**Appendix A: Facilitator Outline**

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| --- | --- | --- | --- |
| **Activity** | **Brief Description** | **In Class or Outside of Class** | **Approximate Time Required** |
| Developing Student Understanding of Climate: Pre-modeling Required for Understanding Main Phenomenon (Latitudinal Diversity Gradient) | Using climatograms students develop an initial model to explain tropical and temperate climates. | In class | 45–60 minutes |
| Modeling the Latitudinal Diversity Gradient |  |  |  |
| 1st activity | 1. Teacher presents students with data of enhanced species diversity from Fischer’s 1960 paper. Student groups construct basic model of latitudinal variation in species richness. 2. Class elucidates and discusses competing models. | In class | 45–75 minutes |
| 2nd activity | 1. Students read Fischer’s 1960 paper. 2. Class notes Fischer’s conclusions/models. | Outside of class/in class | 45–60 minutes |
| 3rd activity | 1. Students read Rohde (1992) and complete Worksheet 1. 2. Class discussion of two competing models. | Outside or inside of class | 45–75 minutes |
| 4th activity | 1. Students read Wright et al. (2006) and complete Worksheet 2. Student groups propose model of ectotherms. 2. Class discussion of models and additional data needed. | Outside or inside of class | 45–75 minutes |
| 5th activity | 1. Students read Gillman et al. (2009) and complete Worksheet 3. Student groups propose model of endotherms. 2. Class discussion of models and additional data needed. | Outside or inside of class | 45–75 minutes |
| 6th activity | 1. Students read Gillman et al., 2010; Wright et al., 2011; Wright et al., 2010. Student groups revise model. 2. Class discussion of models and conclusion of class model regarding higher mutation rates as one cause of the greater biodiversity in the tropic zones. | Outside or inside of class | 45–75 minutes |

**Appendix B: Worksheet 1**

**Names: Date:**

**The Search for Cause(s) of Greater Diversity in the Tropics**

***The Scientific Question/Problem***

Why is there greater species richness in the tropics than in the temperate regions of the Earth?

***Past Knowledge Elicited or, What Do We Know?***

The theory of evolution, built from and informed by a spectacular amount of data regarding changes in various life forms over a wide variety of time periods, predicts that the processes of evolution are at play with respect to this scientific question. Given the vast amount of data collected in both tropical and temperate zones (that you analyzed previously) the *ultimate* explanation of the problem is (without any significant doubt) evolution. But what, specifically, has caused the evolution of species in the pattern that we have witnessed in our global data? What is/are the more *proximate* explanation(s)?

***Building a Scientific Model of Explanation Regarding the Problem: Working Akin to a Community of Scientists***

Our problem is one of historical fascination for the scientific community. You will now explore the problem from a historical perspective, by wrestling with key offerings of data and related scientific arguments and predictions. You will interact with real data collected by real scientists to allow you to construct explanations regarding real problems of scientific interest. Still, the data and related arguments and predictions you will wrestle with in order to build your explanation(s) represent only a fraction of the vast amount of scientific inquiries that informed the strongest explanation(s) currently accepted by the larger scientific community.

***Historical Work on the Problem within the Scientific Community: Inquiry Informed by a Review of Relevant Past Inquiry***

This activity incorporates a new “step” in your inquiry not yet required in this class. We have already reviewed, to a certain extent, the ultimate explanation for the problem “Why is there greater species diversity in the tropics than in the temperate regions of the Earth?” – that being evolution and, specifically, some of the means of evolution. We did this via your proposing hypotheses in the last activity to explain the phenomenon at hand. By doing this, we already touched on some of the commonly accepted knowledge of scientists that has guided their work on this problem. The new step we are requiring allows you to develop insight into other knowledge the scientific community has had for some time now with respect to the problem. This step is a review of pertinent literature pertaining to the problem (although, due to time constraints, a review that is limited and dictated by your instructors). This brief review summarizes relevant data and scientific analysis regarding the problem up to a historical point and launches us well into our more participatory class analysis of data that will allow us to create our scientific explanation(s) concerning the problem.

**Activity I.** Read Klaus Rohde’s 1992 work:

Rohde, K. (1992). Latitudinal gradients in species diversity: the search for the primary cause. *Oikos, 65,* 514–527.

Then answer the following questions on this electronic form on your computer. Save this as Rohde paper\_[date]\_[your complete name(s)].docx (Make sure you and your partner both have a working and final copy.)

Questions regarding Rohde’s article:

1. What were the main hypotheses proposed by Rohde, as informed by his review of past research data, concerning why there is greater species richness in the tropics compared with temperate regions on the Earth?
2. What data or theoretical arguments, specifically, were explored by Rohde with respect to each hypothesis? Include whether data/arguments were for or against the hypothesis. Include names/dates of any relevant researchers’ work.
3. Which hypotheses did Rohde conclude were viable and deserving of further scientific exploration?

Below is a graphic organizer that will allow the class to organize information regarding questions a–c in a systematic way. Add more rows as necessary.

|  |  |  |  |
| --- | --- | --- | --- |
| Hypothesis | Data and/or theoretical arguments for or against hypothesis | Names/dates of researchers associated with data and/or theoretical arguments for or against hypothesis | Hypothesis viable, according to Rohde |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |

You will copy and paste your table from above and revise here as per our next class discussion. Please preserve your group’s original table above!

**Appendix C: Worksheet 2**

**Names: Date:**

**The Search for Cause(s) of Greater Diversity in the Tropics**

***Past Knowledge Elicited or, What Do We Know?***

There is greater species richness in tropical environments than in temperate environments. You all have hypothesized reasons for this phenomenon, including higher rates of mutation and evolution of species.

Organisms with higher body temperatures have been shown to exhibit higher rates of nucleotide substitution (molecular evolution) than cooler-bodied organisms, but these comparisons were done between phylogenetically disparate animal taxa (endotherms and ectotherms) (Martin & Palumbi, 1993) or within a group of organisms existing at various elevations (Bleiweiss, 1998). Allen et al. (2006) demonstrated that the rate of microevolution in Foraminifera in the tropics is greater than at higher latitudes.

Higher rates of metabolism may increase rates of oxygen-induced damage to DNA. DNA nucleotide substitutions could be a result of mutation (along with other causes such as genetic drift and natural selection) and, thus, a marker of molecular evolution and also a good indication of microevolution.

***The Scientific Question/Problem:***

Is the rate of microevolution in plants in the lower-latitude tropics greater than at temperate latitudes?

***Experimental Design:***

Wright, S., Keeling, J. & Gillman, L. (2006). The road from Santa Rosalia: a faster tempo of evolution in tropical climates. *Proceedings of the National Academy of Sciences USA,* *103,* 7718–7722.

Wright and colleagues studied plants (which truly exist as either tropical or temperate, because plants do not engage in seasonal migration), specifically 45 phylogenetically diverse taxon pairings (spanning 18 genera) of congeneric pairs of woody plants. Each taxon of each pairing occurred in either the tropical rainforests or in the temperate zone. Individual taxa making up each pairing occurred in non-overlapping latitudinal distribution with respect to the other taxon in the pair to control for risk of gene flow. Only common species were studied to allow for limiting potential of genetic drift that is more common in smaller populations. A wet ecosystem for each taxon controlled for the risk of water serving as a limiting factor of plant productivity that might influence rates of molecular evolution. Researchers also controlled for other factors that might influence rates of productivity and, thus, molecular evolution by using plants of (a) similar body plan (generation time), (b) similar size (body mass), and (c) from the same forest stratum (light flux). Researchers also analyzed pairings in which there was as much or more speciation in the temperate representatives to control for the possibility that higher speciation may be allowing for more natural selection and genetic drift.

Between the taxa making up each conspecific plant pairing, Wright and colleagues compared the rate of nucleotide substitution using the internal transcriber spacer (ITS) region of the rRNA-encoding DNA. A longer phylogenetic tree branch length for the ITS region connotes more nucleotide substitution (potential mutations).

***Data:***

Data are presented as nucleotide substitution ratios. A ratio approaching 1.0 translates to less difference between tropical and temperate taxon pairings regarding the number of substitutions since a common ancestor. Numbers in bold indicate ratios with a longer branch (more substitutions since a common ancestor) for temperate organisms than for tropical organisms.

**Reproduction of Table 1 from Wright et al. (2006) study showing ingroup pairs, outgroup taxa, and nucleotide substitution ratios (shorter branch length/longer branch length), n = 45.**

|  |  |  |  |
| --- | --- | --- | --- |
| **Tropical Ingroup** | **Temperate Ingroup** | **Outgroup** | **Nucleotide Substitution Ratio** |
| *Agathis borneensis* | *Agathis australis* | *Araucaria araucana* | 0.92672 |
| *Metrosideros salomonensis* | *Metrosideros umbellata* | *Cloezia floribunda* | 0.90795 |
| *Podocarpus archboldii* | *Podocarpus cunninghamii* | *Nageia nagi* | 0.88851 |
| *Lithocarpus rufovillosus* | *Lithocarpus densiflorus* | *Quercus suber* | 0.86659 |
| *Sophora tomentosa* | *Sophora tetraptera* | *Calpurnia aurea* | 0.83811 |
| *Nothofagus grandis* | *Nothofagus antarctica* | *Betula pendula* | 0.78243 |
| *Elmerrillia tsiampacca* | *Magnolia virginiana* | *Liriodendron tulipifera* | 0.74319 |
| *Eucalyptus deglupta* | *Eucalyptus coccifera* | *Angophora costata* | 0.73571 |
| *Geniostoma rupestre* | *Geniostoma rupestre* | *Mitreola petiolata* | 0.72605 |
| *Pennantia cunninghamii* | *Pennantia corymbosa* | *Corynocarpus cribbianusGriselinia lucida* | 0.71942 |
| *Clematis javana* | *Clematis paniculata* | *Naravelia laurifolia* | 0.69887 |
| *Schefflera macrostachya* | *Schefflera digitata* | *Polyscias ledermanii* | 0.69509 |
| *Kunzea graniticola* | *Kunzea ericoides* | *Agonis flexuosa* | 0.68131 |
| *Pittosporum ramiflorum* | *Pittosporum tenuifolium* | *Sollya heterophylla* | 0.67852 |
| *Opocunonia nymanii* | *Caldcluvia paniculosa* | *Ceratopetalum apetalum* | 0.66781 |
| *Araucaria hunsteinii* | *Araucaria araucana* | *Agathis australis* | 0.66353 |
| *Metrosideros whiteana* | *Metrosideros parkinsonii* | *Cloezia floribunda* | 0.66026 |
| ***Rapanea leucantha*** | ***Rapanea howittiana*** | ***Myrsine oliveri*** | **0.61595** |
| *Dysoxylum arborescens* | *Dysoxylum spectabile* | *Guarea glabra* | 0.61172 |
| ***Alectryon connatus*** | ***Alectryon excelsus*** | ***Pappea capensis*** | **0.60566** |
| *Albizia procera* | *Albizia julibrissin* | *Inga edulis* | 0.59658 |
| *Elaeocarpus sphaericus* | *Elaeocarpus hookerianus* | *Aristotelia serrata* | 0.58196 |
| *Coprosma nadeandii* | *Coprosma tenuifolia* | *Nertera dichondrifolia* | 0.56816 |
| *Piper methysticum* | *Macropiper excelsum* | *Sarcorhachis sydowii* | 0.55044 |
| ***Diospyros ferrea*** | ***Diospyros virginiana*** | ***Euclea crispa*** | **0.52719** |
| ***Streblus glaber*** | ***Streblus heterophylla*** | ***Morus wittiorum*** | **0.47233** |
| ***Passiflora foetida*** | ***Passiflora tetrandra*** | ***Adenia heterophylla*** | **0.46786** |
| *Celtis latifolia* | *Celtis occidentalis* | *Trema orientalis* | 0.42441 |
| ***Polyscias ledermanii*** | ***Polyscias sambucifolia*** | ***Schefflera digitata*** | **0.41911** |
| ***Litsea globosa*** | ***Litsea calicaris*** | ***Phoebe formosana*** | **0.40927** |
| *Rhus taitensis* | *Rhus typhina* | *Searsia quartiniana* | 0.40531 |
| *Phyllanthus cicciodes* | *Phyllanthus gunnii* | *Sauropus granulosus* | 0.38169 |
| ***Carpodetus arboreus*** | ***Carpodetus serratus*** | ***Cuttsia viburnea*** | **0.35508** |
| ***Grevillea papuana*** | ***Grevillea robusta*** | ***Buckinghamia celsissima***  ***Opisthiolepis heterophylla*** | **0.35455** |
| ***Acacia aulacocarpa*** | ***Acacia frigescens*** | ***Parkia timoriana*** | **0.34539** |
| *Melicope cf. crassiramus* | *Melicope simplex* | *Haplophyllum bastetanum* | 0.32393 |
| *Pouteria macropoda* | *Pouteria costata* | *Xantolis siamensis* | 0.32046 |
| *Tasmannia insipida* | *Tasmannia lanceolata* | *Takhtajania perrieri* | 0.30354 |
| ***Vitex cofassus*** | ***Vitex lucens*** | ***Callicarpa dichotoma*** | **0.29509** |
| *Acmenosperma claviflorum* | *Syzygium maire* | *Thaleropia queenslandica* | 0.24377 |
| *Ceratopetalum succirubrum* | *Ceratopetalum apetalum* | *Caldcluvia paniculosa* | 0.23931 |
| ***Corynocarpus cribbianus*** | ***Corynocarpus laevigatus*** | ***Griselinia lucida***  ***Pennantia corymbosa*** | **0.17074** |
| *Banksia dentata* | *Banksia marginata* | *Austromuellera trinervia* | 0.14173 |
| *Dodonaea viscosa* | *Dodonaea viscosa* | *Harpullia cupanioides* | 0.01769 |
| *Weinmannia fraxinea* | *Weinmannia racemosa* | *Ackama rosaefolia* | 0.00058 |

***“To do” items for students:***

A) Note conclusions/patterns versus expected (what a pattern due to chance would look like):

B) Hypothesis to explain patterns:

C) What would we still like to know?

Save your group’s work. When every group has had ample time to complete this work, we will discuss answers as a class.

**References**

Allen, A., Gillooly, J., Savage, V. & Brown, J. (2006). Kinetic effects of temperature on rates of genetic divergence and speciation. *Proceedings of the National Academy of Sciences USA, 103,* 9130–9135.

Bleiweiss, R. (1998). Slow rate of molecular evolution in high-elevation humming birds. *Proceedings of the National Academy of Sciences USA, 95,* 612–616.

Martin, A.P. & Palumbi, S.R. (1993). Body size, metabolic rate, generation time, and the molecular clock. *Proceedings of the Royal Society B, 90,* 4087–4091.

**Appendix D: Worksheet 3**

**Names: Date:**

**The Search for Cause(s) of Greater Diversity in the Tropics**

***Past Knowledge Elicited or, What Do We Know?***

There is greater species richness in tropical environments than in temperate environments. One possible explanation supported by earlier research is that the rate of microevolution is greater in the tropics than at higher (temperate) latitudes. Faster rates of microevolution have been discovered in plants (Wright et al., 2006) and Foraminifera (Allen et al., 2006) in the tropics than in their temperate climate counterparts. Both of these previously studied taxonomic groups are ectotherms. Perhaps organisms with external-temperature-dependent body temperatures respond more drastically to external temperatures, thus allowing a warmer climate to increase their metabolism and, thus, the rate of DNA mutations. On the other hand, endotherms (such as mammals) maintain a relatively constant body temperature that fluctuates little with external temperature changes. It has been assumed that since metabolic rate does not vary in endotherms across latitudes, microevolution across latitudes would not vary systematically.

***The Scientific Question/Problem:***

Is the increased rate of microevolution in the tropics seen among mammal species?

***Experimental Design:***

Gillman, L., Keeling, D.J., Ross, H.A. & Wright, S.D. (2009). Latitude, elevation and the tempo of molecular evolution in mammals. *Proceedings of the Royal Society B, 276,* 3353–3359.

The cytochrome *b* gene of 10 orders and 29 families of mammals was assessed for rates of microevolution. Comparisons were made between 130 sister species (closely related) pairs, in which one species occurred at a lower latitude or elevation (climatic differences between different elevations are similar to climatic differences between different latitudes) than the other species of the pair.

***Data:***

Paired mammal species comparisons and relative rates of evolution. Branch length ratio is the ratio of the phylogenetic tree branch length for the warmer (lower latitude or elevation) species in relation to that for the cooler (higher latitude or elevation), or Warmer species branch length / Cooler species branch length. E = Elevation, L = Latitude. Ratios >1 indicate that the warmer species underwent a greater rate of evolution than the cooler species.

***“To do” items for students:***

A) Looking at data from the Gillman et al. (2009) paper, make conclusions/note patterns. You will most likely need to perform some basic mathematical calculations to verify what you notice with respect to:

Within specific orders/families

By latitude

By elevation

Overall

B) Hypothesis:

C) What would we still like to know?

D) Now read the original paper by Gillman et al. (2009) and respond to the following:

1. With respect to the data provided, how did your model compare with the explanation by the researchers?
2. Summarize the five possibilities the researchers propose may be causing the patterns you have noted.
3. Reflect on the process(es) with which you have been involved up to this point in class:
   1. How have these processes paralleled the work of scientists? How have they fallen short?
   2. Overall, how has this experience differed from other science curriculum and instruction you have experienced?

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Order/Family** | **Cooler** | **Warmer** | **Comparison**  **(L = Latitude,**  **E = Elevation)** | **Branch Length Ratio** |
| Carnivora  Procyonidae | *Bassariscus astutus* | *Bassariscus sumichrasti* | L | 0.379 |
| Carnivora  Herpestidae | *Galerella pulverulenta* | *Galerella sanguinea* | L | 1.448 |
| Carnivora  Mustelidae | *Martes zibellina* | *Martes melampus* | L | 0.584 |
| Carnivora  Mustelidae | *Mustela altaica* | *Mustela nivalis* | E | 1.318 |
| Carnivora  Viverridae | *Prionodon pardicolor* | *Prionodon linsang* | L | 2.664 |
| Carnivora  Canidae | *Pseudalopex gymnocercus* | *Pseudalopex vetulus* | L | 1.726 |
| Chiroptera  Phyllostomidae | *Artibeus hirsutus* | *Artibeus inopinatus* | L | 0.724 |
| Chiroptera  Phyllostomidae | *Carollia subrufa* | *Carollia benkeithi* | L | 3.186 |
| Chiroptera  Phyllostomidae | *Chiroderma doriae* | *Chiroderma trinitatum* | L | 0.159 |
| Chiroptera  Vespertilionidae | *Eptesicus serotinus* | *Eptesicus hottentotus* | L | 2.929 |
| Chiroptera  Phyllostomidae | *Glossophaga leachi* | *Glossophaga longirostris* | L | 0.647 |
| Chiroptera  Vespertilionidae | *Myotis bechsteini* | *Myotis sicarius* | L | 1.427 |
| Chiroptera  Vespertilionidae | *Myotis emarginatus* | *Myotis tricolor* | L | 2.089 |
| Chiroptera  Vespertilionidae | *Myotis macropus* | *Myotis hasseltii* | L | 0.783 |
| Chiroptera  Vespertilionidae | *Myotis oxyotus* | *Myotis levis* | E | 2.525 |
| Chiroptera  Rhinolophidae | *Rhinolophus cornutus* | *Rhinolophus monoceros* | L | 2.057 |
| Dasyuromorphia  Dasyuridae | *Antechinus flavipes* | *Antechinus bellus* | L | 0.585 |
| Dasyuromorphia  Dasyuridae | *Dasyurus geoffroii* | *Dasyurus spartacus* | L | 1.140 |
| Dasyuromorphia  Dasyuridae | *Dasyurus viverrinus* | *Dasyurus albopunctatus* | L | 0.766 |
| Dasyuromorphia  Dasyuridae | *Myoictis wavicus* | *Myoictis wallacei* | E | 0.496 |
| Dasyuromorphia  Dasyuridae | *Parantechinus apicalis* | *Parantechinus bilarni* | L | 0.577 |
| Dasyuromorphia  Dasyuridae | *Planigale tenuirostris* | *Planigale ingrami* | L | 1.048 |
| Dasyuromorphia  Dasyuridae | *Sminthopsis aitkeni* | *Sminthopsis griseoventer* | L | 1.218 |
| Dasyuromorphia  Dasyuridae | *Sminthopsis dolichura* | *Sminthopsis archeri* | L | 1.491 |
| Dasyuromorphia  Dasyuridae | *Sminthopsis granulipes* | *Sminthopsis hirtipes* | L | 1.376 |
| Dasyuromorphia  Dasyuridae | *Sminthopsis macroura* | *Sminthopsis virginiae* | L | 1.546 |
| Didelphimorphia  Marmosidae | *Monodelphis osgoodi* | *Monodelphis handleyi* | E | 3.178 |
| Didelphimorphia  Didelphidae | *Philander frenata* | *Philander mcilhennyi* | L | 1.098 |
| Insectivora  Soricidae | *Chimarrogale himalayica* | *Chimarrogale phaeura* | L | 0.831 |
| Insectivora  Soricidae | *Crocidura dsinezumi* | *Crocidura attenuata* | L | 0.845 |
| Insectivora  Soricidae | *Crocidura flavescens* | *Crocidura goliath* | L | 1.706 |
| Insectivora  Soricidae | *Crocidura lasiura* | *Crocidura kurodai* | L | 0.972 |
| Insectivora  Talipidae | *Mogera imaizumii* | *Mogera insularis* | L | 1.916 |
| Insectivora  Talpidae | *Scapanus orarius* | *Scapanus latimanus* | L | 2.698 |
| Insectivora  Soricidae | *Sorex hydrodromus* | *Sorex jacksoni* | L | 1.543 |
| Insectivora  Soricidae | *Sorex portenkoi* | *Sorex camtschatica* | L | 0.060 |
| Insectivora  Soricidae | *Blarina brevicauda* | *Blarina carolinensis* | L | 0.386 |
| Isectivora  Soricidae | *Sorex araneus* | *Sorex granarius* | L | 0.809 |
| Isectivora  Soricidae | *Sorex cinereus* | *Sorex longirostris* | L | 2.272 |
| Isectivora  Soricidae | *Sorex trowbridgii* | *Sorex saussurei* | L | 1.924 |
| Isectivora  Soricidae | *Sorex tundrensis* | *Sorex daphaenodon* | L | 0.776 |
| Isectivora  Soricidae | *Sorex vagrans* | *Sorex ornatus* | L | 1.501 |
| Lagomorpha  Leporidae | *Lepus americanus* | *Lepus californicus* | L | 0.988 |
| Lagomorpha  Leporidae | *Lepus arcticus* | *Lepus townsendii* | L | 1.219 |
| Lagomorpha  Leporidae | *Lepus oiostolus* | *Lepus comus* | E | 1.940 |
| Lagomorpha  Leporidae | *Lepus timidus* | *Lepus capensis* | L | 2.183 |
| Lagomorpha  Ochotonidae | *Ochotona collaris* | *Ochotona princeps* | L | 0.732 |
| Lagomorpha  Ochotonidae | *Ochotona thomasi* | *Ochotona daurica* | E | 4.808 |
| Lagomorpha  Leporidae | *Sylvilagus obscurus* | *Sylvilagus floridanus* | E | 1.188 |
| Peramelemorpha  Peramelidae | *Perameles gunnii* | *Perameles nasuta* | L | 0.748 |
| Primates  Cebidae | *Callicebus nigrifrons* | *Callicebus hoffmannsi* | L | 3.305 |
| Primates  Lemuridae | *Eulemur macaco* | *Eulemur coronatus* | L | 0.774 |
| Primates  Megaladaphidae | *Lepilemur microdon* | *Lepilemur edwardsi* | L | 1.344 |
| Primates  Cheirogaleidae | *Microcebus griseorufus* | *Microcebus ravelobensis* | L | 2.489 |
| Primates  Indriidae | *Propithecus verrauxi* | *Propithecus tattersalli* | L | 1.116 |
| Rodentia  Cricetidae | *Abrothrix andinus* | *Abrothrix olivaceus* | E | 0.532 |
| Rodentia  Muridae | *Acomys russatus* | *Acomys ignitus* | L | 1.001 |
| Rodentia  Muridae | *Akodon montensis* | *Akodon cursor* | E | 0.998 |
| Rodentia  Muridae | *Akodon mystax* | *Akodon paranaensis* | E | 1.609 |
| Rodentia  Muridae | *Akodon spegazzinii* | *Akodon subfuscus* | L | 1.373 |
| Rodentia  Muridae | *Akodon torques* | *Akodon aerosus* | E | 2.893 |
| Rodentia  Muridae | *Alticola strelzowi* | *Alticola argentatus* | L | 1.167 |
| Rodentia  Muridae | *Apodemus alpicola* | *Apodemus sylvaticus* | E | 2.305 |
| Rodentia  Cricetidae | *Arborimus longicaudus* | *Arborimus pomo* | L | 0.482 |
| Rodentia  Muridae | *Auliscomys pictus* | *Auliscomys sublimus* | E | 1.353 |
| Rodentia  Muridae | *Batomys granti* | *Batomys salomonseni* | L | 0.643 |
| Rodentia  Muridae | *Bolomys amoenus* | *Bolomys urichi* | E | 0.808 |
| Rodentia  Muridae | *Bullimus luzonicus* | *Bullimus bagobus* | L | 1.777 |
| Rodentia  Cavidae | *Cavia tschudii* | *Cavia aperea* | E | 0.500 |
| Rodentia  Muridae | *Crunomys suncoides* | *Crunomys melanius* | E | 0.589 |
| Rodentia  Ctenomyidae | *Ctenomys frater* | *Ctenomys conoveri* | E | 0.855 |
| Rodentia  Ctenomyidae | *Ctenomys maulinus* | *Ctenomys boliviensis* | L | 1.124 |
| Rodentia  Ctenomyidae | *Ctenomys mendocinus* | *Ctenomys flamarioni* | L | 2.164 |
| Rodentia  Sciuridae | *Cynomys leucurus* | *Cynomys gunnisoni* | L | 0.304 |
| Rodentia  Sciuridae | *Cynomys ludovicianus* | *Cynomys mexicanus* | L | 0.254 |
| Rodentia  Muridae | *Delomys dorsalis* | *Delomys sublineatus* | L | 1.326 |
| Rodentia  Heteromyidae | *Dipodomys elator* | *Dipodomys phillipsii* | L | 1.956 |
| Rodentia  Muridae | *Eligmodontia puerulus* | *Eligmodontia typus* | E | 1.317 |
| Rodentia  Muridae | *Ellobius tancrei* | *Ellobius fuscocapillus* | L | 1.289 |
| Rodentia  Muridae | *Eospalax baileyi* | *Eospalax rothschildi* | E | 1.931 |
| Rodentia  Geomyidae | *Geomys personatus* | *Geomys tropicalis* | L | 1.503 |
| Rodentia  Muridae | *Gerbilliscus robustus* | *Gerbilliscus vicinus* | L | 0.958 |
| Rodentia  Sciuridae | *Glaucomys sabrinus* | *Glaucomys volans* | L | 3.698 |
| Rodentia  Sciuridae | *Hylopetes phayrei* | *Hylopetes lepidus* | L | 0.687 |
| Rodentia  Cricetidae | *Juliomys rimofrons* | *Juliomys pictipes* | E | 1.436 |
| Rodentia  Chinchillidaeidae | *Lagidium viscacia* | *Lagidium peruanum* | L | 1.317 |
| Rodentia  Heteromyidae | *Liomys irroratus* | *Liomys pictus* | E | 1.343 |
| Rodentia  Sciuridae | *Marmota broweri* | *Marmota menzbieri* | L | 0.962 |
| Rodentia  Muridae | *Mastomys coucha* | *Mastomys huberti* | L | 1.365 |
| Rodentia  Muridae | *Meriones crassus* | *Meriones rex* | L | 1.413 |
| Rodentia  Muridae | *Mesocricetus newtoni* | *Mesocricetus brandti* | L | 1.332 |
| Rodentia  Muridae | *Mesocricetus raddei* | *Mesocricetus auratus* | L | 2.240 |
| Rodentia  Muridae | *Microtus longicaudis* | *Microtus oregoni* | E | 1.146 |
| Rodentia  Muridae | *Microtus montanus* | *Microtus pennsylvanicus* | E | 1.274 |
| Rodentia  Muridae | *Microtus oeconomus* | *Microtus kikuchii* | L | 1.502 |
| Rodentia  Muridae | *Microtus pinetorum* | *Microtus quasiater* | L | 0.432 |
| Rodentia  Muridae | *Microtus xanthognathus* | *Microtus ochrogaster* | L | 0.874 |
| Rodentia  Muridae | *Mus pahari* | *Mus crociduroides* | L | 1.381 |
| Rodentia  Muridae | *Neotoma cinerea* | *Neotoma mexicana* | L | 0.445 |
| Rodentia  Muridae | *Niviventer rapit* | *Niviventer cremoriventer* | E | 1.388 |
| Rodentia  Muridae | *Oligoryzomys andinus* | *Oligoryzomys chacoensis* | E | 1.191 |
| Rodentia  Muridae | *Oligoryzomys longicaudatus* | *Oligoryzomys fornesi* | L | 2.082 |
| Rodentia  Muridae | *Onychomys leucogaster* | *Onychomys arenicola* | L | 2.150 |
| Rodentia  Muridae | *Oryzomys palustris* | *Oryzomys couesi* | L | 2.575 |
| Rodentia  Muridae | *Oryzomys russatus* | *Oryzomys emmonsae* | L | 1.110 |
| Rodentia  Heteromyidae | *Perognathus fasciatus* | *Perognathus flavescens* | L | 1.016 |
| Rodentia  Muridae | *Peromyscus attwateri* | *Peromyscus difficilis* | L | 1.011 |
| Rodentia  Muridae | *Peromyscus beatae* | *Peromyscus levipes* | L | 1.016 |
| Rodentia  Sciuridae | *Petaurista leucogenys* | *Petaurista elegans* | L | 4.108 |
| Rodentia  Muridae | *Phyllotis andium* | *Phyllotis amicus* | E | 1.964 |
| Rodentia  Muridae | *Phyllotis darwini* | *Phyllotis magister* | L | 0.705 |
| Rodentia  Muridae | *Rattus everetti* | *Rattus praetor* | L | 0.781 |
| Rodentia  Sciuridae | *Sciurus niger* | *Sciurus stramineus* | L | 1.035 |
| Rodentia  Muridae | *Sigmodon arizonae* | *Sigmodon mascotensis* | L | 0.931 |
| Rodentia  Sciuridae | *Spermophilus beecheyi* | *Spermophilus atricapillus* | L | 5.310 |
| Rodentia  Sciuridae | *Spermophilus citellus* | *Spermophilus xanthoprymnus* | L | 1.277 |
| Rodentia  Sciuridae | *Spermophilus elegans* | *Spermophilus richardsoni* | E | 2.010 |
| Rodentia  Sciuridae | *Spermophilus saturatus* | *Spermophilus madrensis* | L | 0.873 |
| Rodentia  Sciuridae | *Spermophilus spilosoma* | *Spermophilus perotensis* | L | 1.076 |
| Rodentia  Sciuridae | *Spermophilus tridecemlineatus* | *Spermophilus mexicanus* | L | 0.788 |
| Rodentia  Erethizontidae | *Sphiggurus villosus* | *Sphiggurus melanura* | L | 1.438 |
| Rodentia  Muridae | *Stenocephalemys albocaudata* | *Myomys albipes* | E | 0.960 |
| Rodentia  Muridae | *Synaptomys borealis* | *Synaptomys cooperi* | L | < 1.000 |
| Rodentia  Sciuridae | *Tamias canipes* | *Tamias durangae* | L | 1.715 |
| Rodentia  Sciuridae | *Tamias merriami* | *Tamias obscurus* | L | 1.803 |
| Rodentia  Sciuridae | *Tamias townsendii* | *Tamias sonomae* | L | 2.912 |
| Rodentia  Muridae | *Thomasomys aureus* | *Thomasomys notatus* | E | 2.255 |
| Rodentia  Sciuridae | *Xerus inauris* | *Xerus rutilus* | L | 0.299 |
| Rodentia Ctenomyidae | *Ctenomys magellanicus* | *Ctenomys coyhaiquensis* | L | 0.717 |
| Scandentia  Tupaiidae | *Tupaia chinensis* | *Tupaia belangeri* | L | 6.552 |

**References**

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