students' research can be expanded to cover learning points from 4.2.1, e.g. conservation status of the species and the reasons behind it.

Learner Activity 2**OCR Topic Exploration Pack – The Development of Species 4.2.2 (d, e, g, h)**

A teacher pack and student activity sheet written to support the A Level Biology B specification, which also supports many aspects of the Biology A specification.

The Development of Species – Teacher Pack:

<https://www.ocr.org.uk/Images/169850-the-development-of-species.pdf>

The Development of Species – Activity Sheet:

<https://www.ocr.org.uk/Images/169849-the-development-of-species-activity.docx>

The Five Kingdom System – cards

Prokaryotae

Protoctista

Fungi

Plantae

Animalia

What kingdom am I? questions

1. *Homo sapiens* – eukaryotic, multicellular organism, the only hominin species still in existence
Answer: Animalia
2. *Neurospora crassa* – has a chitinous cell wall, can be a contaminant of bakeries
Answer: Fungi
3. *Arabidopsis thaliana* – eukaryotic, multicellular organism with cell walls containing cellulose
Answer: Plantae
4. *Escherichia coli* – a prokaryotic, unicellular organism usually present in the intestine of mammals
Answer: Prokaryotae
5. *Saccharomyces cerevisiae* – eukaryotic, unicellular organism used in baking and brewing
Answer: Fungi
6. *Erithacus rubecula* – a eukaryotic, multicellular organism, with the ability to fly
Answer: Animalia
7. *Bacillus subtilis* – a unicellular organism with a thick peptidoglycan cell wall
Answer: Prokaryotae
8. *Drosophila melanogaster* – a heterotrophic, multicellular organism used in the study of genetics
Answer: Animalia
9. *Lemna gibba* – eukaryotic, multicellular organism, autotroph, living in aquatic conditions
Answer: Plantae
10. *Tetrahymena thermophila* – a free-living, eukaryotic ciliate, found in freshwater ponds
Answer: Protoctista
11. *Carcinus maenas* – a eukaryotic multicellular organism with a hard external skeleton containing chitin
Answer: Animalia
12. *Mycobacterium tuberculosis* – has no nucleus and no membrane-bound organelles
Answer: Prokaryotae
13. *Pleurotus ostreatus* – a saprotroph that decomposes wood, it has a mycelium which consists of hyphae
Answer: Fungi
14. *Sulfolobus solfataricus* – a prokaryotic thermophile found in volcanos
Answer: Prokaryotae (though this is an archaeal species, which could lead into discussions on the six kingdoms, or domain classification system)
15. *Tobacco mosaic virus* (TMV) – single-stranded RNA virus that infects plants
Answer: Viruses do not fit into any cellular organism kingdom classification

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