

## How to Build an Alien

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## Alien Life Forms

- ⌘ Many science fiction story lines involve alien life forms.
- ⌘ From a literary prospective, aliens often serve as metaphors for something more familiar.
- ⌘ From a practical prospective, they make stories more interesting and TV more eye-catching.
- ⌘ What are the "limits" on these aliens?

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## What is Life?

- ⌘ My definition – Any self replicating process that turns energy into order.
- ⌘ One problem is we still have only a single example (Earth life) from which to extrapolate.
- ⌘ I'll restrict my discussion chemical based life forms. There are certainly other very interesting possibilities, but we only have 50 minutes.

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## Extrapolating Forms

- ⌘ I assume the universality of physical laws (i.e., no magic).
- ⌘ I assume the alien life form of interest arose naturally (via evolution) rather than being the product of some preexisting life form (i.e., no gods).
- ⌘ Sociological and Psychological Patterns (are any of these universal?)
- ⌘ In general, I'll be pretty conservative in my speculations.

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## Life Needs Energy

- ⌘ Life requires energy to overcome entropy.
- ⌘ For every type (biochemistry system) of life there is probably a lower limit on the energy density required to sustain it.
- ⌘ The energy must also interact with the matter in the life form ways that can produced controlled chemical reactions.

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## Earth's Energy Source

- ⌘ Light (visible solar radiation).
  - ⌘ On Earth plants harvest light.
    - Herbivores eat the plants, concentrating their energy.
    - Omnivores eat plants and animals.
    - Carnivorous eat animals.
  - ⌘ Each of these steps has an energy transfer efficiency of only about 10%, so there should be substantially less biomass at each successive level.
  - ⌘ This would probably also be true elsewhere.

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### Alternate Energy Sources

- ⌘ Chemical gradients.
- ⌘ Non-visible electromagnetic radiation.
- ⌘ Electric fields.
- ⌘ Subatomic particles.
- ⌘ Thermal gradients.
- ⌘ Pressure gradients.
- ⌘ Gravitational fields.
- ⌘ All possible, but have limitations. See <http://www.msoe.edu/~tritt/sf/life.html> for more considerations.

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### Chemical Basis

- ⌘ Isaac Asimov speculated at length on possible alternate biochemistries.
- ⌘ There are undoubtedly alternatives to Earth's carbon and water based, DNA, RNA, ATP, amino acid, carbohydrate and fat system.
- ⌘ However, the energetics work out very nicely on Earth with compatible temperature ranges and photon energies and fluxes.

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### Mass Balance Limitations

- ⌘ Mass is generally conserved.
- ⌘ Elemental composition is generally conserved.
- ⌘ Aliens will have particular dietary requirements.
- ⌘ Aliens may be able to shape shift, but shouldn't be able to change mass or elemental composition (turn to stone, etc.).

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### Size Limitations

- ⌘ Mechanical strength goes up as the square of size while mass (and therefore loads) goes up as the cube.
- ⌘ Mass transfer (diffusion & permeation) limits the size of cells and to some extent the size of organisms.
- ⌘ This results in a limit on how large cells and many common terrestrial body forms can become.

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### Size Limitations (continued)

- ⌘ There are also lower limits on the size of cells and intelligent aliens.
- ⌘ Cell size is restricted by the size of its genetic material (not necessary DNA) and the minimal chemical machinery needed for cell growth.
- ⌘ Intelligence requires some minimum number of interconnections between the alien equivalent of neurons.

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### Mechanical Limitations

- ⌘ Aliens with technology will probably need to have hand like appendages.
- ⌘ Bilaterally symmetric, quadrupedal body form seem to work well on land (hexapedal also works).
- ⌘ The forelimbs of quadrupeds clearly can become adapted for fine manipulation.

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### Environmental Limitations

- ⌘ Water/Carbon system life forms are probably limited to relatively Earth-like temperatures and pressure ranges.
- ⌘ Aliens with technology will probably have to be terrestrial.
  - ⌘ Technology as we know it requires combustion.
  - ⌘ Combustion is difficult under water.
- ⌘ Aliens with different biochemistries might develop very different technologies.

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### Sensory Issues

- ⌘ All organisms will probably have some sense of touch and body position (these are necessary for survival).
- ⌘ All organisms will probably have EM imaging organs (eyes). The wavelength sensitivity might be different for alternate biochemistries.
- ⌘ Some type of acoustical organs are likely. Again the wavelength sensitivity might differ from ours.

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### More Sensory Issues

- ⌘ Chemical senses (smell and taste) are likely. Responses might be quite different. I wouldn't recommend eating at any alien restaurants.
- ⌘ Are other sense possible?
  - ⌘ Probably, but there form is pretty hard to predict.
  - ⌘ Must provide a survival/reproductive benefit.
  - ⌘ Must be physically and chemically possible.

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### Additional Sensory Issues

- ⌘ Visual and auditory senses generally require two receptors each if the source of the stimuli is to be located.
- ⌘ Smell and taste not be any more effective with multiple receptors.
- ⌘ Placing the special sensory organs on a movable platform (a head), towards front of the organism and near the brain provides the best performance (One head is better than none).

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### Reproductive Issues

- ⌘ Sexual reproduction has worked well here on Earth.
- ⌘ It provides both stability and variability.
- ⌘ Variations on this theme are possible (even likely):
  - ⌘ Hermaphroditic (in time or space).
  - ⌘ Alternating sexual/asexual reproduction.
- ⌘ More than two sexes unlikely (due to reduced odds of necessary interactions).

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### Mating Types

- ⌘ On Earth, fungi often have mating types.
- ⌘ This provides a mechanism that prevent an individual fungus from inadvertently mating with its self.
- ⌘ Fungi often grow as an extended mycelium that permeates their local environment.
- ⌘ One portion of an individual's mycelium of an individual is likely to meet another part.

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### Mating Types (continued)

- ⌘ It would be genetically pointless for an individual to mate with itself.
- ⌘ Typically fungal species have multiple (often 10 to 20) mating types.
- ⌘ Each individual will exhibit one of these types.
- ⌘ An individual typically can mate with all mating types other than its own.
- ⌘ It is conceivable (ha, ha) that an alien race could exhibit mating types.

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### Conclusions

- ⌘ Intelligent aliens will most likely:
  - ⌘ Be carbon based, but probably not nutritionally compatible.
  - ⌘ Be humanoid and about our size.
  - ⌘ Have sensory organs similar to ours.
  - ⌘ Reproduce sexually with two sexes, but probably not be mechanically or biologically compatible with humans.
- ⌘ Hollywood may have (coincidentally) gotten it mostly right.

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### Some Resources

- ⌘ Any good "undergraduate, for majors" ecology, biology, anatomy, physiology pathology and microbiology books.
- ⌘ My science fiction web pages <http://people.msoe.edu/~tritt/sf/index.html> (currently out of date, but I plan to update them "someday").

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