

# Entropy and Information

Feb 7, 2010

# *Review*

$$I = I_0 - S = I_0 - k \langle \ln p \rangle$$

$$\Delta I = - \Delta S$$

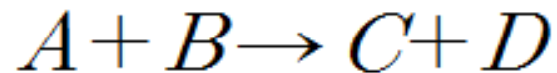
$$F := E - TS$$

$$\Delta F = - P \Delta V - S \Delta T$$

$$G := H - TS$$

$$\Delta G = V \Delta P - S \Delta T$$

## Gibbs free energy in chemical reaction



$$\Delta G = \Delta G^{\circ} + RT \ln \frac{[C][D]}{[A][B]}$$

$$\Delta G^{\circ} = -RT \ln [K_{eq}]$$

( $K_{eq}$  : equilibrium constant)

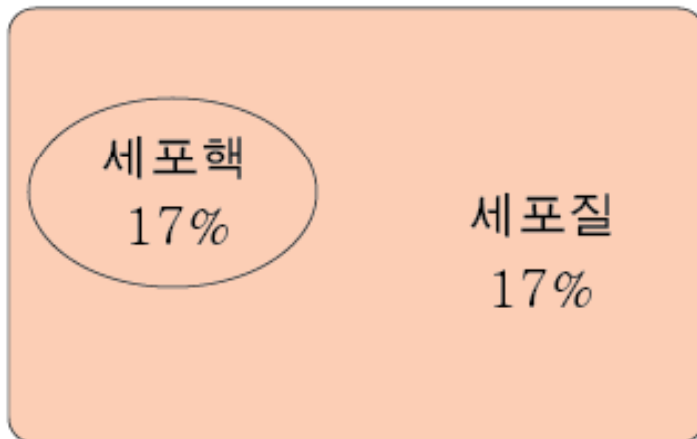
1

The free energy of a living human is in general much larger than that of a dead body. Explain why.

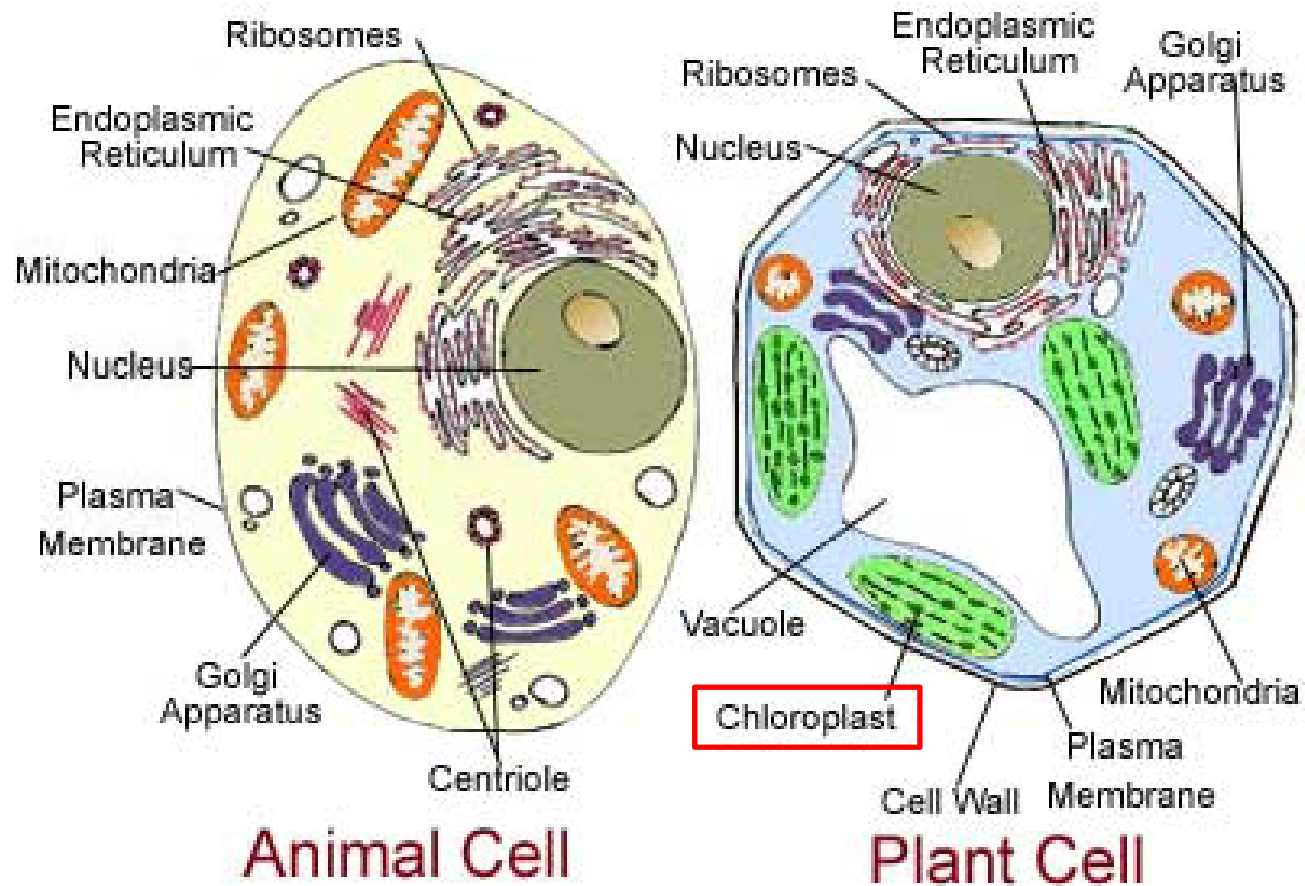
Suppose that the human absorbs energy from the Earth. Show that its free energy cannot increase in this process.

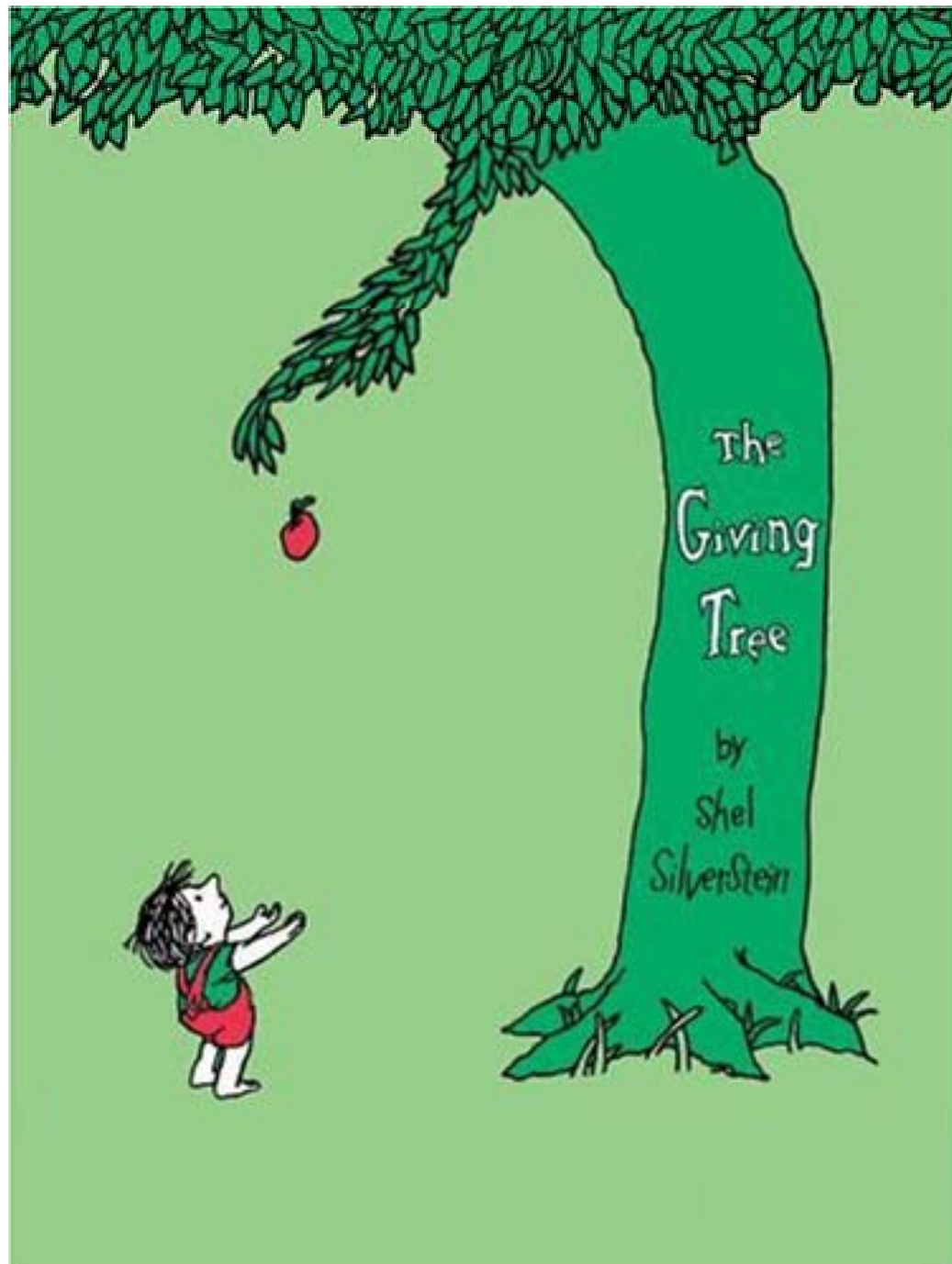


엔트로피 1.00161배 증가



# Difference between animal and plant cells

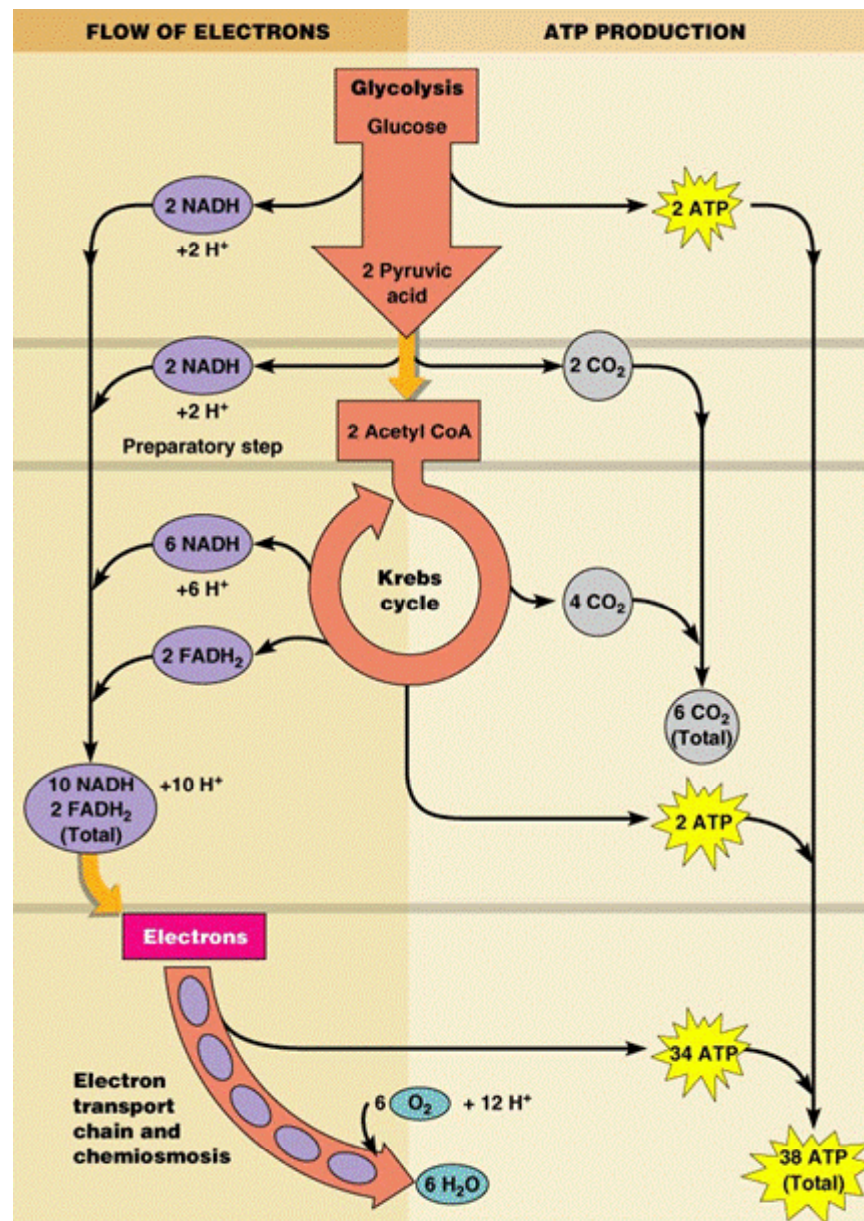
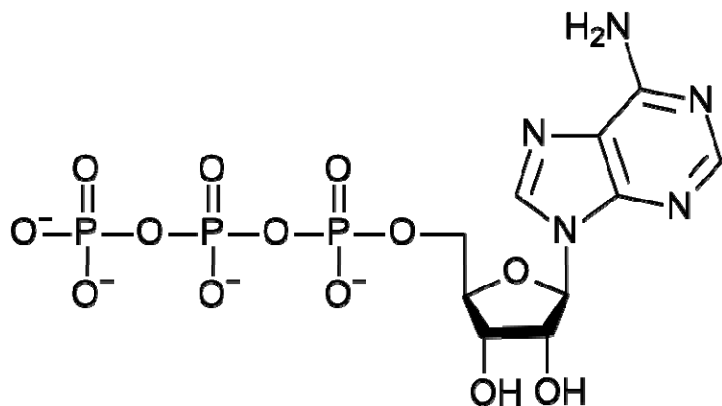




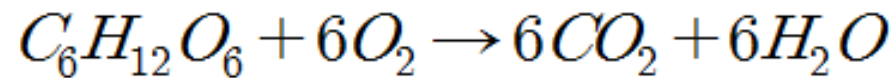
2

In order to live, a human must eat some food. Show that the human can increase her/his free energy by reducing the free energy of food, in the process of absorbing energy from the food.

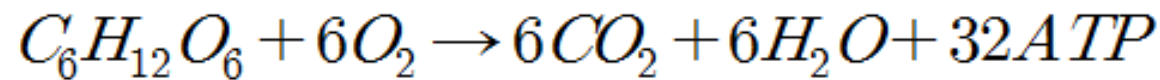
# Digestion of the Glucose



## Free energy acquisition during the digestion of glucose



$$\Delta G_c = G_p - G_r = -2870 \text{ Kj/mol}$$



$$\Delta G_m = -1893 \text{ Kj/mol}$$

$$\eta = \frac{\Delta G_{ATP}}{\Delta G_c} \approx 34\%$$

Carbohydrate : 400g/day

Protein : 100g/day

Fat : 50g/day

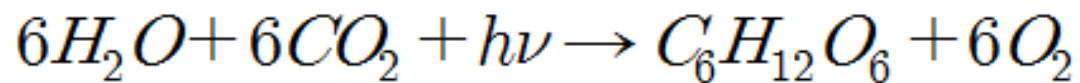
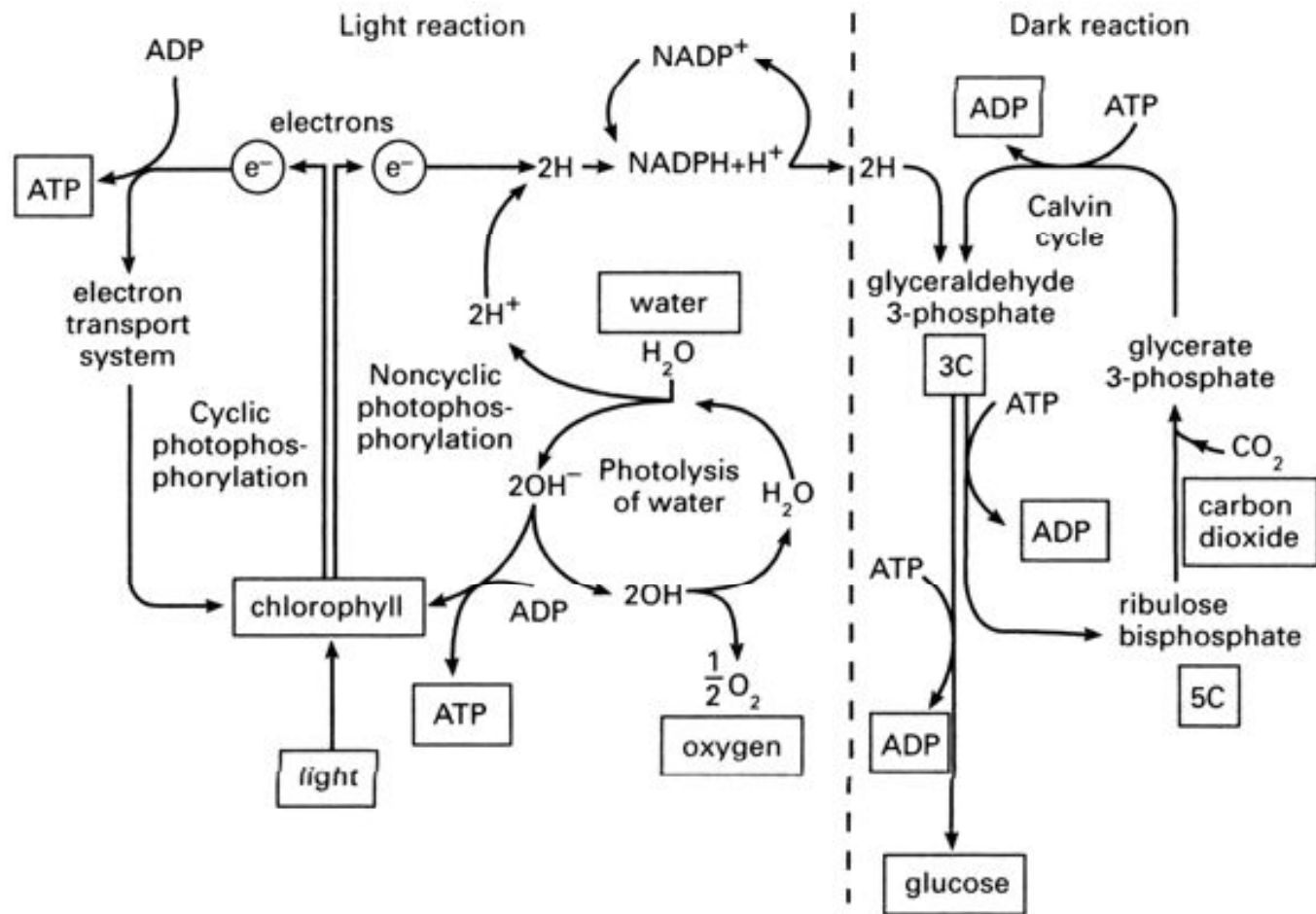


$\Delta G = 3076.65 \text{ KJ/day}$



3

Accordingly, what is needed is the food with large free energy, the origin of which is the photo-synthesis of plants. Estimate the maximum possible increase of the free energy of a plant in a day, as it absorbs energy from the sun.



$$\Delta G = 2870 \text{ KJ/mol}$$

$\Delta G$  provided by one pine tree per day

$$(CO_2) \ 6.72 \times 10^{-4} \text{ mol/day}$$



$$3.21 \times 10^2 \text{ J/day}$$



$\Delta G$  provided by all photo-synthetic organism on the Earth per day

$$(CO_2) \ 5.95 \times 10^{12} \text{ mol/day}$$



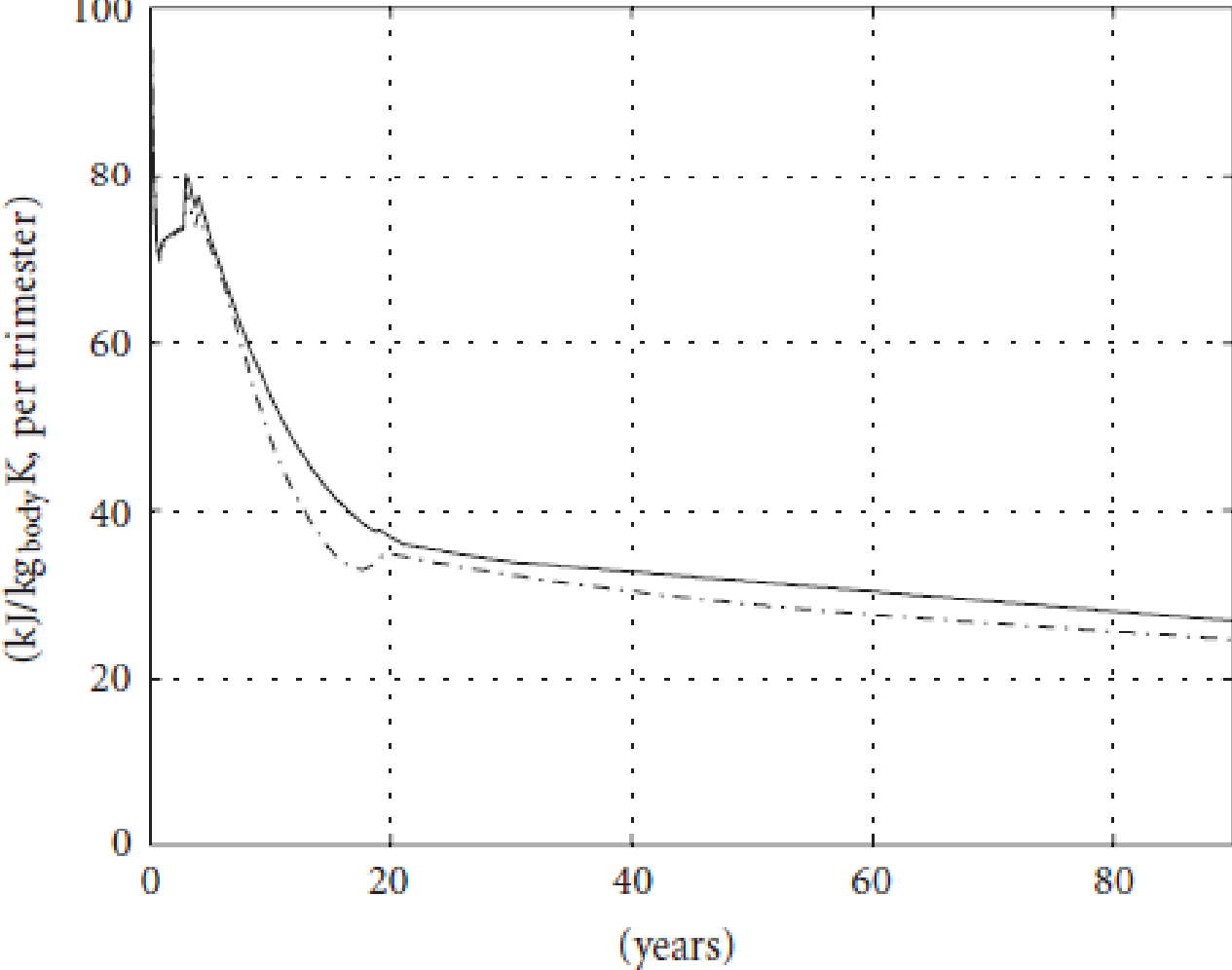
$$2.84 \times 10^{18} \text{ J/day} \quad \rightarrow \quad \text{약 2700억명}$$



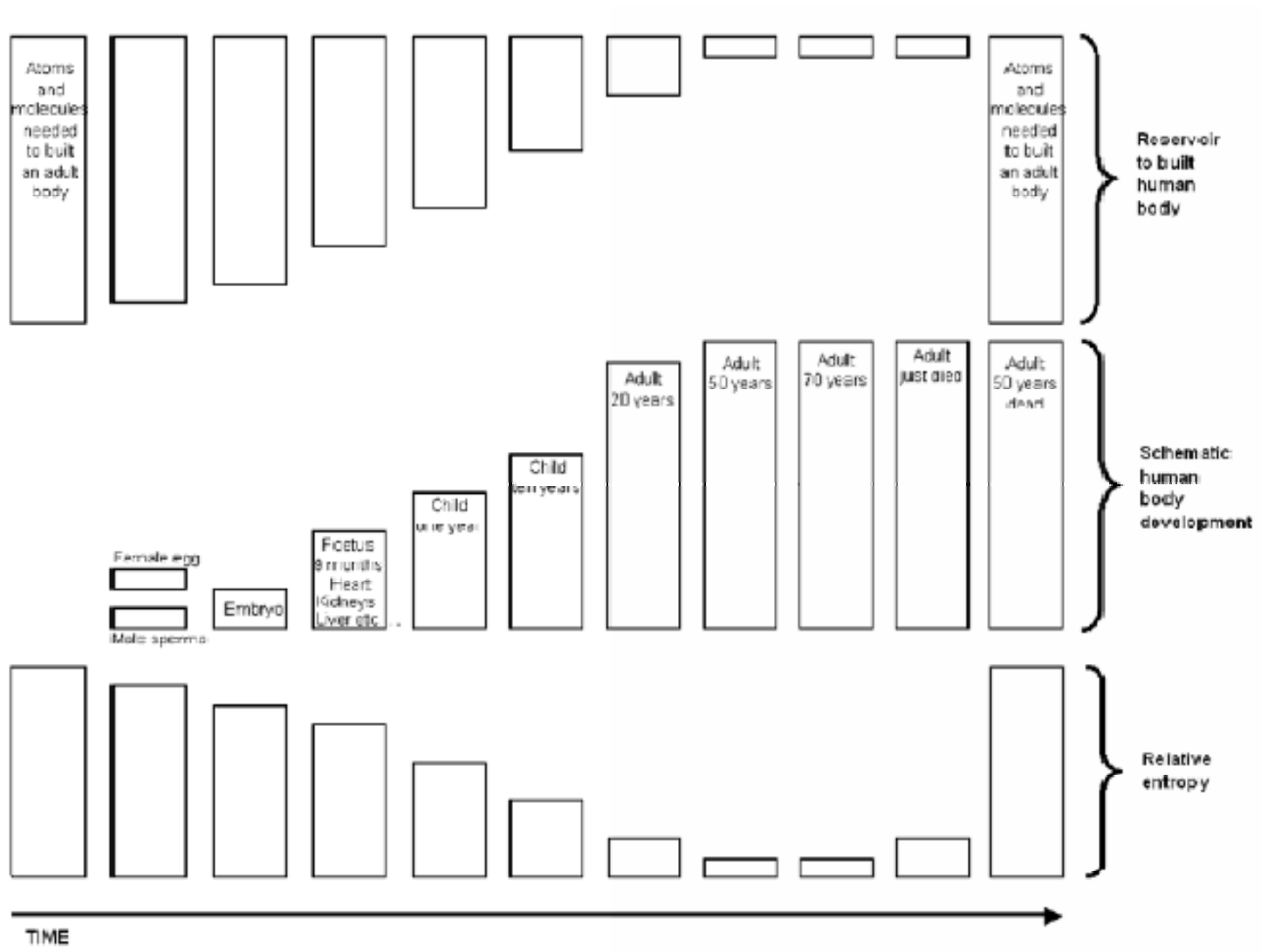
4

Discuss the above process in terms of information transfer. Estimate the information content of a human, and discuss how it varies throughout her/his life.

Entropy generation rate per body mass, low active PAL



— Male  
- - - Female



5

**Discuss how the information contents of the Earth and the Sun vary**

## Entropy change

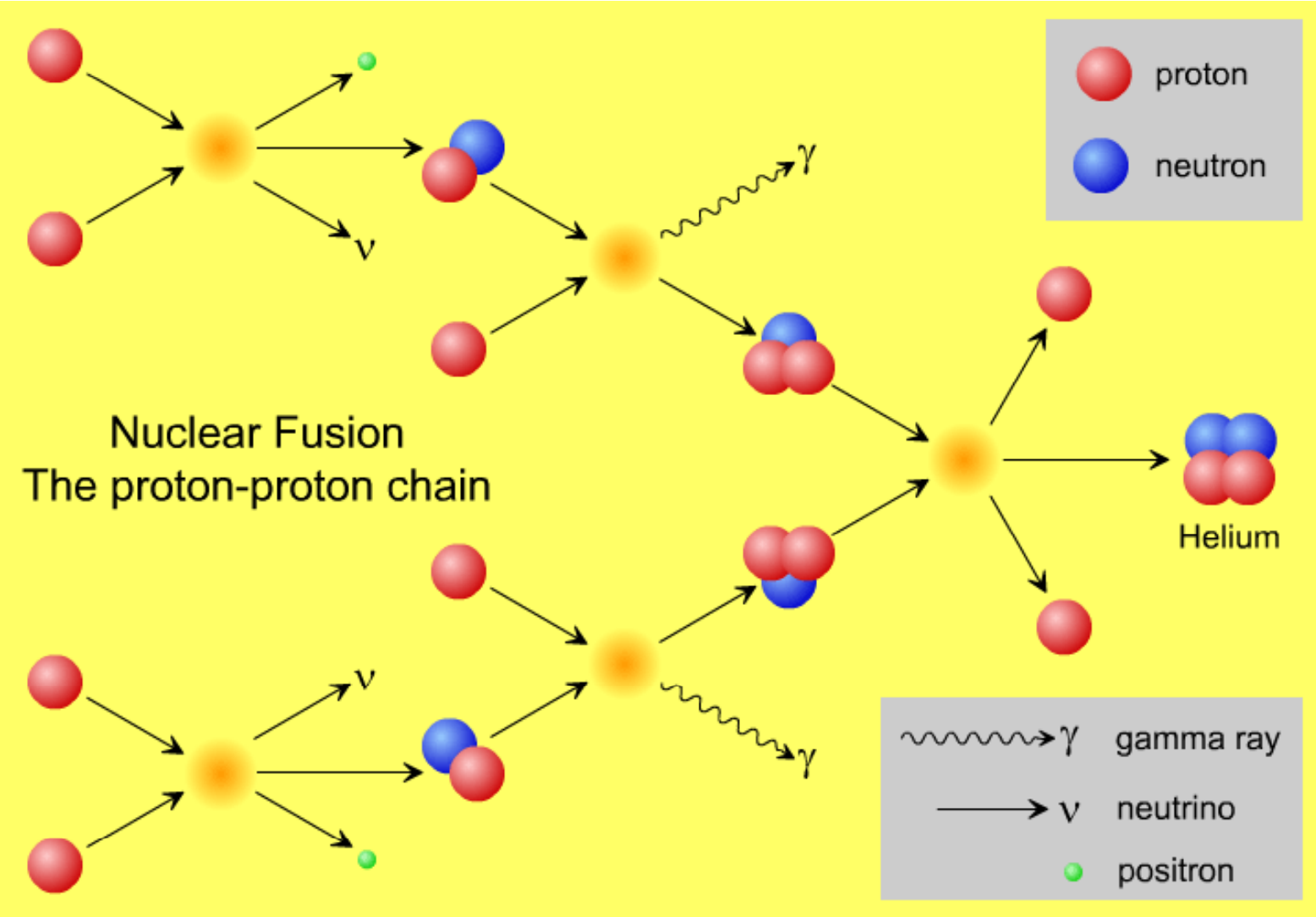
$$\sigma = (4 \cdot \pi^2 \cdot V/45) \cdot (k_B \cdot T/\hbar \cdot c)^3$$

$$d\sigma_L/dt = 0.5 \cdot (4 \cdot \pi^2 \cdot \pi \cdot R_L^2 \cdot c/45) \cdot (k_B \cdot T_s/\hbar \cdot c)^3 \approx 5.6 \cdot 10^{36} \text{ s}^{-1}$$

$$d\sigma_E/dt = 0.5 \cdot (4 \cdot \pi^2 \cdot 4\pi \cdot R_E^2 \cdot c/45) \cdot (k_B \cdot T_E/\hbar \cdot c)^3 \approx 1.22 \cdot 10^{38} \text{ s}^{-1}$$

$$d\sigma_{input}/dt = d\sigma_L/dt - d\sigma_E/dt = -1.16 \cdot 10^{38} \text{ s}^{-1}$$

# Entropy change



6

**Discuss how the information content of the Universe evolves.**

