Haldane’s Dilemma

Current Cost of Substitution today is 30 (30 times more die than survive)

Average Reproductive Excess is 10% (the number that the species can afford to lose)

The rate of gene replacement = \( \frac{\text{Cost of Substitution}}{\text{Reproductive Excess}} \)

\[ = \frac{30}{10\%} \]

\[ = 300 \text{ generations for each new gene} \]

Maximum number of genes replaced in 10 mil yrs = \( \frac{\text{number of years}}{\text{rate of gene replacement per year}} \)

\[ = \frac{10,000,000}{(20 \times 300)} \]

\[ = 1667 \text{ nucleotides} \]

How much genetic material is 1667 nucleotides?

Percentage of total nucleotides = \( \frac{\text{total amount of genetic material} \times 100}{\text{No. nucleotides changed}} \)

\[ = \frac{7,000,000,000}{1667} \times 100 \]

\[ = 0.000002\% \]

How long then for the ape to evolve into a human?

0.00002% changes in 10,000,000 years

\[ \therefore 1\% \text{ changes in} \frac{10,000,000}{0.00002} \text{ years} \]

\[ = 500 \text{ billion years} \]

But, if a 10% change in genetic material is need for the ape to evolve into a human, then.....

a 10% change requires 500 billion x 10 years

\[ = 5000 \text{ billion years} \]

If 5,000 billion years is required to change 10% of the genetic material, but 90% of the time is in stasis, then.....

the 10% non-stasis period is 5,000 billion years

\[ \therefore 100\% \text{ of the time needed for our 10\% change in genetic material} \]

\[ = 5,000 \text{ billion years} \times 10 \]

\[ = 50,000 \text{ billion years} \]

BUT....

(1) Apes are said to have evolved into humans in 5 million years

(2) The earth is said to be only 5 billion years old

(3) The Big Bang occurred 20 billion years ago
<table>
<thead>
<tr>
<th>Starting Occurrence of Gene</th>
<th>Cost of Dominant Gene</th>
<th>Cost of Recessive Gene</th>
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</thead>
<tbody>
<tr>
<td>500,000</td>
<td>14</td>
<td>1,000,013</td>
</tr>
<tr>
<td>50,000</td>
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<tr>
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<tr>
<td>500</td>
<td>7</td>
<td>1,006</td>
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</tbody>
</table>
Data:

(1) POPULATION SIZE = 100,000

(2) LENGTH OF A GENERATION = 20 years

(3) STATUS FOR THE NEW TRAIT = higher survival rate than the old trait

(4) NEW TRAIT GENERATION METHOD = mutation

(5) MODE OF ACTION OF MUTATION = alter one DNA nucleotide in the chromosomes

(6) AMOUNT OF GENETIC MATERIAL = $7 \times 10^9$ nucleotide sites in the DNA (typical of a mammal)

(7) LENGTH OF EVOLUTION = 10,000,000 years (10 million years)

(8) TYPE OF EVOLUTION = perfect, uninterrupted & continuous for the whole time

(9) CONTRA-EVOLUTION FACTORS = not considered