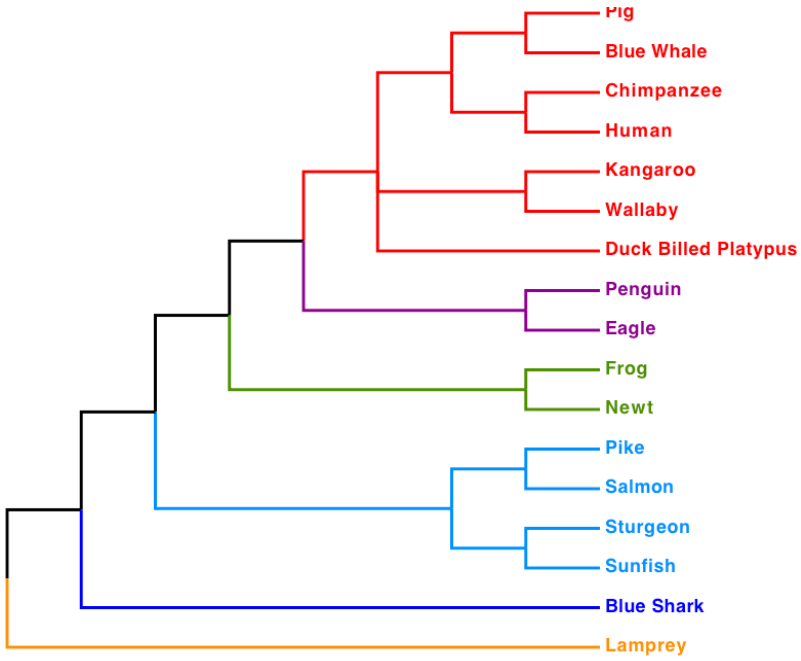
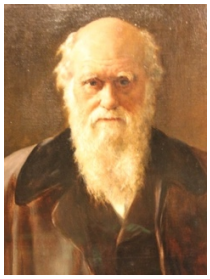
Investigating Vertebrate Evolutionary Trees

Student Guide





Investigating Vertebrate Evolutionary Trees

Appropriate for
Opportunities for CPAC assessment: 1(a), 2(a), (b), 4(a), 5(a)
Aim: To use computer modelling software to investigate evolutionary relationships between major vertebrate groups

Objectives

- ✓ Using protein sequences to determine evolutionary distances between species
- ✓ To create evolutionary trees to study the relationships between vertebrate species and groups of species

Purpose/Relevance

Modern evolutionary trees are created from amino acid sequences taken from important proteins. Shared amino acids will lead to animals being clustered together, while differences between species lead to them being separated on branches.

Evolution often occurs in a regular, clocklike, fashion. This means closely related animals have very similar sequences and the number of differences in amino acids increases over evolutionary time.

We will use the protein **NADH dehydrogenase 3** to study how vertebrates (animals with backbones) have evolved. The dataset provided will show the closest relatives of humans and also how major vertebrate groups are related to each other.

Notes

- All protein sequences have been downloaded from the NCBI database
- Sequences will be aligned using ClustalX 2.1
- Evolutionary trees will be generated in ClustalX 2.1 and viewed using FigTree 1.4.3

Health and Safety

- Do not eat or drink near the computer

Exercise 1

- In this first experiment we will compare the human protein with the same protein from a chimpanzee
- Copy the protein sequences, including the title line, for human and chimpanzee and paste into a Notepad^{++} document.
- Save the document as a .txt file (e.g. HumanChimp.txt)
- Open ClustalX and click on **Load Sequences** from the **File** Menu
- Open your HumanChimp.txt file
- From the **Alignment** menu click on **Do Complete Alignment** – Clustal will now match the amino acids from humans with the corresponding amino acids from the chimpanzee.
- Clustal shows matches of amino acids with *****. Non-matches are shown by **:**, **.** or a **gap**
- How many amino acids differ between the human and chimpanzee? Make a note of this number.

Exercise 2

- We now want to compare the human protein with the protein from a Neanderthal. The Neanderthals were a species of human who are now extinct. Do you think the human protein will be more similar to the chimpanzee or Neanderthal?
- Copy the protein sequences, including the title line, for human and Neanderthal and paste into a new Notepad^{++} document.
- Save the document as a .txt file (e.g. HumanNeanderthal.txt)
- Open ClustalX and click on **Load Sequences** from the **File** Menu
- Open your HumanNeanderthal.txt file
- From the **Alignment** menu click on **Do Complete Alignment**.
- How many amino acids differ between the human and Neanderthal? Make a note of this number.
- From the evidence of NADH dehydrogenase 3 can you say if humans are more closely related to Neanderthals or chimpanzees?

Exercise 3

- In this exercise we will look at deeper evolutionary relationships by studying three well known mammals.
- Using the protocol from above determine the number of differences between the cow protein and the pig protein.
- In a new text file now compare the cow protein with the giraffe protein.
- Do you think cows are more closely related to pigs or giraffes?

Exercise 4

- Comparing two protein sequences can give us important information on the divergence between two species.
- We can gain more information by aligning multiple sequences and creating an evolutionary tree.
- In this exercise we will create an evolutionary tree of the primates. We will use this to test the results we gained in the first two exercises.
- Copy and paste all of the primate proteins, along with their titles, into a new Notepad^{++} document and save as Primates.txt.
- Load your primate file into Clustal and align the amino acids. You should notice now there are fewer asterisks – this means there are more evolutionary changes in this alignment.
- We can now create our evolutionary tree of primates. Go to the **Trees** menu and click on **Draw Trees**.
- Open the program FigTree to view your tree. Click on **Open** in the **File** menu and open the file name Primates.ph
- To read the tree correctly we need to 'root' it. This means to place the oldest group at the bottom of the tree. In this tree the root is between the howler and woolly monkeys and the other primates.
- With the cursor click on the branch leading to the howler and woolly monkeys. Now press Reroot.
- Closely related organisms share more branches, so we can see that humans are more closely related to Neanderthals than chimpanzees. Is this what you found before?
- FigTree allows us to highlight different groups. Click on the branch that leads to the five species of ape.
- Click on the **Clade** button. This should highlight all of the branches in the group of apes.
- Press Colour and choose a colour to denote the apes on your tree.
- You can save your tree by going to **File** and clicking **Export PDF**. This will give you an image file of your evolutionary tree.

Exercise 5

- We will now create an evolutionary tree of all of the mammal proteins.
- Paste the protein sequences, along with their titles into a new Notepad^{++} document. Save as **Mammals.txt**. Do not paste in the subheadings, e.g. ***Primates***.
- Align your sequences in Clustal.
- We can now create our evolutionary tree of mammals. Go to the **Trees** menu and click on **Draw Trees**.
- Open the program FigTree to view your tree. Click on **Open** in the **File** menu and open the file named Mammals.ph
- To read the tree correctly we need to 'root' it. In this tree the root is between the marsupials (kangaroo, wombat and Tasmanian Devil) and the other mammals.
- With the cursor click on the branch leading to the marsupials. Now press Reroot.
- Colour code the different mammal groups using **Clade** and **Colour**.

Questions

- Have all of the groups been correctly recovered as intact groups?
- What mammals are the closest relatives of the primates?
- Are the marine mammals all closely related to each other or do they form different groups? You will need to identify the marine mammals in the tree to answer this.
- From your tree can you determine if the giant panda is more closely related to the red panda or bears?

Exercise 6

In the last exercise we will create an evolutionary tree using all of the proteins in our dataset. This will give us a broad picture on how the vertebrates have evolved for the last 470 million years.

- Paste the protein sequences, along with their titles into a new Notepad^{++} document.
- Save as **Vertebrates.txt**. Do not paste in the subheadings, e.g. ***Primates***.
- Align your sequences in Clustal.
- We can now create our evolutionary tree of vertebrates. Go to the **Trees** menu and click on **Draw Trees**.
- Open the program FigTree to view your tree. Click on **Open** in the **File** menu and open the file named Vertebrates.ph.
- To root this evolutionary tree correctly you will need to place the root between the sharks and rays and the other vertebrates.
- With the cursor click on the branch leading to the sharks and rays. Now press Reroot.
- Colour code the different vertebrate groups using **Clade** and **Colour**.

Questions

- Have all of the vertebrate groups been correctly recovered as intact groups in the tree?
- Using your tree can you tell if the bony fish called the coelocanths are more closely related to land verterbrates or other bony fish?
- Your tree shows the evolutionary origin of birds. Which group of vertebrates did the birds evolve from?
- If you look at the Clustal alignment for all vertebrates you will see very few columns have asterisks. This means that most amino acids in NADH dehydrogenase 3 have changed during vertebrate evolution – can you think why some amino acids have not changed?

Glossary

Alignment: An ordered manner of writing out amino acid or nucleotide sequences. Columns in the alignment should contain characters with shared evolutionary history.

Branch: Lines in a *phylogenetic tree* which show evolutionary history. Branch length is proportional to time, e.g. long branches represent long evolutionary time. Branches split at points called *nodes*.

Clade: An evolutionary group with a single origin. None of the organisms in the group have evolved into other types of species.

Node: A point in a *phylogenetic tree* where a *branch* splits into two. This represents a point where one species diverges into two.

Phylogenetic Tree: A graphical representation of how organisms or genes have evolved. Phylogenetic trees are estimates based upon a particular dataset, so different datasets may give different trees.

Root: The oldest point in a *phylogenetic tree*. All species have evolved from the organism that existed at the time of the root.

NADH Dehydrogenase 3 Protein Sequences

Mammals

Primates

>Human
MNFALILMINTLLALLLMIITFWLPQLNGYMEKSTPYECGFDPMSPARVPFSMKFFLVAITFLLFDLEIA
LLLPLPWALQTTNLPLMVMSSLLLIIILALSLAYEWLQKGLDWTE
>Neanderthal
MNFALILMINTLLALLLMIITFWLPQLNGYMEKSTPYECGFDPMSPARVPFSMKFFLVAITFLLFDLEIA
LLLPLPWALQTTNLPLMVTSSLLLIIILALSLAYEWLQKGLDWAE
>Chimpanzee
MNFVLILMTNTLLALLLMIITFWLPQLNSYMEKSTPYECGFDPMSPARVPFSMKFFLVAITFLLFDLEIA
LLLPLPWALQTANLPLMVTSSLLLITILALSLAYEWLQKGLDWTE
>Gorilla
MNFALILMTNTLLALLLMIITFWLPQLNSYMEKTNPYECGFDPVSPARIPFSMKFFLVAITFLLFDLEIA
LLLPLPWALQTTNLPLMVMSSLLLIIILTLSLAYEWLQKGLDWAE
>Orangutan
MNFVLALTINTLLALLLMILTFWLPQLNPYMEKSDPYECGFDPAYPARIPFSMKFFLVAITFLLFDLEIA
LLLPLPWALQTTNLPLMTTSSLMLIIILALGLTYEWSQKGLDWAE
>Black_Howler_Monkey
MNLTLTLATNTLLALLLVTITFWLPQLNTYTEKFNPYECGFDPTTSAHLPFSMKFFLVAITFLLFDLEIA
LLLPLPWATQTNNLMLTINTILTLIIILALGLAYEWTQKGLDWVE
>Brown_Woolly_Monkey
MNLMLTLTTNILLALVLITITFWLPQLNIYTEKFNPYECGFDPTTSARLPFSMKFFLIAITFLLFDLEIA
LLLPLPWATQTNNLMLTINMILALIVILAVGLAYEWTQKGLDWIE
>SnubNosed_Monkey
MNLVLALTINTLLTLLLMIIMFWLPQLNPYAEKINPYECGFDPLNSARIPFSMKFFLVAITFLLFDLEIA
LLLPLPWALQTTSLPMMFKSSIMLIVILTLSLAYEWTQKGLEWIE
>Rhesus_Monkey
MNLVLALTINTLLTSLLMIIMFWLPQLNPYTEKTSPYECGFDPLNPARIPFSMKFFLVAITFLLFDLEIA
LLLSLPWAIQTTNLPMMIKSTIAFIIILILSLTYEWTQKGLDWAE

Rabbits & Hares

>European_Hare
MNLILVLLINMTISLILVTIAFWLPQLNIYSEKTSPYECGFDPMGSARLPFSMKFFLVAITFLLFDLEIA
LLLPLPWAAQFNNLNLVLIMALMLISILALGLAYEWIQKGLEWVE
>Rabbit
MNLMLVLLINTTISLVLVTIAFWLPQLNIYSEKSSPYECGFDPMGSARLPFSMKFFLVAITFLLFDLEIA
LLLPLPWAAQFNNLNLVLIMALMLISILALGLAYEWIQKGLEWVE

Ungulates (Hoofed Animals)

>Pig
MNIMLTLLTNVTLASLLVLIAFWLPQLNAYSEKTSPYECGFDPMGSARLPFSMKFFLVAITFLLFDLEIA
LLLPLPWASQANNLKTMLTMALFLLILLAASLAYEWTQKGLEWAE
>Deer
MNLMLALLTNFTLASLLVIIAFWLPQLNVYSEKTSPYECGFDPMGSARLPFSMKFFLVAITFLLFDLEIA
LLLPLPWASQTNNLGTMLTMALFLILLLAASLAYEWTQKGLEWTE
>Giraffe
MNLMLTLLINLLLATLLVTIAFWLPQLNVYSEKTSPYECGFDPMGSARLPFSMKFFLVAITFLLFDLEIA
LLLPLPWASQTNDLYTMLTMALLLILLLAASLAYEWTQKGLEWTE
>Cow
MNLMLALLTNFTLATLLVIIAFWLPQLNVYSEKTSPYECGFDPMGSARLPFSMKFFLVAITFLLFDLEIA
LLLPLPWASQTANLNTMLTMALFLIILLAVSLAYEWTQKGLEWTE
>Killer_Whale
MNLLSTLLTNTTLALLLMLIAFWLPQLNTYAEKTSPYECGFDPMGSARLPFSMKFFLVAITFLLFDLEIT
LLLPLPWAIQTNNLTTMLLMALFLISLLATSLAYEWTQKGLEWNK
>Blue_Whale
MNLLLTLLTNTTLALLLVFIAFWLPQLNVYAEKTSPYECGFDPMGSARLPFSMKFFLVAITFLLFDLEIA
LLLPLPWAIQSNNLNTMLTMALFLISLLAASLAYEWTQEGLEWAE
>Bottlenose_Dolphin
MNLLLTLLTNTTLALLLMLIAFWLPQLNTYAEKTSPYECGFDPMGSARLPFSMKFFLVAITFLLFDLEIA
LLLPLPWAIQTNNLTTMLLMALFLISLLAASLAYEWTQKGLEWDK
>Sperm_Whale
MNILLTLLTNTTLALLLMLIAFWLPQLNAYTEKTSPYECGFDPMQSARLPFSMKFFLVAITFLLFDLEIA
LLLPLPWATQTNNLKTMLTTALFLISLLAASLAYEWTQEGLEWAE

Carnivores

>Fur_Seal
MNMILALLTNTILASLLVLIAFWLPQLNIYSEKASPYECGFDPMGSARLPFSMKFFLVAITFLLFDLEIA
LLLPLPWASHANNLTTTLTMALMLISLLAASLAYEWTEKGLEWTE
>Walrus
MNMILTLLTNTALASLLMLIAFWLPQLNTYSEKASPYECGFDPMGSARLPFSMKFFLVAITFLLFDLEIA
LLLPLPWASHANNMTTVLTTALMLISLLAASLAYEWAEKGLEWTE
>Cat
MNVMLALLTNTLLSTLLVLIAFWLPQLNIYAEKASPYECGFDPMGSARLPFSMKFFLVAITFLLFDLEIA
LLLPLPWASQTDKLPTMLTMALLLISLLAASLAYEWTQKGLEWTE
>Lion
MNVMLALLTNTLLSTLLALIAFWLPQLNISAEKASPYECGFDPMGSARLPFSMKFFLVAITFLLFDLEIA
LLLPLPWASQTNKLSTMLTMALLLISLLAASLAYEWTQKGLEWTE
>Tiger
MNMMLALLTNTLLSTLLMLIAFWLPQLNTYAEKASPYECGFDPMGSARLPFSMKFFLVAITFLLFDLEIA
LLLPLPWASQTNKLSTMLITALLLISLLAASLAYEWTQKGLEWTE
>Dog
MNVMLTLMTNVTLASLLVLIAFWLPQLNIYTDKTSPYECGFDPMGSARLPFSMKFFLVAITFLLFDLEIA
LLLPLPWASQTNKLTTMLIMALLLISLLAASLAYEWTEKGLEWTE
>Wolf
MNVMLTLMTNVTLASLLVLIAFWLPQLNIYTDKTSPYECGFDPMGSARLPFSMKFFLVAITFLLFDLEIA
LLLPLPWASQTNKLTTMLIMALLLISLLAASLAYEWTEKGLEWTE
>Fox
MNMMLTLMTNITLASLLVMIAFWLPQLNIYADKTSPYECGFDPMGSARLPFSMKFFLVAITFLLFDLEIA
LLLPLPWASQTNKLTTMLIMALLLISLLAASLAYEWTEKGLEWTE
>Badger
MNMLLTLLINVSLASLLVLIAFWLPQLNIYTEKASPYECGFDPLGSARLPFSMKFFLVAITFLLFDLEIA
LLLPLPWASQSSNLNTTLATALLLILLLATSLAYEWAEEGLEWNE
>Otter
MNMMLTLFTNVSLASLLILIAFWLPQLNIYTEKAGPYECGFDPLGSARLPFSMKFFLVAITFLLFDLEIA
LLLPLPWASQSINLKTTLTTALTLVSLLAVSLAYEWTEEGLEWNE
>Brown_Bear
MNLVLALFTNMLLASLLVLIAFWLPQLNIYAEKASPYECGFDPMGSARLPFSMKFFLVAITFLLFDLEIA
LLLPLPWASQTDNLMTMLTMALLLISLLAVSLAYEWAEKGLEWAE
>Polar_Bear
MNLILALFTNMLLASLLVLIAFWLPQLNIYAEKASPYECGFDPMGSARLPFSMKFFLVAITFLLFDLEIA
LLLPLPWASQTDNLMTMLTMALLLISLLAVSLAYEWTEKGLEWAE
>Giant_Panda
MNLILALLTNVLLASLLVLIAFWLPQLNIYAEKVSPYECGFDPMGSARLPFSMKFFLVAITFLLFDLEIA
LLLPLPWALQTNNLMTMLIMALLLISLLAASLAYEWTEKGLEWAE
>Red_Panda
MNLIMTLFINITLTSLLVLIAFWLPQLNIYTEKTSPYECGFDPMGSARMPFSMKFFLVAITFLLFDLEIA
LLLPLPWATQTVNLTTMLTTALLLISLLAVSLAYEWTEKGLEWTE

Afrotheria (Mammals Who Evolved From Africa)

>African_Elephant
MNLMTTLLTNTMLTSLMVLIAFWLPQTYTYSEKTSPYECGFDPMGSARLPFSMKFFLVAITFLLFDLEIA
LLLPLPWAIQANDTNLTLLMSFMLIILLAIGLAYEWLQKGLEWTK
>Asian_Elephant
MNLMTTLLTNTMLTSLMVLIAFWLPQTYTYSEKTSPYECGFDPMGSARLPFSMKFFLVAITFLLFDLEIA
LLLPLPWAIQANNTNLTLLMSFMLIILLAIGLAYEWLQKGLEWTK
>Woolly_Mammoth
MNLMATLLTNTMLTSLMVLIAFWLPQTYTYSEKTSPYECGFDPMGSARLPFSMKFFLVAITFLLFDLEIA
LLLPLPWAIQANNTNLTLLMSFMLIILLAIGLAYEWLQKGLEWTK
>Seacow
MNLMLTLFTNATLASLLILIAFWLPQSYAYAEKVTPYECGFDPMGSARLPFSMKFFLVAITFLLFDLEIA
LLLPLPWAIQATNLNLVLFMALALITLLALSLAYEWIQKGLEWVE

Marsupial Mammals

>Kangaroo
MNLIITLIINTALSTIIVLIAFWLPQLYLYLEKSSPYECGFDPLGSARLPFSMKFFLIAITFLLFDLEIA
LLLPLPWAIQLPTPNSTLILAYCLIILLTAGLAYEWIQKGLEWTE
>Tasmanian_Devil
MNLMLTLLINSTLATVVVLIAFWLPQLYLYLEKSSPYECGFDPLGSARLPFSMKFFLVAITFLLFDLEIA
LLLPLPWAIQLPTANTILFLSYFIIILLTGGLAYEWFQKGLEWTE
>Wombat
MINLIITLIVNSLLSTIIVLIAFWLPQLYLYMEKSSPYECGFDPLGSARLPFSLKFFLIAITFLLFDLEI
ALLLPLPWAVQLSNPNTMLILSYGLILLLTAGLAYEWLQKGLEWTE

Birds

>Golden_Eagle
MNMITFMLTLTLTLSILLITLNLWLAQTNPDSEKLSPYECGFDPLGSARLPFSIRFFLVAILFLLFDLEI
ALLLPLPWAMQLQSPTTTLTWASIIISLLTLGLIYEWLQGGLEWAE
>Jackass_Penguin
MNMITFMLILSLALSVALTTLNFWLAQTNPDSEKLSPYECGFDPLGSARLPFSIRFFLVAILFLLFDLEI
ALLLPLPWAIQLQSPTTTLTWASAIILLLTLGLIYEWMQGGLEWAE
>Puffin
MNMITFMLTLSLALSVILTTLNFWLAQMNPDSEKLSPYECGFDPLGSARLPFSIRFFLVAILFLLFDLEI
ALLLPLPWAVQLQSPTTTLIWTFTIIILLTLGLIYEWMQGGLEWAE
>Parrot
MNMIMFMLISSIILSMALTTLNFWLTQMTPDSEKLSPYECGFDPLGSARLPFSIRFFLVAILFLLFDLEI
ALLLPLPWATQLKHPTTTLIWASTIILLLTLGLIYEWSQGGLEWAE
>Peregrine_Falcon
MNTILFMLTLSLTLSIILISLNFWLAQTTPDSEKLSPYECGFDPLGSARLPFSIRFFLVAILFLLFDLEI
ALLLPLPWATQLQSPTTTLTWTLLIITLLTLGLIYEWLQGGLEWAE
>Swan
MNMLMFMFALSSILSAALIALNFWLAQMNPDSEKLSPYECGFDPLGSARLPFSVRFFLVAILFLLFDLEI
ALLLPLPWAIQLQSPLMTLAWTVAILLLLTLGLAYEWVQGGLEWAE
>Duck
MNMLTFMFSLSLVLSAILTALNFWLAQMTPDSEKLSPYECGFDPLGSARLPFSIRFFLVAILFLLFDLEI
ALLLPLPWAIQLQSPLMTLAWTAAILSLLTLGLAYEWAQGGLEWAE

Reptiles

>Sand_Lizard
MNLMTMFIITTLISTILILISFWLPQMLPDMEKLSPYECGFDPLGSARLPFSIRFFLVAILFLLFDLEIA
LLLPTPWATNLPYPMVTVSWVYTIITLLTLGLIYEWTQGGLDWAE
>Komodo_Dragon
MNFVLMLLASFTISTLLIALSFWLPQTMPDMEKLSPYECGFDPLGSARLPFSLHFFLVAILFLLFDLEIA
LLLPLPWATNLPNPTITLILTLIILSLLTLGLIYEWKQGGLEWAI
>Turtle
MNMTISTMTIAITLSTILMVLNHWLTLMKPDTEKLSPYECGFDPLESARLPFSIRFFLVAILFLLFDLEI
ALLLPLPWAIQLPSPTCTFTWALIILLLLTLGFMHEWIQGGLEWAE
>Terrapin
MNVTISTMTIAITLSTILMALNYWLTLMKPDTEKLSPYECGFDPLESARLPFSIRFFLVAILFLLFDLEI
ALLLPLPWAIQLPSPIYTFTWALIILLLLTLGLIYEWVQGGLEWAE
>Tortoise
MNTTISIMIISLALSTILIMLNYWLTLMKPDNEKLSPYECGFDPLESARLPFSIRFFLVAILFLLFDLEI
ALLLPLPWAIQLPHPTHSFTWALTILSLLTLGLIYEWIQGGLEWAE

Amphibians

>Japanese_Gliding_Frog
MMLVFTLMALTLSVILALISFWLPTILPDTEKLSPYECGFDPLGSARLPYSMRFFLVAILFLLFDLEIAL
LLPMPWAIQLTTPPSVMMWAMMVLLLLTMGFIYEWDQAGLEWAE
>Marsh_Frog
MLLFFSIASLLSIILAAVSFWLPLITPDTEKLSPYECGFDPLGSARLPYSMRFFLVAILFLLFDLEIALL
LPTPWAIQLPNPLMTIIWASIIVILLTLGFIYEWLQGGLEWAE
>Marine_Toad
MSLFVFITLAIVLILATVSFWLPMINPDSEKLSPYECGFDPLGSARLPYSMRFFLVAILFLLFDLEIALL
LPTPWAAQLPHPTLSIFWASIILILLTLGFIYEWLQGGLEWAE
>Tibetan_Toad
MTLFVILTLVIVSILASISFWLPTINSDSEKLSPYECGFDPLGSARLPYSMRFFLVAILFLLFDLEIALL
LPTPWAAQLPYPTLSILLASVILILLTLGFVYEWLQGGLEWAE

Bony Fish

>Coelocanth
MNLILAGLLIMSILSMILAVIAFWLPNMTPDTEKLSPYECGFDPLGSARLPFSLRFFLVAILFLLFDLEI
ALLLPLPWADQLTNPTLVLTWTTSIIALLTLGLIHEWTQGGLEWAE
>Menado_Coelocanth
MNLILAGLLIMSILSMILAVIAFWLPNMTPDTEKLSPYECGFDPLGSARLPFSLRFFLVAILFLLFDLEI
ALLLPLPWADQLTNPTLVLTWTTSIIALLTLGLIHEWTQGGLEWAE
>Salmon
MNLITTIIAITITLSAVLATISFWLPQMTPDAEKLSPYECGFDPLGSARLPFSLRFFLIAILFLLFDLEI
ALLLPLPWGDQLTTPALTLAWSAAVLALLTLGLIYEWTQGGLEWAE
>Cod

MNLISTVILIASALSLILILVSFWLPQLSPDYEKLSPYECGFDPLGSARLPFSLRFFLIAILFLLFDLEI
ALLLPLPWGDQLSNPTLTFMWATSVLALLTLGLIYEWLQGGLEWAE
>Haddock
MNLISTVILIASALSLILILVSFWLPQLSPDYEKLSPYECGFDPLGSARLPFSLRFFLIAILFLLFDLEI
ALLLPLPWGDQLSNPSLTFMWATSVLALLTLGLIYEWLQGGLEWAE
>Trout
MNLITTIIAITITLSAVLATVSFWLPQITPDAEKLSPYECGFDPLGSARLPFSLRFFLIAILFLLFDLEI
ALLLPLPWGDQLATPALTLAWSAAVLALLTLGLIYEWTQGGLEWAE
>Stickleback
MNLVTTVVTITAALSIVLALVSFWLPQMTPDHEKLSPYECGFDPLGSARLPFSLRFFLVAILFLLFDLEI
ALLLPLPWGDQLATPLLTFLWATAVLALLTLGLIYEWMQGGLEWAE
>Pike
MNLISTIFVITITLSAILATLSFWLPQMSPDTEKLSPYECGFDPLGTARLPFSLRFFLVAILFLLFDLEI
ALLLPLPWADQLSSPTLTFLWATTILTLLTLGLIYEWIQGGLEWAE
>Goldfish
MNLIMTILTITTALSLILATISFWLPQMNPDAEKLSPYECGFDPLGSARLPFSLRFFLVAILFLLFDLEI
ALLLPLPWGDQLNNPTGTFFWATTVLILLTLGLIYEWTQGGLEWAE
>Barracuda
MSLITTIILITLILSVILATVSFWLPQMNPDYEKLSPYECGFDPLGSARLPFSLRFFLIAILFLLFDLEI
ALLLPLPWGDQLASPLLTFLWASAVLILLTLGLIYEWLQGGLEWAE
>Herring
MSLIMVVLAITLILSIILVIVSFWLPQMTPDAEKLSPYECGFDPRGSARMPFSLRFFLVAILFLLFDLEI
ALLLPLPWAYQLDNPVMTVVWAGAVLALLTLGLVYEWLQGGLEWAE
>Sardine
MSLIMVVLAITLILSIILVIVSFWLPQMTPDAEKLSPYECGFDPRGSARMPFSLRFFLVAILFLLFDLEI
ALLLPLPWAYQLANPLTTVAWATAVLVLLTLGLVYEWIQGGLEWAE

Sharks & Rays

>Great_White_Shark
MNLIMSSVAATALISLILVFIAFWLPSLNPDNEKLSPYECGFDPLGNARLPFSLRFFLVAILFLLFDLEI
ALLLPLPWGNQLLSPLHTLFWATTILILLTLGLIYEWLQGGLEWAE
>Tiger_Shark
MNLIMSSVVATALVSLMLALIAFWLPLLNPDNEKLSPYECGFDPLGNARLPFSLRFFLVAILFLLFDLEI
ALLLPLPWGNQSLTPLSTLFWATIILILLILGLIYEWSQGGLEWAE
>Dogfish
MNLVMSSVAATALISLILAFVAFWLPLLNPDNEKLSPYECGFDPLGSARLPFSLRFFLVAILFLLFDLEI
ALLLPLPWGNQLLTPFISLLWATSIIILLTLGLIYEWLQGGLEWAE
>Whale_Shark
MSLIMSSIAITALISLILATIAFWLPLLNPDNEKLSPYECGFDPLGNARLPFSLRFFLVAILFLLFDLEI
ALLLPLPWGDQLPMPSYTLLWASIILMLLTLGLIYEWFQGGLEWAE
>Basking_Shark
MSLITSSVAATALISLILVFITFWLPSLSPDNEKLSPYECGFDPLGSARLPFSLRFFLVAILFLLFDLEI
ALLLPLPWGDQLLSPLSTLLWAATILILLTLGLIYEWLQGGLEWAE
>Manta_Ray
MNLITFIVALTALISLILAILAFWLPSLNPDNEKMSPYECGFDPLGTARLPFSLRFFLIAILFLLFDLEI
ALLLPLPWGDQLTSPLITSLWAATILFLLTLGLIYEWLQGGLEWAE
>Stingray
MNLITFIVALTALISLILATLAFWLPILNPDSEKMSPYECGFDPLGTARLPFSLRFFLVAILFLLFDLEI
ALLLPLPWGDQLNSPLTTSLWATIILLLLTLGLVYEWLQGGLEWAE