Introduction
Some proteins are shared among all living things. Even though these proteins carry out the same function, their exact shape and size—which depends on the amino acids they are made up of—can be different from one organism to the next.
Yet if all living things are descended from a common ancestor, we would expect to find similarities in their protein sequences.
Are proteins that have the same job made up of similar sequences of amino acids? What patterns are there in amino acid sequences from different organisms?

PCNA (Proliferating Cell Nuclear Antigen) Protein
When three of these proteins come together, they form a ring that wraps around a single strand of DNA. The ring acts as a clamp for DNA polymerase—the molecular machine that copies DNA—so it can “lock” onto the DNA template strand during DNA replication. Because copying DNA is essential for life, all types of living things make this protein.

Comparing Amino Acid Sequences
You will be comparing amino acid sequences of PCNA protein from several different organisms to PCNA protein from mouse. PCNA has about 260 amino acids in all. You’re going to look at just the last 63 or so of them.

Instructions
1. Fold along the dotted line, below the mouse sequence.

MOUSE – PCNA amino acid sequence (partial):
NEPVHLTFALRYLNFFTKATPLSPTVTLSMSADVPLVVEYKIADMGLKYYYYLPKIEDEEAS

Structure of PCNA protein (from Arabidopsis thaliana). Three interconnected molecules of PCNA are pictured; DNA fits into the space in the center.

based on RCSB PDB reference 2zvw
4. Calculate the percent of amino acids that are identical between mouse and chicken:
\[
\frac{\text{Number of matches}}{62} = \% 
\]

5. Repeat for the other sequences:

- Percent identical between mouse and fruit fly:
\[
\frac{\text{Number of matches}}{62} = \% 
\]

- Percent identical between mouse and soybean:
\[
\frac{\text{Number of matches}}{62} = \% 
\]
percent identical between mouse and yeast: \[
\frac{\text{# that are the same}}{62} = \% 
\]

percent identical between mouse and E. coli: \[
\frac{\text{# that are the same}}{62} = \% 
\]

percent identical between mouse and the random sequence: \[
\frac{\text{# that are the same}}{62} = \% 
\]

6. Fill in the boxes on the cards with the percent identical numbers. Make sure to write your numbers BIG. Cut the cards apart.
Comparing Amino Acid Sequences

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MOUSE – PCNA amino acid sequence (partial):

NEPVHLTFALRYLNFKTATPLSPTVTLSSADVPLVVEYKIADMGLKYYLYLAPKIEDEEAS
2. Line up the mouse sequence with the sequence below, and mark matches and mismatches:
   - CIRCLE matches; SLASH mismatches
   - If both are dashes, don’t count it at all

   Example: 5 matches out of 10 = 50%

COW – PCNA amino acid sequence (partial):
NEPVQLTFALRYLNFFTKATPLSPTVTLSMADVPLVVEYKIADMGHLKYYLAPKIEDEEGS

4. Calculate the percent of amino acids that are identical between mouse and cow:
   \[ \frac{\text{matches}}{62} = \text{\%} \]

5. Repeat for the other sequences:

FROG – PCNA amino acid sequence (partial):
NEPVQLTFALRYLNFFTKATPLSPTVILSMADIPLVVEYKIADMGHVVKYYLAPKIEDEEAAS

   percent identical between mouse and frog:
   \[ \frac{\text{matches}}{62} = \text{\%} \]

NEMATODE – PCNA amino acid sequence (partial):
KDPVNVNSIKYMQFTKTALSDRVRLSCLNDVPVVEYPIEENGYLRFLAPKIDDENM

   percent identical between mouse and nematode:
   \[ \frac{\text{matches}}{62} = \text{\%} \]
CORN – PCNA amino acid sequence (partial):
QEPVSLTFALRYMNSSFTKASLSSEQVTISLSSLSEPVVVEYKIAEMGYIRFYLAPKIEDDEEM

percent identical between mouse and corn: \[
\frac{\text{number of identical residues}}{62} = \% \\
\text{(if that are the same)}
\]

M. JANNASCHII – PCNA amino acid sequence (partial):
KEEAKSAFNLDYLDMVKGVSSGDIIKIYLGNMPLKLEYSIAG-VNLTFLLAPRIEG----

percent identical between mouse and M. janneschii: \[
\frac{\text{number of identical residues}}{62} = \% \\
\text{(if that are the same)}
\]

RANDOM amino acid sequence:
PQMGBKAGEMRWSHTRMSVSMQLPVARNEFLHPVWKYHICKACMEAMFNMHWGDGYDDLG

percent identical between mouse and the random sequence: \[
\frac{\text{number of identical residues}}{62} = \% \\
\text{(if that are the same)}
\]

6. Fill in the boxes on the cards with the percent identical numbers. Make sure to write your numbers BIG. Cut the cards apart.
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Topoisomerase 1 Protein

As DNA is copied to make more DNA or RNA, it must unwind so that cellular machinery can access the sequences they need. Then it rewinds itself to stay compact.

Unwinding and rewinding adds twists and tension to DNA, much like a pair of tangled headphone wires. Topoisomerase 1 cuts one strand of DNA, allows it to untwist and relax, then puts the strand back together. Because managing DNA is essential for life, all types of living things make this protein.

Comparing Amino Acid Sequences

You will be comparing amino acid sequences of Topoisomerase protein from several different organisms to Topoisomerase protein from mouse. This protein has about 865 amino acids in all. You’re going to look at about 60 of them.

Instructions

1. Fold along the dotted line, below the mouse sequence.

MOUSE – Topoisomerase 1 amino acid sequence (partial):

S S R I K G E K D W Q K Y E T A R - - - - - - - - - L K K C V D K I R N Q Y R E D W K - - - - - - - - - - - - - S K E M K V R Q R A V A L Y F
2. Line up the mouse sequence with the sequence below, and mark matches and mismatches:
   - CIRCLE matches; SLASH mismatches
   - If both are dashes, don’t count it at all

   Example: 5 matches out of 10 = 50%

3. Calculate the **percent of amino acids that are identical** between mouse and cow:

   \[
   \frac{\text{number of matches}}{50} = \% \tag{# that are the same}
   \]

4. Repeat for the other sequences:

   - **COW** — Topoisomerase 1 amino acid sequence (partial):
     \[
     \text{SSRIKGEKDWQKYTEAR}---\text{RLKKCVDKIRNQYREDWK}-----\text{SKEMKVRQRAVALYF}
     \]

   **percent identical** between mouse and cow:

   \[
   \frac{\text{number of matches}}{50} = \% \tag{# that are the same}
   \]

   - **CHIMP** — Topoisomerase 1 amino acid sequence (partial):
     \[
     \text{SSRIKGEKDWQKYTEAR}---\text{RLKKCVDKIRNQYREDWK}-----\text{SKEMKVRQRAVALYF}
     \]

   **percent identical** between mouse and chimp:

   \[
   \frac{\text{number of matches}}{50} = \% \tag{# that are the same}
   \]

   - **NEMATODE** — Topoisomerase 1 amino acid sequence (partial):
     \[
     \text{SSKIKGEKDFEKYTEAR}---\text{RLKKKIGGIREYTDFFK}-----\text{SKEMRVRQRATAYLF}
     \]

   **percent identical** between mouse and nematode:

   \[
   \frac{\text{number of matches}}{50} = \% \tag{# that are the same}
   \]
percent identical between mouse and moss: \[
\frac{\text{number that are the same}}{60} = \%
\]

percent identical between mouse and E. coli: \[
\frac{\text{number that are the same}}{60} = \%
\]

percent identical between mouse and the random sequence: \[
\frac{\text{number that are the same}}{50} = \%
\]

6. Fill in the boxes on the cards with the percent identical numbers. Make sure to write your numbers BIG. Cut the cards apart.
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Unwinding and rewinding adds twists and tension to DNA, much like a pair of tangled headphone wires. Topoisomerase 1 cuts one strand of DNA, allows it to untwist and relax, then puts the strand back together. Because managing DNA is essential for life, all types of living things make this protein.

Comparing Amino Acid Sequences

You will be comparing amino acid sequences of Topoisomerase protein from several different organisms to Topoisomerase protein from mouse. This protein has about 865 amino acids in all. You’re going to look at about 60 of them.

Instructions

1. Fold along the dotted line, below the mouse sequence.

MOUSE – Topoisomerase 1 amino acid sequence (partial):

SSRIKGEKDWQKYETAR---RLKKCDKIRNQYREDWK---SKEKMKVQRARAVLYF
2. Line up the mouse sequence with the sequence below, and mark matches and mismatches:
   - CIRCLE matches; SLASH mismatches
   - If both are dashes, don’t count it all
   
   ![Mouse Sequence]

   ![Chicken Sequence]

   ![Fruit Fly Sequence]

4. Calculate the percent of amino acids that are identical between mouse and chicken:
   
   \[
   \frac{\text{5 matches}}{50} = \% \]

   5. Repeat for the other sequences:
   
   ![Yeast Sequence]

   \[
   \frac{\text{percent identical}}{50} = \% \]

   \[
   \frac{\text{percent identical}}{50} = \% \]
percent identical between mouse and moss: \[
\frac{\text{# that are the same}}{60} = \frac{\text{# that are the same}}{60} \%
\]

percent identical between mouse and M. janneschii: \[
\frac{\text{# that are the same}}{60} = \frac{\text{# that are the same}}{60} \%
\]

percent identical between mouse and the random sequence: \[
\frac{\text{# that are the same}}{50} = \frac{\text{# that are the same}}{50} \%
\]

6. Fill in the boxes on the cards with the percent identical numbers. Make sure to write your numbers BIG. Cut the cards apart.
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DNA Polymerase 1 Protein
DNA Polymerase is a molecular machine that copies DNA. It moves along one strand of DNA, adding one building block (nucleotide) at a time to make a new, complementary DNA strand. Because copying DNA is essential for life, all types of living things make this protein.

Comparing Amino Acid Sequences
You will be comparing amino acid sequences of DNA Polymerase 1 protein from several different organisms to DNA Polymerase 1 protein from mouse. DNA Polymerase 1 is a very large protein, up to about 1,465 amino acids in size. You’re going to look at about 54 amino acids.

Instructions
1. Fold along the dotted line, below the mouse sequence.

MOUSE – DNA Polymerase 1 amino acid sequence (partial):
LIEIGENVLNGSVPVSQFEINKALTKDPODYPDRKSLPHVHALWINSQGG
4. Calculate the percent of amino acids that are identical between mouse and chimp:
   \[ \frac{\text{matches}}{51} = \% \]

5. Repeat for the other sequences:

   - ZEBRAFISH — DNA Polymerase 1 amino acid sequence (partial):
     \[ \text{LIEIGEKVANGNIPLNMFEIHKSLLTKEPQDYPDJKSLPHVHVWALWINSQGG} \]
   
   \[ \frac{\text{percent identical}}{51} = \% \]

   - NEMATODE — DNA Polymerase 1 amino acid sequence (partial):
     \[ \text{LREIRAKLDGTVPLFMQISKQLTRNPEQYADVKAQCHAAVAQRNLNSG} \]
   
   \[ \frac{\text{percent identical}}{51} = \% \]
<table>
<thead>
<tr>
<th>Sequence</th>
<th>Amino Acid Sequence</th>
<th>Percent Identical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasmodium — DNA Polymerase 1</td>
<td>LRTINQRINQDNEFDLDYYITKKLTKNVHEYQDKNSLGHVLAERMIKД — G</td>
<td>( \frac{\text{# that are the same}}{51} \times 100 )</td>
</tr>
<tr>
<td>Y. Pestis — DNA Polymerase 1</td>
<td>VRDYLEARTLYGELDEQLVYRKRLRRRLDDYQRN — VPPHARAADEFNTRKLG</td>
<td>( \frac{\text{# that are the same}}{51} \times 100 )</td>
</tr>
<tr>
<td>RANDOM</td>
<td>ETQWFMGANEGRATVQKSKFKYNRPFDGAFIYLKQKHAYQYYNALQTHWQD</td>
<td>( \frac{\text{# that are the same}}{51} \times 100 )</td>
</tr>
</tbody>
</table>

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You will be comparing amino acid sequences of DNA Polymerase 1 protein from several different organisms to DNA Polymerase 1 protein from mouse. DNA Polymerase 1 is a very large protein, up to about 1,465 amino acids in size. You’re going to look at about 54 amino acids.

Instructions
1. Fold along the dotted line, below the mouse sequence.

**MOUSE – DNA Polymerase 1 amino acid sequence (partial):**

```
LIEIGENVLNGSVPVSQFEINKALTDPDYPDRKSLPHVHVALWINSQGG
```
4. Calculate the percent of amino acids that are identical between mouse and cow:

- CIRCLE matches; SLASH mismatches
- If both are dashes, don’t count it all

\[
\text{percent identical between mouse and cow:} \quad \frac{\text{# that are the same}}{51} = \% \\
\]

Example: 5 matches out of 10 = 50%

5. Repeat for the other sequences:

COW – DNA Polymerase 1 amino acid sequence (partial):

\[
\text{L I E I G E N V L N G S V P V S Q F E I N K A L T K D P Q D Y P D K K S L P H V H V A L W I N S Q G G}
\]

FRUIT FLY – DNA Polymerase 1 amino acid sequence (partial):

\[
\text{L E K I K T Q I A E G V V P L P L F V I T K Q L T R T P Q E Y A N S A S L P H V Q V A L R M N R E R N}
\]

YEAST – DNA Polymerase 1 amino acid sequence (partial):

\[
\]
6. Fill in the boxes on the cards with the percent identical numbers. Make sure to write your numbers BIG. Cut the cards apart.
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What patterns are there in amino acid sequences from different organisms?

RNA Polymerase 2 Protein

RNA Polymerase is made up of several proteins that work together (in yeast, there are 10). RNA Polymerase transcribes DNA: it moves along one strand and builds a complementary strand of RNA. Because transcribing the information from DNA to make RNA is essential for life, all types of living things make RNA Polymerase.

Comparing Amino Acid Sequences

You will be comparing amino acid sequences of RNA Polymerase 2 protein subunits from several different organisms to the Subunit B protein from mouse. This protein has about 1,255 amino acids in all. You’re going to look at just 60 of them.

Instructions

1. Fold along the dotted line, below the mouse sequence.
2. Line up the mouse sequence with the sequence below, and mark matches and mismatches:

- CIRCLE matches; SLASH mismatches
- If both are dashes, don’t count it at all

Example: 5 matches out of 10 = 50%

3. Calculate the **percent of amino acids that are identical** between mouse and chimp:

\[
\frac{5}{60} = \% 
\]

4. Repeat for the other sequences:

- **Percent identical** between mouse and fruit fly:

\[
\frac{5}{60} = \% 
\]

- **Percent identical** between mouse and yeast:

\[
\frac{5}{60} = \% 
\]
percent identical between mouse and corn:  

\[
\frac{}{60} = \% 
\]

percent identical between mouse and S. aureus:  

\[
\frac{}{60} = \% 
\]

percent identical between mouse and the random sequence:  

\[
\frac{}{60} = \% 
\]

6. Fill in the boxes on the cards with the percent identical numbers. Make sure to write your numbers BIG. Cut the cards apart.
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Introduction

Some proteins are shared among all living things. Even though these proteins carry out the same function, their exact shape and size—which depends on the amino acids they are made up of—can be different from one organism to the next.

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Are proteins that have the same job made up of similar sequences of amino acids? What patterns are there in amino acid sequences from different organisms?

RNA Polymerase 2 Protein

RNA Polymerase is made up of several protein subunits (in yeast, there are 12) that work together. RNA Polymerase transcribes DNA: it moves along one strand and builds a complementary strand of RNA. Because transcribing the information from DNA to make RNA is essential for life, all types of living things make RNA Polymerase.

Comparing Amino Acid Sequences

You will be comparing amino acid sequences of RNA Polymerase 2 protein subunits from several different organisms to the Subunit B protein from mouse. This protein has about 1,255 amino acids in all. You’re going to look at just 60 of them.

Instructions

1. Fold along the dotted line, below the mouse sequence.

MOUSE — RNA Polymerase 2 amino acid sequence (partial):

YHLRGNEVLYNGFTGRKITSQIFIQPTYYQRLKHMVDKIHSCRARGPIQILNRPMEGRS
2. Line up the mouse sequence with the sequence below, and mark matches and mismatches:
   - CIRCLE matches; SLASH mismatches
   - If both are dashes, don’t count it all

   Example: 5 matches out of 10 = 50%

4. Calculate the **percent of amino acids that are identical** between mouse and zebrafish:

   \[ \frac{\text{number of matches}}{60} \times 100\% \]

5. Repeat for the other sequences:

   **MOSS** – RNA Polymerase 2 amino acid sequence (partial):

   \[ \text{YQMRGFMNGHTGKLTAHI}FL\text{GPTYQR}L\text{KHMVDDKIHSRGPGVQLTRQPAEGRS} \]

   \[ \text{percent identical between mouse and moss:} \quad \frac{}{60} = \quad \% \]

   **PENICILLIUM** – RNA Polymerase 2 amino acid sequence (partial):

   \[ \text{YQSRGFMNGHTGKLVAQVF}L\text{GPTYQR}L\text{RHMVDDKIHRARGPTQILTRQPVEGRA} \]

   \[ \text{percent identical between mouse and mold:} \quad \frac{}{60} = \quad \% \]
percent identical between mouse and plasmodium: \[ \frac{\text{# that are the same}}{60} = \% \]

percent identical between mouse and M. janneschii: \[ \frac{\text{# that are the same}}{60} = \% \]

percent identical between mouse and the random sequence: \[ \frac{\text{# that are the same}}{60} = \% \]

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Recombination Protein RecA

This protein has different names in different species, including RecA, RadA, and Rad51. Whatever the name, this protein helps cells repair damage to their DNA.

RadA binds to single-stranded DNA and recruits other proteins needed to repair broken DNA strands. Because maintaining and repairing DNA are essential for life, all types of living things make this protein.

Comparing Amino Acid Sequences

You will be comparing amino acid sequences of RecA-related proteins from several different organisms to RecA protein from mouse. RecA has about 352 amino acids in all. You’re going to look at about 60 of them.

Instructions

1. Fold along the dotted line, below the mouse sequence.

MOUSE – RecA amino acid sequence (partial):

NIKGISEAKADKILTEAAKLVPMSGFFTATEF------HQRREIIQITTGSKELDKLLQ--GGI
2. Line up the mouse sequence with the sequence below, and mark matches and mismatches:

- CIRCLE matches; SLASH mismatches
- If both are dashes, don’t count it at all

Example: 5 matches out of 10 = 50% 

4. Calculate the percent of amino acids that are identical between mouse and zebrafish:

\[
\frac{\text{number of matches}}{56} = \% 
\]

5. Repeat for the other sequences:

- percent identical between mouse and nematode:

\[
\frac{\text{number of matches}}{56} = \% 
\]

- percent identical between mouse and moss:

\[
\frac{\text{number of matches}}{56} = \% 
\]
PLASMODIUM — RecA amino acid sequence (partial):


percent identical between mouse and plasmodium: \[ \frac{\text{# that are the same}}{56} = \% \]

Y. PESTIS — RecA amino acid sequence (partial):


percent identical between mouse and Y. pestis: \[ \frac{\text{# that are the same}}{60} = \% \]

RANDOM amino acid sequence:


percent identical between mouse and the random sequence: \[ \frac{\text{# that are the same}}{56} = \% \]

6. Fill in the boxes on the cards with the percent identical numbers. Make sure to write your numbers BIG. Cut the cards apart.
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Instructions

1. Fold along the dotted line, below the mouse sequence.

MOUSE – RecA amino acid sequence (partial):

NIKGISEAKADKILTEAAKLVPMGFTTATEF---HQRREIIQITTGSKELDKLLQ-GGI
2. Line up the mouse sequence with the sequence below, and mark matches and mismatches:

- CIRCLE matches; SLASH mismatches
- If both are dashes, don’t count it at all

Example: 5 matches out of 10 = 50%

4. Calculate the percent of amino acids that are identical between mouse and chimp:

\[
\frac{\text{# that are the same}}{56} = \ \ %
\]

5. Repeat for the other sequences:

- **YEAST** — RecA amino acid sequence (partial):
  \[
  \text{EIKGISEAKDKILNAAARLVPMGFTADDF---HMRSELICLTTGSKNLDTLLLG-GGV}
  \]
  \[
  \text{percent identical between mouse and yeast:} \quad \frac{\text{# that are the same}}{56} = \ \ %
  \]

- **CORN** — RecA amino acid sequence (partial):
  \[
  \text{QIKGISEAKDKEAASKIVPLGFSSQL---HAQRLVEIQVTTGSRKDLKILE-GGI}
  \]
  \[
  \text{percent identical between mouse and corn:} \quad \frac{\text{# that are the same}}{56} = \ \ %
  \]
percent identical between mouse and M. jannaschii: \[
\frac{\text{number of identical amino acids}}{56} = \% \]

percent identical between mouse and E. coli: \[
\frac{\text{number of identical amino acids}}{60} = \% \]

percent identical between mouse and the random sequence: \[
\frac{\text{number of identical amino acids}}{56} = \% \]

6. Fill in the boxes on the cards with the percent identical numbers. Make sure to write your numbers BIG. Cut the cards apart.