Evolution
Darwinian Definition of Life

• Self-sustaining and reproducing
• Capable of evolving
Darwinian Evolution

Evolution is reproduction with error.

Error means changes in the DNA base sequence.

Many changes are neutral, because
• codons are redundant
• mutations happen in junk DNA

Some changes are lethal, because they result in non-functional proteins.

A few changes result in useful proteins.
The Cause of Mutations

Genetic damage due to radiation
  • Photons (X-rays, $\gamma$-rays)
  • Particles (cosmic rays)

Transcription errors
Particulate Radiation

Alpha particles
• Helium nuclei
• penetrate < 10 cm in air, 60 µm in tissue
• stopped by paper

Beta particles
• Electrons
• Penetrate a few mm into tissue

Neutrons

Fission Fragments
Electro-Magnetic Radiation

Penetrating radiation:
- X-rays
- $\gamma$ rays
Radiation Sources

• Radioactive decay
• High energy collisions
• Particle acceleration
• Astrophysical processes
Definitions

1 Becquerel (Bq) = 1 disintegration/second (dps)
1 Curie = $3.7 \times 10^{10}$ dps
1 Röntgen = amount of ionizing radiation that produces 1 esu/cm$^3$ in dry air
1 rad (Röntgen absorbed dose) = 100 erg/gm
1 Gray (Gy) = 100 rads = 1 Joule/kg
Dose = 0.869 f R
  \[ f = \text{mass absorption coefficient/air} \]
Rem (biological equivalent dose) = rads x QF
  \[ \text{QF (quality factor)} \approx \# \text{ ion pairs / cm} \]
1 Sievert (Sv) = 100 rem
Half Life

Time for half the original sample to decay

\[ N = N_0 e^{-0.693 \frac{T}{T_{1/2}}} t \]
Radioactivity Levels

Human being: 3000 Bq
Kg of coffee: 1000 Bq
Kg of Granite: 1000 Bq
Kg of coal ash: 2000 Bq
Air inside a 100 m² house: 3000 Bq
Kg, superphosphate fertilizer: 5000 Bq
Smoke detector: 30,000 Bq
Kg of low level radioactive waste: $10^6$ Bq
Kg of Uranium: $10^7$ Bq
Medical radioisotopes (diagnosis) $10^9$ Bq
Medical radioisotopes (therapy): $10^{14}$ Bq
Can You Avoid Radiation?

No.

<table>
<thead>
<tr>
<th>Source</th>
<th>Dose Rate (millirem/year)</th>
<th>Lifetime Cancer Risk assuming validity of LNT*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indoor radon</td>
<td>200</td>
<td>7,500 per 1,000,000</td>
</tr>
<tr>
<td>Cosmic rays (at sea level)</td>
<td>30</td>
<td>1,100 per 1,000,000</td>
</tr>
<tr>
<td>Cosmic rays (Denver at 5000 ft elevation)</td>
<td>55</td>
<td>2,000 per 1,000,000</td>
</tr>
<tr>
<td>Human body (from food we eat)</td>
<td>40</td>
<td>1,500 per 1,000,000</td>
</tr>
<tr>
<td>Soil and rock</td>
<td>30 - 50</td>
<td>1,100 to 1,900 per 1,000,000</td>
</tr>
<tr>
<td>Soil and rock (Colorado plateau)</td>
<td>90</td>
<td>3,400 per 1,000,000</td>
</tr>
<tr>
<td>Living in a brick house</td>
<td>7</td>
<td>260 per 1,000,000</td>
</tr>
<tr>
<td>Working in granite buildings</td>
<td>50 - 200</td>
<td>1,200 per 1,000,000</td>
</tr>
<tr>
<td>One round trip from LA to NY</td>
<td>6</td>
<td>3 per 1,000,000</td>
</tr>
<tr>
<td>Smoking 1 pack of cigarettes per day (polonium-210)</td>
<td>8,000</td>
<td>200,000 per 1,000,000</td>
</tr>
<tr>
<td>Sleeping next to one’s partner</td>
<td>2</td>
<td>50 per 1,000,000</td>
</tr>
</tbody>
</table>

* LNT. The linear-no-threshold (LNT) model of radiation risk assumes even the smallest incremental exposure to radiation has an associated cancer risk. There is no scientific evidence to support this theoretical model.
Evolution of Microbes

Mutations are important, since they will be copied (transcribed) into future generations.

Microbes may have a new generation every 30 minutes.

Microbes also share genetic material.
Genetic Diversity

A population carries lots of diverse traits.
- Some are crucial,
- Some are beneficial,
- Some are detrimental,
- Some are neutral

If the environment does not change
- The population of beneficial traits increases
- The population of detrimental traits decreases

Traits are ultimately determined by genes
Diversity and Stress

If the environment changes, the population may be stressed

• *Beneficial traits* may no longer be beneficial
• *Detrimental traits* may become useful
• *Neutral traits* may become beneficial or detrimental

The population will change in response to stress
Mutations in the Higher organisms

Single-point mutations, except in germ cells, are unimportant.

Isolated populations change in response to different environmental stresses

Over time, isolated populations may change sufficiently that they can no longer inter-breed. This is the definition of distinct species.
The Direction of Evolution

There is none. **Evolution is blind.**

All living species are successful.

All living species are adapted to their environment.

Some have failed to adapt to change, and become *extinct.*

The average species survives about 1 million years.