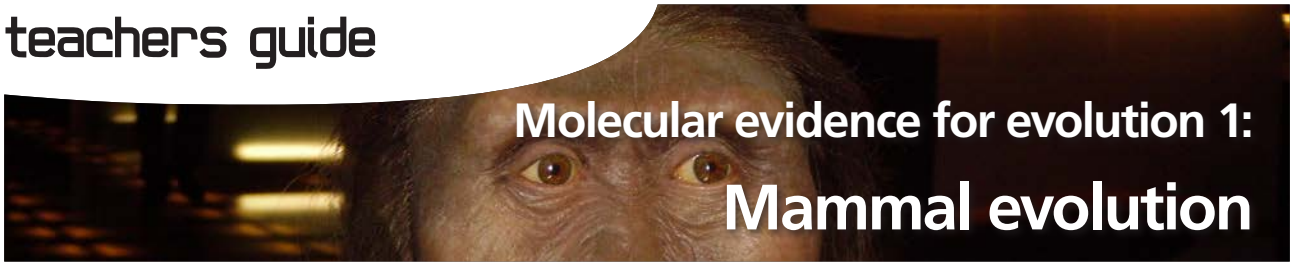
teachers guide



Molecular evidence for evolution 1: Mammal evolution

Components

	NAME	DESCRIPTION	AUDIENCE
	Mammal evolution teachers guide	This guide describes how a card game may be used to engage student interest in mammalian evolutionary relationships. Suggestions for teaching strategies and discussion points are included.	teachers
	Phylogenetics background sheet	This background sheet provides teachers with information about the modern classification of organisms: phylogenetic systematics. It includes information about molecular evidence for evolution and implications of this evidence for eutherian (placental mammal) evolutionary history.	teachers
	Mammalian clades background sheet	This background sheet provides teachers with details about mammals featured in the card game, *Who's related?* It includes information about how molecular evidence has led to a revised evolutionary history of eutherians (placental mammals).	teachers
	Who's related? card game	This card game engages student interest in evidence used to determine evolutionary relationships between mammals.	students
	Who's related? Rules of the game procedure sheet	This document explains rules of the card game, *Who's related?*	students
	Introducing clades presentation	This presentation contains material to stimulate class discussion before and after playing the game, *Who's related?* It is also available in interactive whiteboard format.	teachers

Purpose

To **Engage** student interest in types of evidence used to determine evolutionary relationships between organisms; and in the impact of molecular evidence on our understanding of these evolutionary relationships.

Outcomes

Students:

- appreciate that all eutherians (placental mammals) share a common evolutionary history;
- make decisions about grouping eutherians, based on evolutionary evidence;
- understand that various types of evolutionary evidence are used to make informed decisions about evolutionary relationships; and
- recognise molecular evidence is a powerful tool in determining evolutionary relationships between organisms.

Activity summary

ACTIVITY	POSSIBLE STRATEGY
Review information about clades and evolutionary history of eutherians (placental mammals) in background sheets, *Phylogenetics* and *Mammalian clades*.	teacher, before lesson
Lead a discussion about evolutionary history of eutherians. The first 10 screens of the presentation, *Introducing clades*, include discussion questions and activities.	whole class
Instruct students how to play the card game, *Who's related?*	whole class
Divide students into groups of four to six students. Provide each group with a set of cards and a rule sheet.	group activity
When the game is finished distribute answer matrix, at end of this guide. It shows the correct grouping of eutherians.	group activity
Lead a discussion using notes provided below, and/or use the presentation, *Introducing clades*. Discussion focus: how students made decisions about grouping mammals; and which type of evidence was most useful. Introduce students to molecular evidence for evolution and its implications for how organisms are grouped.	whole class

Introducing the card game

Explain that all mammals are related, but some share a more recent common ancestor, and thus a closer evolutionary relationship. One way to show evolutionary relationships is by grouping mammals into clades.

A clade is a group of organisms that includes a common ancestor and all living and extinct descendants of that ancestor. Members of a clade share characteristics (traits) that may be traced back to a common ancestor.

All eutherians (placental mammals), including humans, belong to one of four major clades: Afrotheria, Xenarthra, Laurasiatheria, and Euarchontoglires.

Evolution of the four eutherian clades is linked with biogeography. One hundred million years ago the world's supercontinents separated, thus isolating early mammal species. The common ancestor of each eutherian clade is believed to have evolved in a specific region.

Present day mammals (class Mammalia) are divided into two subclasses: Prototheria (monotremes — egg-laying mammals) and Theria (live young). Theria are further subdivided into two infraclasses: Metatheria (marsupials) and Eutheria (placental mammals).

Eutherians are commonly referred to as 'placental mammals' due to nourishment of the young in the uterus through a complex placenta. However Metatheria also have a placenta, though it is short-lived. Eutheria is considered a more accurate name than Placentalia, used previously.

Molecules that make up animals are important evidence in determining evolutionary relationships. Useful molecules include proteins, DNA and RNA. New technology means scientists may compare differences and similarities in the structure of these molecules. This information is used to determine evolutionary relationships amongst organisms, and is crucial in determining the four eutherian clades.

A summary of these ideas is included in the first part of the presentation, *Introducing clades*. The section that follows contains eight slides, each depicting three different mammals. Students compare features of these mammals and discuss which are most closely related. Answers and evidence that supports the groupings are included.

Use of the an IWB with the presentation facilitates interactive class discussion, as well as capturing and saving students' ideas for later reference.

Object of the game

Explain the object of the card game: to match each mammal to its correct clade by using evidence provided on both playing and clade cards. Direct students to use evidence provided, to discuss the validity of each other's decisions, after each turn.

Rules of the game are outlined on the procedure sheet for students, *Who's related? Rules of the game*.

Depending on group size, the card game takes approximately 20 minutes to complete.

After completing the card game, encourage students to sort remaining playing cards into correct clades, and to discuss reasons for each placement.

Students may find it difficult to organise, accurately, the four eutherian clades. The cards omit essential evidence: molecular evidence.

After the game, pose the following questions in a class discussion: If you were unable to group these animals, how do scientists do it? Is some evidence missing?

Allow students to explore alternate ideas about other lines of evidence, before explaining that molecular evidence determines the four eutherian clades.

After the game

Follow the card game with a class discussion about the most useful evidence in determining evolutionary relationships amongst mammals. Discuss evidence presented on the cards, and establish how students weighted their decisions about grouping mammals.

Possible discussion points after the card game are outlined on the next page as well as in the final section of the presentation, *Introducing clades.*

What types of evidence were useful when organising animals into clades?

EVIDENCE	DISCUSSION POINTS
distribution	An animal's geographic distribution can provide some clues about its origin. For example, clade Xenarthra (armadillos, sloths, anteaters) is found only in the Americas, the place of origin of the common ancestor. However, over geological time, many species have dispersed widely from their place of origin. This dispersion is the result of events such as continental movement and the creation of land bridges. Ungulates (hoofed mammals) evolved in Laurasia, but dispersed worldwide, excluding Antarctica and Australia.
diet	Animals that share a similar diet aren't necessarily related. For example, aardvarks and anteaters both eat termites, but they aren't closely related, belonging to different clades.
habitat	Animals that share similar habitats aren't necessarily related. For example, marine mammals such as sea cows and whales inhabit marine environments, but they aren't closely related, belonging to different clades.
taxonomic order	Linnaean taxonomy groups animals on the basis of overall similarity, but the Linnaean system doesn't always accurately reflect an animal's evolutionary history, particularly within higher-level groupings. Animals can share similar anatomical and ecological features without sharing a common ancestor. Similarities may be the result of convergent evolution.
anatomy	Anatomical evidence is important in understanding evolutionary relationships between organisms. Skeletal, muscular and reproductive evidence are all used in phylogenetics. Animals that share anatomical characteristics are likely to have evolved from a common ancestor. Anatomical evidence is limited, as similar traits can be the result of convergent evolution. For example, the mole and golden mole share similar anatomical and ecological features, but belong to separate clades. Their similarities are the result of convergent evolution.
fossils	Fossil evidence is significant in understanding evolutionary relationships between organisms. Fossils allow us to reconstruct species that are no longer living, and can also reveal times when major evolutionary change occurred. Fossil evidence is limited: fossils aren't easy to find, soft tissue is rarely preserved, and it is rare to discover an intermediate species.
molecular	Molecular evidence provides powerful evidence for evolutionary relationships between organisms. Evolution is the result of genetic change. Looking directly at genetic material provides information on evolutionary relationships. Comparing differences and similarities in genetic material between organisms helps determine evolutionary relationships. The four eutherian clades in the card game are supported by molecular evidence. Except for clade Xenarthra, it's unlikely these clades would have been discovered without molecular evidence.
What evidence is most important?	Evolutionary biologists collect evidence from multiple sources: anatomy, embryology, fossils and molecules. Combining all evidence helps build a clearer understanding about evolutionary relationships between animals. Links between mammals, established by molecular studies, are often followed by anatomical studies that substantiate proposed evolutionary relationships.

Technical requirements

The guide, background sheets, procedure sheet and card set require Adobe Reader which is a free download from www.adobe.com. Laminating of cards is recommended to ensure future use.

The presentation is available in two formats:

- Microsoft PowerPoint presentation
- Adobe PDF format

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Acknowledgements

Thanks to Dr Kevin C. Rowe, Senior Curator of Mammals, Museum Victoria.

Designed and developed by the Centre for Learning Technology, The University of Western Australia. Production team: Anton Ball, Pauline Charman, Jan Dook, Alwyn Evans, Dan Hutton, Bec McKinney, Emma Pointon, Paul Ricketts, Jodie Ween and Michael Wheatley. Thanks to Bob Fitzpatrick, Jenny Gull, Beate Ferbert-Booth and Wendy Sanderson.

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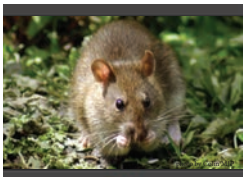
Molecular evidence for evolution 1: Mammal evolution may be used in conjunction with related SPICE resources to teach the topic of molecular evidence for evolution.

DESCRIPTION	LEARNING PURPOSE
Molecular evidence for evolution (overview)	
Molecular evidence for evolution 1: Mammal evolution A card game engages student interest in evidence used to determine evolutionary relationships between eutherians (placental mammals).	**Engage**
Molecular evidence for evolution 2: Primates Students use interactive learning objects to explore how anatomical evidence may be used to determine relatedness.	**Explore**
Molecular evidence for evolution 3: Evolutionary trees The use of molecular evidence to determine relatedness between species is explained. Students draw evolutionary trees to represent relatedness.	**Explain**
Molecular evidence for evolution 4: Viral evolution Students use the Influenza Research Database to investigate virus evolution. This bioinformatics database is an authentic research tool used to compare genetic sequences of virus strains, and to construct cladograms to draw conclusions about their relatedness.	**Elaborate**

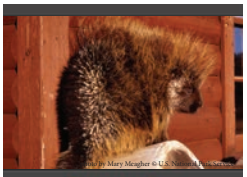
Who's related?

Answers
Clade Euarchontoglires



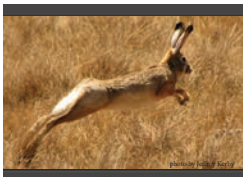
Rat

Distribution	worldwide, excluding Antarctica
Diet	omnivorous
Habitat	varied
Order	Rodentia
Clues	two continuously growing incisors in upper jaw, lack canines, diastema (space between incisors and molars), Laurasian (Eurasian and North American) origin



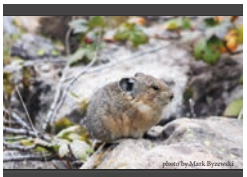
Porcupine

Distribution	Americas, Europe and Africa
Diet	herbivorous
Habitat	varied
Order	Rodentia
Clues	two continuously growing incisors in upper jaw, lack canines, diastema (space between incisors and molars), modified hair to form quills



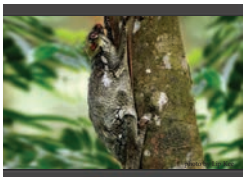
Hare

Distribution	Eurasia and Americas
Diet	herbivorous
Habitat	varied
Order	Lagomorpha
Clues	four continuously growing incisors in upper jaw, lack canines, diastema (space between incisors and molars), Asian origin



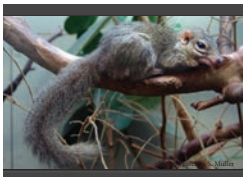
Pika

Distribution	Asia, North America, eastern Europe
Diet	herbivorous
Habitat	rocky mountainous terrain
Order	Lagomorpha
Clues	four continuously growing incisors in upper jaw, lack canines, diastema (space between incisors and molars), Asian origin



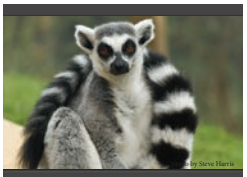
Colugo

Distribution	South-east Asia
Diet	herbivorous
Habitat	arboreal
Order	Dermoptera
Clues	gliding membrane (patagium), forward facing eyes, lower incisors with comb-like cusps



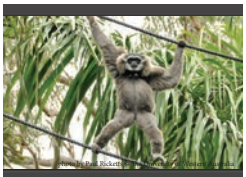
Tree shrew

Distribution	South-east Asia
Diet	omnivorous
Habitat	forest
Order	Scandentia
Clues	side-facing eyes, toothcomb (grooming incisors), fossil evidence suggests Asian origin



Lemur

Distribution	Madagascar
Diet	omnivorous, herbivorous
Habitat	varied
Order	Primates
Clues	pseudo-opposable thumbs, forward facing eyes, toothcomb (grooming incisors)



Gibbon

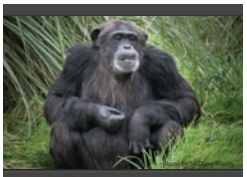
Distribution	South-east Asia
Diet	herbivorous
Habitat	forest
Order	Primates
Clues	opposable thumbs, ball and socket wrist joint, cleft between first and second toes on forefeet

Orang-utan

Distribution	Indonesia and Malaysia
Diet	herbivorous
Habitat	forest
Order	Primates
Clues	opposable thumb, opposable big toe, fist walkers, elongated arms, large brain case, prognathism (forward jutting of jaw)

Gorilla

Distribution	Africa
Diet	herbivorous
Habitat	forest
Order	Primates
Clues	opposable thumbs, knuckle walkers, large brain case, prognathism (forward jutting of jaw)



Chimpanzee

Distribution	Africa
Diet	omnivorous
Habitat	forest
Order	Primates
Clues	opposable thumbs, knuckle walkers, large brain case, prognathism (forward jutting of jaw)

Human

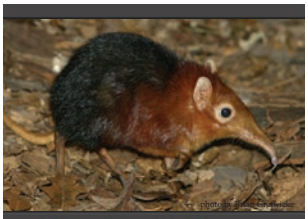
Distribution	worldwide, excluding Antarctica
Diet	omnivorous
Habitat	varied
Order	Primates
Clues	opposable thumbs, precision grip, bipedal, large brain case, reduced prognathism (forward jutting of jaw)

Australopithecus

Distribution	Africa
Diet	herbivorous
Habitat	forest
Order	Primates
Clues	bipedal, pronounced sexual dimorphism, prognathism (forward jutting of jaw), diminutive (less than 5 feet tall)

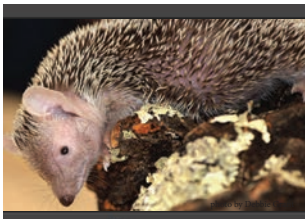
Who's related?

Answers
Clade Afrotheria



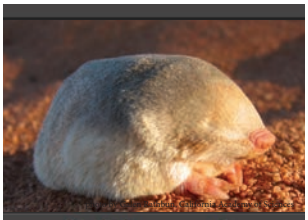
Elephant shrew

Distribution	Africa
Diet	insectivorous
Habitat	varied
Order	Macroscelidea
Clues	abdominal testes, teeth similar to the hyrax



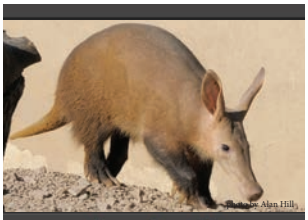
Tenrec

Distribution	Madagascar, southern Africa
Diet	insectivorous
Habitat	varied
Order	Afrosoricida
Clues	abdominal testes, cloaca (common urogenital opening), low body temperature



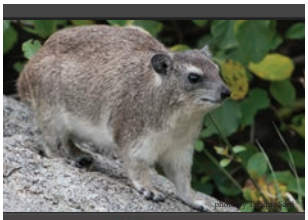
Golden mole

Distribution	southern Africa
Diet	insectivorous
Habitat	subterranean
Order	Afrosoricida
Clues	abdominal testes, cloaca (common urogenital opening), low body temperature



Aardvark

Distribution	sub-Saharan Africa
Diet	ants and termites
Habitat	savannah, grassland, woodland
Order	Tubulidentata
Clues	limbs modified for digging, lack incisors and canines, long tongue



Hyrax

Distribution	Africa and Middle East
Diet	herbivorous
Habitat	rock dwellers and arboreal
Order	Hyracoidea
Clues	abdominal testes, low body temperature, tusk-like incisors

Sea cow

Distribution	Indian Ocean, western and north Pacific Ocean, Caribbean, Amazon Basin
Diet	herbivorous
Habitat	aquatic
Order	Sirenia
Clues	abdominal testes, incisor tusks, females with two teats located near fore flippers, vestigial toenails

Elephant

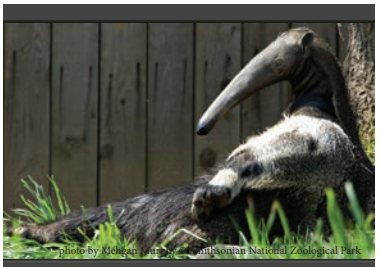
Distribution	Africa and Asia
Diet	herbivorous
Habitat	forest, savannah, woodland
Order	Proboscidea
Clues	incisor tusks, abdominal testes, females with two teats located near the forelimbs

Mammoth

Distribution	Africa, Europe, Asia, North America
Diet	herbivorous
Habitat	savannah, grassland, tundra
Order	Proboscidea
Clues	incisor tusks, two-finger trunk similar to African elephants

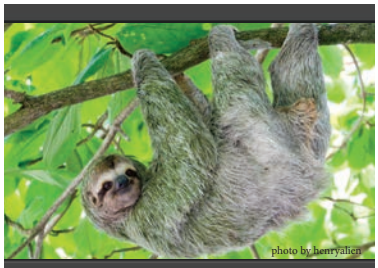
Who's related?

Answers
Clade Xenarthra



Anteater

Distribution	Central and South America
Diet	ants and termites
Habitat	forest and savannah
Order	Pilosa
Clues	lack teeth, long tongue, specialised lumbar vertebrae, double vena cava, South American origin



Sloth

Distribution	Central and South America
Diet	folivores (leaf eaters)
Habitat	forest, arboreal
Order	Pilosa
Clues	specialised claws, specialised lumbar vertebrae, double vena cava

Armadillo

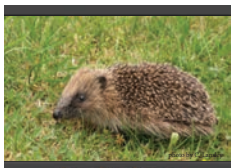
Distribution	Central, South and North America
Diet	ants, termites, invertebrates
Habitat	forest, grasslands, semi-arid
Order	Cingulata
Clues	low metabolic rate, armoured plates, specialised lumbar vertebrae, double vena cava

Glyptodon

Distribution	Americas
Diet	herbivorous
Habitat	grassland
Order	Cingulata
Clues	shell composed of thick bony plates, lack incisors and canines, South American origin

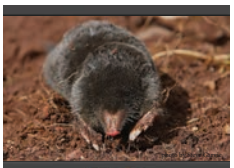
Who's related?

Answers
Clade Laurasiatheria



Hedgehog

Distribution	Europe, Asia, Africa
Diet	insectivorous, omnivorous
Habitat	woodlands
Order	Erinaceomorpha
Clues	modified hairs form spines, plantigrade (walk on sole), North American origin



Mole

Distribution	Europe, Asia, Africa, North America
Diet	omnivorous
Habitat	subterranean
Order	Soricomorpha
Clues	polydactyl hands (extra thumb), high metabolic rate, possible northern hemisphere origin

Shrew

Distribution	worldwide, excluding polar regions and Australasia
Diet	insectivorous, carnivorous
Habitat	varied
Order	Soricomorpha
Clues	born with adult teeth, high metabolic rate, possible northern hemisphere origin

Bat

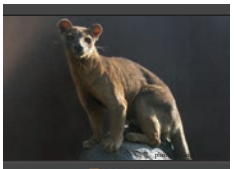
Distribution	worldwide, excluding Arctic and Antarctic
Diet	insects, fruit, fish
Habitat	varied
Order	Chiroptera
Clues	forelimbs modified into wings, possible northern hemisphere origin

Pangolin

Distribution	tropical Asia and Africa
Diet	ants, termites, invertebrates
Habitat	forest, woodland, grassland
Order	Pholidota
Clues	overlapping scales, long tongue, lack teeth, European origin

Lion

Distribution	Africa, Asia
Diet	carnivorous
Habitat	savannah, woodland
Order	Carnivora
Clues	carnassial teeth, digitigrade (walk on the toes), retractable claws, long conical canines

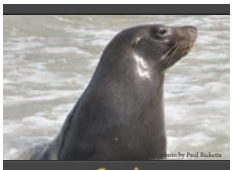


Fossa

Distribution	Madagascar
Diet	carnivorous
Habitat	forest
Order	Carnivora
Clues	carnassial teeth, plantigrade (walks on sole), semi-retractable claws, flexible ankles

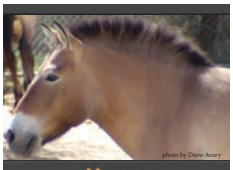
Wolf

Distribution	Eurasia, North America, North Africa
Diet	carnivorous
Habitat	varied
Order	Carnivora
Clues	carnassial teeth, digitigrade (walk on toes), Eurasian origin



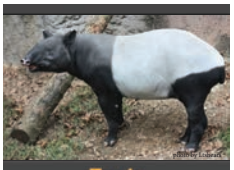
Seal

Distribution	Pacific, Indian, Atlantic, Arctic and Southern Ocean
Diet	carnivorous
Habitat	semi-aquatic
Order	Carnivora
Clues	limbs modified to form flippers, fossil evidence supports terrestrial ancestor



Horse

Distribution	Eurasia
Diet	herbivorous
Habitat	grassland, savannah, steppe
Order	Perissodactyla
Clues	hoofs, odd-toed, North American origin

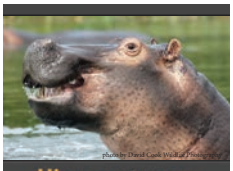


Tapir

Distribution	Central and South America, South-east Asia
Diet	herbivorous
Habitat	forest
Order	Perissodactyla
Clues	hoofs, odd-toed, flexible proboscis (snout), North American origin

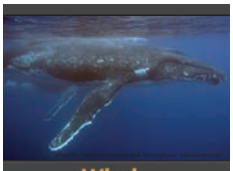
Rhinoceros

Distribution	Africa and Asia
Diet	herbivorous
Habitat	forest, savannah, bushland
Order	Perissodactyla
Clues	hoofs, odd-toed, one or two horns



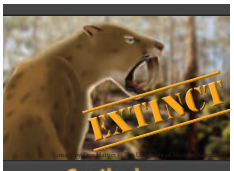
Hippopotamus

Distribution	Africa
Diet	herbivorous
Habitat	semi-aquatic
Order	Artiodactyla
Clues	hoofs, even-toed, shared common ancestry with whale (Cetacea)



Whale

Distribution	worldwide oceans
Diet	krill, fish, squid
Habitat	aquatic
Order	Cetacea
Clues	vestigial hind limbs, fossil evidence of terrestrial ancestor, shared common ancestry with hippopotamus



Smilodon

Distribution	North and South America
Diet	carnivorous
Habitat	grasslands, forest
Order	Carnivora
Clues	carnassial teeth, extremely long upper canines, North American origin