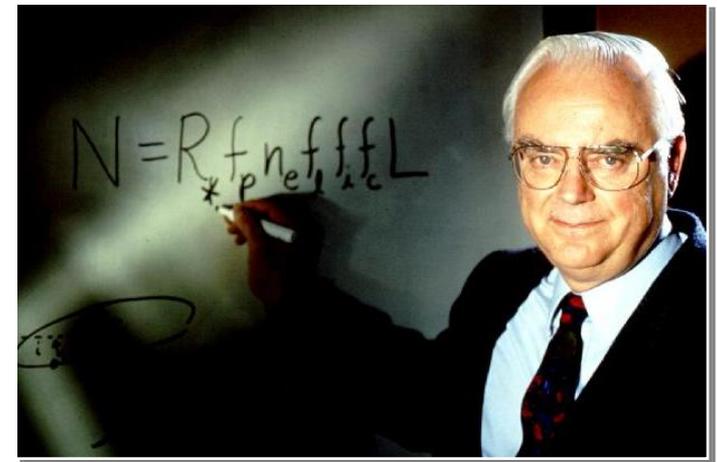


# The Drake Equation



$R_*$  average star formation rate ( $\text{yr}^{-1}$ )

$F_p$  fraction of stars with planets

$N_e$  number of planets (per star) that could support life

$F_l$  fraction of planets that could support life that develop life

$F_i$  fraction of planets with life that develop intelligence

$F_c$  fraction of intelligent species that develop IS communication

$L$  lifetime of civilizations

$$N = R_* f_p n_e f_l f_i f_c L$$

# Drake's estimates for the Drake Equation

- 5  $R_*$  average star formation rate ( $\text{yr}^{-1}$ )
- 0.5  $F_p$  fraction of stars with planets
- 2  $N_e$  number of planets (per star) that could support life
- 1  $F_l$  fraction of planets that could support life that develop life
- 0.2  $F_i$  fraction of planets with life that develop intelligence
- 1  $F_c$  fraction of intelligent species that develop IS communication
- 10,000  $L$  lifetime of civilizations

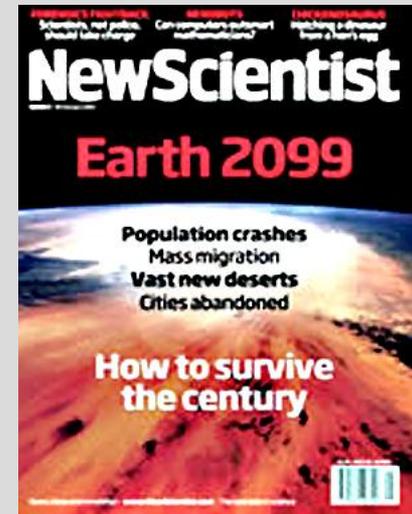
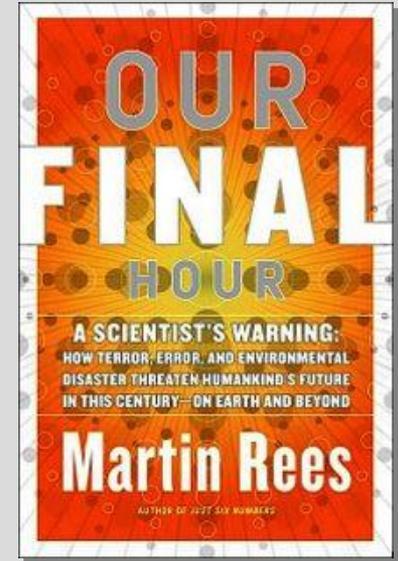
$$N = 10,000$$

$$10^4 / 3 \times 10^{11} = 30 \text{ ppb!}$$

# Two extreme views of our future

A) ☹️ People (*or et equivalents*) are short-lived. As vermin of a planet, technologically savvy organisms do themselves in, in short order. Earth would be better off without us!

B) 😊 Technological species are the only hope for long term survival of advanced life on planets. People can divert asteroids- dolphins cannot. People can survive and terraform for billions of years until the Sun becomes a red giant!



Are we as bad as some of us think? Are we lem

# The Voluntary Human Extinction Movement - VHEMT

*What do humans do for the Earth's biosphere that isn't about humans?*



QuickTime™ and a TIFF (LZW) decompressor are needed to see this picture.

**May we live long and die out**   
Voluntary Human Extinction Movement P.O. Box 86646 Portland OR 97286-0646

**Thank you for not breeding**   
Voluntary Human Extinction Movement P.O. Box 86646 Portland OR 97286-0646

QuickTime™ and a TIFF (LZW) decompressor are needed to see this picture.

# Longevity of species

>99% of Earth's species are extinct

Most species last a few million years

Some last for  $> 10^8$  years

How long can people last?

Will we be the last animal standing ?

Are we nearly extinction proof ?

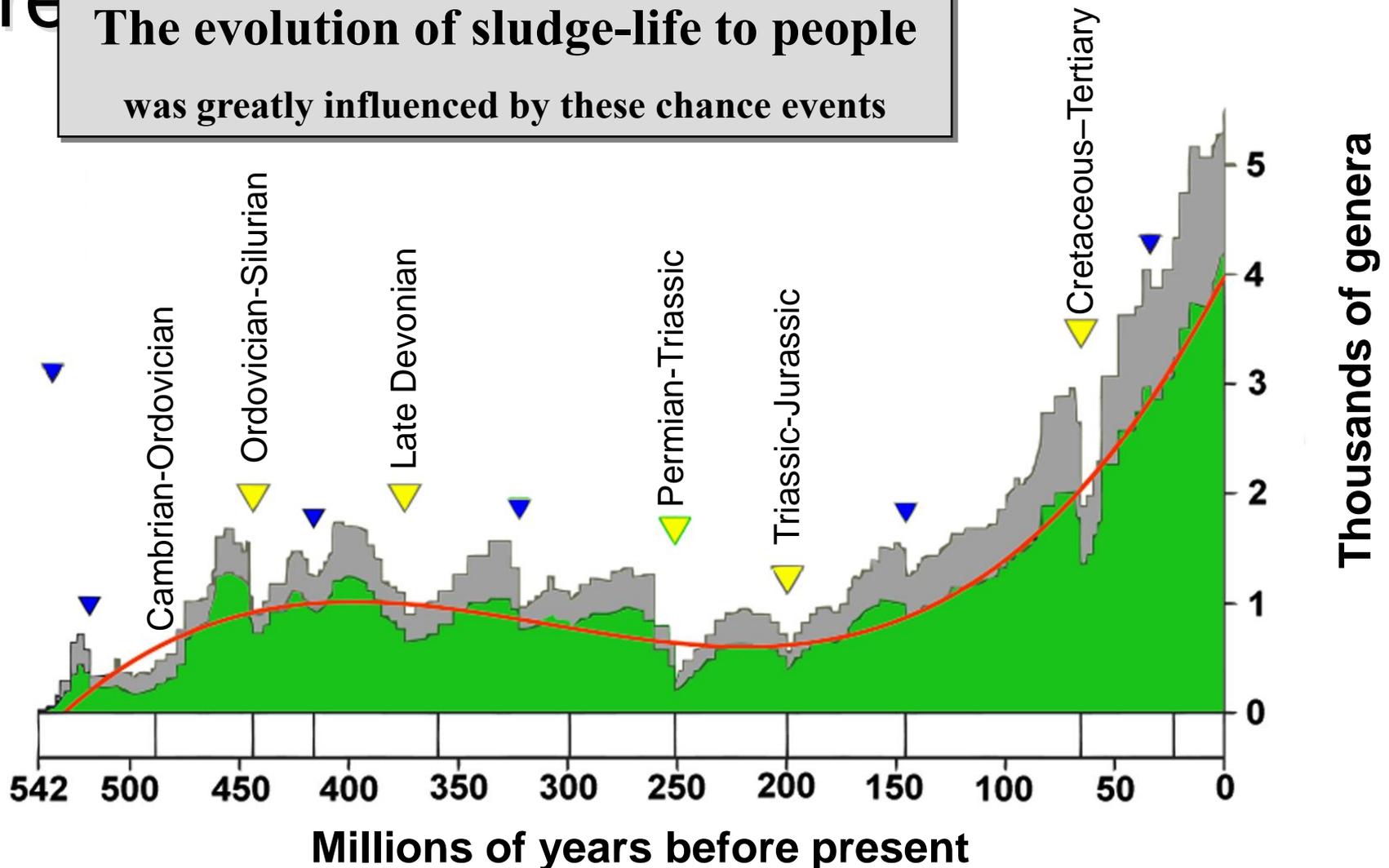
QuickTime™ and a  
TIFF (LZW) decompressor  
are needed to see this picture.

QuickTime™ and a  
TIFF (LZW) decompressor  
are needed to see this picture.

Sharks have lasted  
100's of millions of years

# Major mass extinctions in the fossil record

The evolution of sludge-life to people was greatly influenced by these chance events

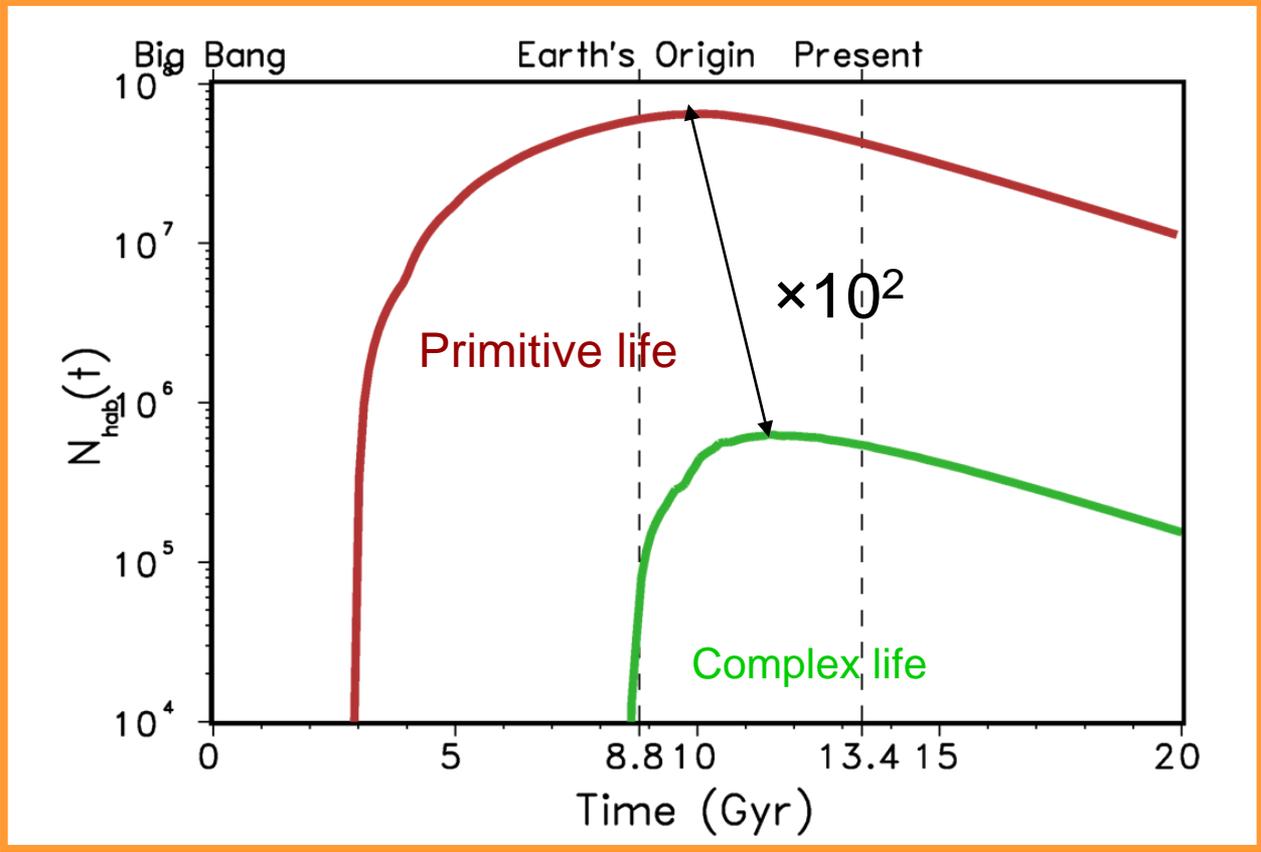


## Long term threats to advanced life

- **Impacts**
- **Misc mass extinction events**
- **Loss of CO<sub>2</sub>**
- **Loss of Oceans**
- **Red Giant Sun**

**Effects due to the increasing  
brightness of the Sun  
~10% per billion years  
until the red giant phase**

# Number of habitable planets



Without interdiction -  
all intelligent life on planets will be done in by impacts



All planets are exposed to impacts!

**Earth has many intelligent species  
Only humans have science and tec**



# Events in Earth's Future

Next glacial cycle?

Return of Super-continent

Decline in CO<sub>2</sub>

Devolution

Mass extinctions

End of plants & animals

Loss of oceans

Merge with M31

Red Giant Sun

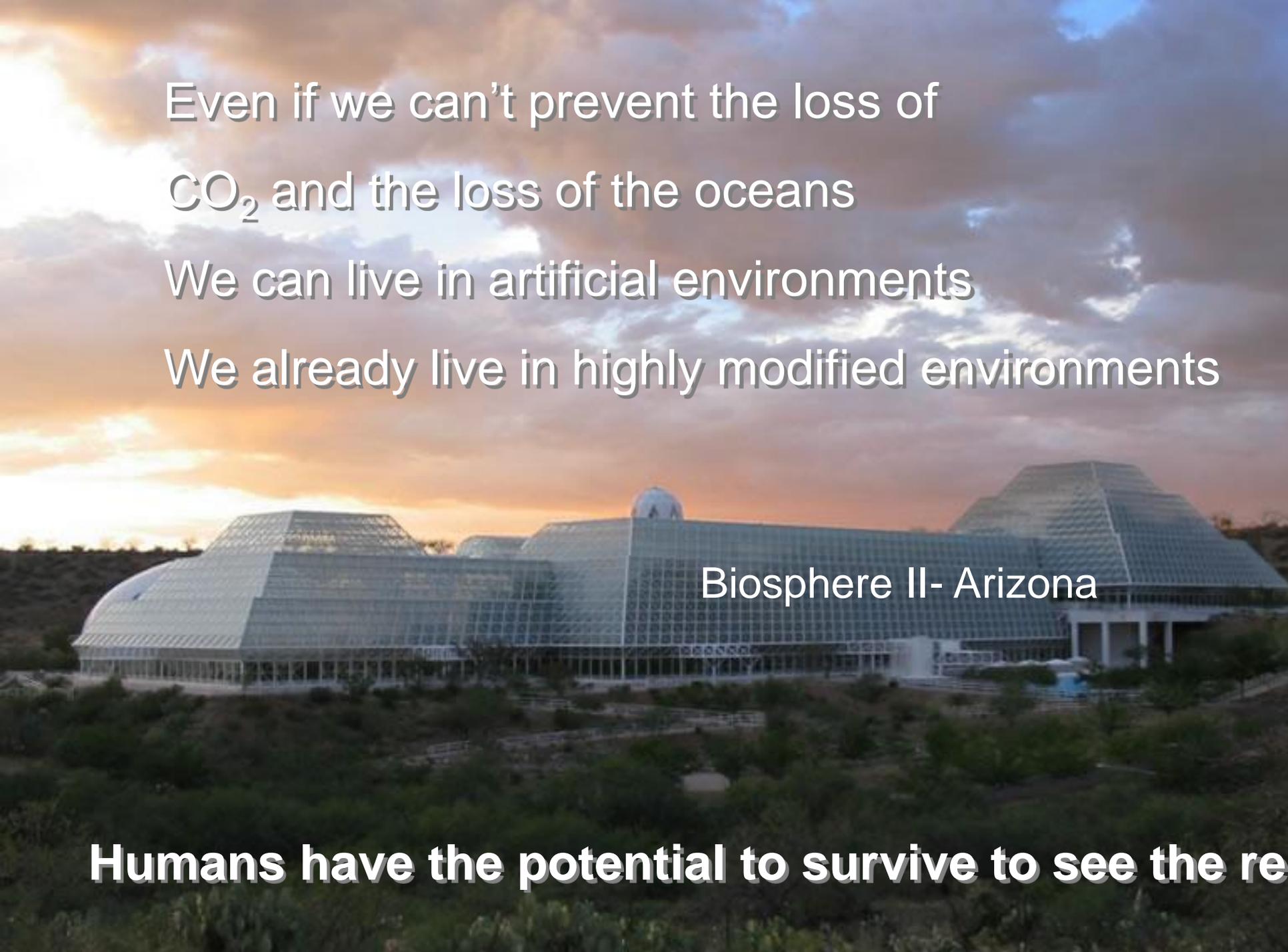
Lunar impact

Even if we can't prevent the loss of

CO<sub>2</sub> and the loss of the oceans

We can live in artificial environments

We already live in highly modified environments

A large, multi-lobed glass and steel structure, known as Biosphere II, is shown against a dramatic sky with orange and blue hues. The building has several distinct sections with varying roof shapes, including a large dome on the left and a smaller one in the center. The foreground is filled with dense green vegetation.

Biosphere II- Arizona

**Humans have the potential to survive to see the re**

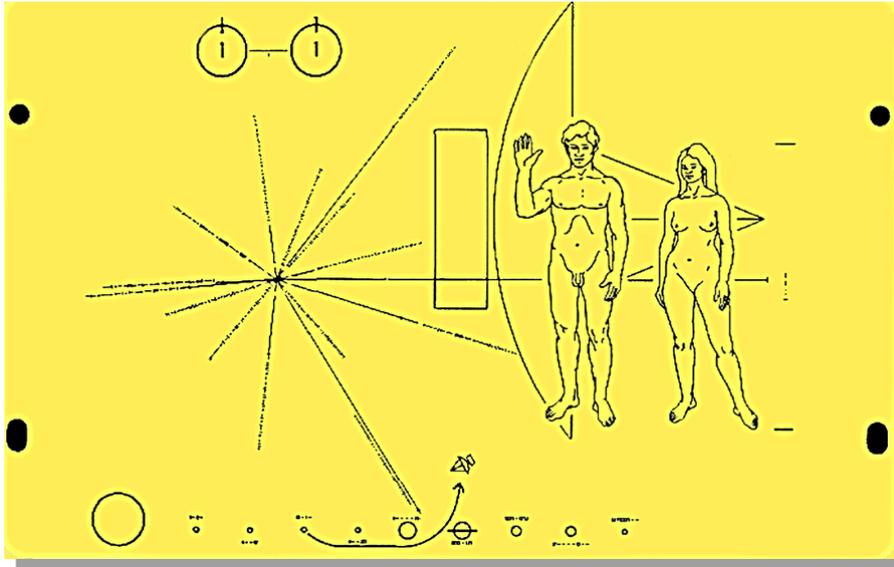
# For good & bad

Humans control the fates of kilogram and larger land organisms

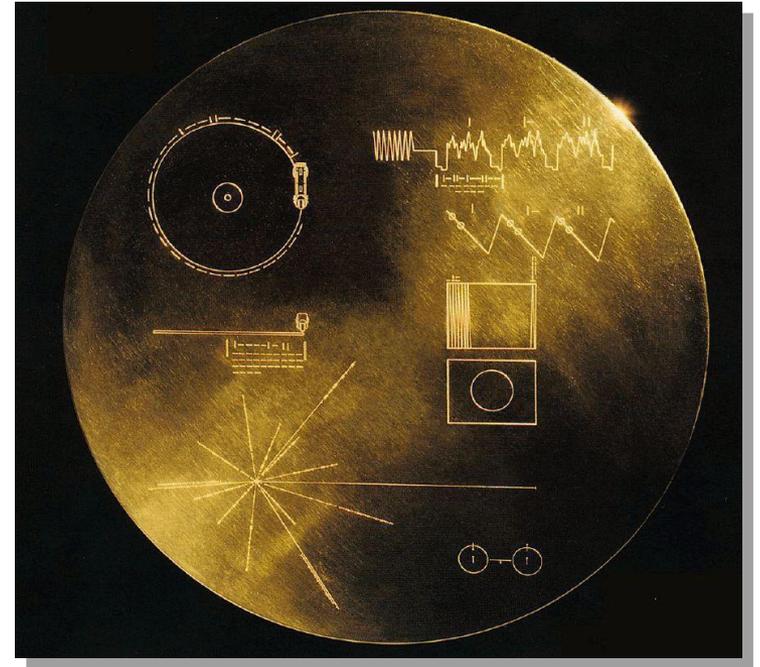


We are likely to control much of future life Alexis Rockman

# Pioneer 10



# Voyager



# Stardust

QuickTime™ and a  
GIF decompressor  
are needed to see this picture.

# Contact

