Week 1:
Size Does Matter
The Science of Science Fiction
Course Outline

Week One: Size Does Matter
2: Time Travel
3: Beaming Up
4: Not-So Superheroes
5: Aliens Among Us
6: Grab Bag

From “Honey, I Shrunk the Kids”
Before we begin…

I love science fiction, and the last thing I want to do in this course is decrease anyone’s enjoyment of the genre. I firmly believe that an understanding and critical application of science does not conflict with appreciating SF any more than being strict about grammar prevents one from reading and re-reading *Huck Finn*.

That being said, let’s get started…
Size Does Matter

What would be involved in miniaturizing a person down to smaller size?
The ABC’s of Miniaturization

To miniaturize a person to 1/100 of the original height would mean that a man 180 centimeters tall (about six feet) would now be 1.8 cm high (about three quarters of an inch). If you keep the same shape, the volume would now be one millionth of the original. If you also want to preserve the same general composition, there are three possible options...

From the 1966 movie Fantastic Voyage
Option A: Remove some of the atoms

Not just some of the atoms, but practically all of them: *all but one millionth of them would have to be removed* in order to reduce an object to 1/100 of its original linear size. For a simple structure like a diamond, composed of carbon atoms in a regular crystal structure, this would be difficult enough: breaking all the chemical bonds, keeping only one atom in a million, and then rearranging these back into a similar shape. But if you were using this method to miniaturize a *person*...
Shrinking a living person such as Lily Tomlin and keeping her alive would be ridiculously difficult:

- There are so many different *types* of atom and molecules in a human being, and keeping the correct fraction of each one in the right place would be a frighteningly difficult task.
- The smallest blood vessels in the body are the capillaries, and it is hard enough already to push blood through them: water molecules “cling” to each other, and on a smaller scale water would act more like pudding. It would be basically impossible to push water through blood vessels that small.
- There are many very fragile systems in the body; shrinking their thickness to 1/100 in thickness would make these membranes (such as the eardrum) unable to hold their structure together.
Option B: Push the atoms closer together

The amount of pressure needed to compress normal matter to one million times its initial density would be a complex problem in its own right: only white dwarf stars can create enough force to do this. And any form of matter with this kind of density would sink right into the floor: it would be like pressing your entire weight onto the head of a pin.

And even if it were possible to create this amount of pressure, it would kill instantly any living cells in this environment. There are good reasons that atoms and molecules stay as far apart as they do.
Option C: Shrink the atoms themselves

Granted, we have no idea how this would be done, and what we know about science says that it is quite impossible—but this course is about stretching the impossible into the real world. We would be shrinking not only people, but atoms themselves, even the protons and electrons, meaning literally everything gets smaller.

Of the three options, this seems to be the only one with even a remote chance of ever happening—so we shall assume from here on that this is what is being done, and somebody has found a way to do it.

That being said...
...the related difficulties, usually ignored in sci-fi usage, are (forgive me) immense. We shall investigate some of these.

For visual reasons, this theme has been used in sci-fi movies much more than in print.

The reverse effect, which we might call *gigantification*, would have equivalent but inverted difficulties—but this theme seems to be used less often.
Selected Sci-Fi Miniaturization Movies

1957

1966

1987

1989
1957: The Incredible Shrinking Man
(with Grant Williams)

Accidental exposure to a radioactive cloud causes Scott Carey to gradually shrink in size, with medical science unable to find a way to reverse the process.
1966: **Fantastic Voyage**
(with Stephen Boyd, Raquel Welch)

Science has found a way to miniaturize anything, but when the key scientist to the project is critically injured, the only effective surgery must be done on his brain by a team of doctors sent through the bloodstream in a miniaturized submarine.

In this scene, the sub has been forced to divert through the inner ear, and the doctors around the patient have had to observe absolute silence while the divers clear a blockage in the cooling vents.

One current Hollywood rumor is that a remake of this film is in the works.
1987: **Innerspace**  
(with Martin Short, Dennis Quaid, Meg Ryan)

In a lighthearted variation of *Fantastic Voyage*, a miniaturized submarine accidentally is injected into the body of a bumbling hypochondriac grocery clerk without his knowing it.

Steven Spielberg served as executive producer.
1989: Honey, I Shrunk the Kids
(Rick Moranis)

In this Disney feature, four children are shrunk down to tiny size and then released into the violent micro-world of their own back yard, where insects are deadly predators.
"Oh no, not homework again."

Time for a break
Some questions that we should be asking...

• If an object is miniaturized, what happens to the missing mass? And if it is giganticized, where does the new mass come from?

• If that object is a person,
  o How can they breathe normal-sized air molecules, or drink normal sized molecules of water?
  o How can their eyes see normal sized wavelengths of light?
  o On that person’s new scale, the acceleration of gravity would be a great multiple of its normal value; wouldn’t falling objects seem to drop a lot faster?
If you were unfamiliar with both of these species, could you tell from the photograph alone which one is larger?
Ask yourself this question: If a mosquito was enlarged to the size of an elephant, would it be able to stand?
Let us imagine that the standing figure here is doubled in size: all three dimensions doubled means that now the figure has twice the length, width, and height—so eight times the volume, and eight times the mass.

So now there is four times as much foot surface touching the floor, but it is supporting eight times more weight—so the pressure on each square inch of feet and ankles is double what it was before. It would be as if each of the four people on the bottom level was supporting another person’s weight.

This is why elephants have such massive legs: to spread out the weight over a larger surface. Similarly, insects such as mosquitoes need only very thin legs, since they support such a small amount of weight.
The massive legs supporting the dinosaur known as Brontosaurus were necessary because of its huge size—and this is one reason that it has long been believed that these creatures lived surrounded by a watery environment: the water’s buoyancy would provide support to the animal’s weight.

The water may also have served as a type of thermostat. While there is still debate over the warm-blooded vs cold-blooded dinosaurs, the water could have provided a valuable cooling mechanism for the body temperature.
An instant later, both Professor Waxman and his time machine are obliterated, leaving the cold blooded/warm blooded dinosaur debate still unresolved.
What about the King?

(Wasn’t he supposed to be *climbing* one of these buildings? Even the woman is larger than they are...) 

Flesh and bone could not possibly keep a creature this size upright. That is why skyscrapers are made of steel and concrete.
I hope you are still able to enjoy the movie, but images like this should have you shaking your head by now.
There are other aspects of living creatures that go up or down with the square of the change in linear size, while the weight changes with the cube.

In other words, shrinking (or enlarging) a body by a factor of ten changes these “squared” properties by 100 times, but the weight changes by a factor of 1000.
Body heat

One of these factors is the amount of heat given off by warm-blooded animals, which depends on the amount of surface area exposed to the environment.

The tiny Etruscan shrew is the smallest mammal known, less than an inch and a half long, and due to its tiny size it gives off internal heat at an extremely high rate—which requires it to eat almost constantly to replace the rapid loss of energy. Living creatures smaller than this are invariably cold-blooded...
...which brings us to Spider-man.

Did you ever wonder why creatures that can walk on walls are always small ones? It really has very little to do with their being insects.

The suction or adhesion or whatever that attaches an animal to a wall is a function of surface area, proportional to the square of the size—but the weight that it needs to support goes up with the cube. A spider enlarged to the size of a human would lack the ability to climb walls.
What else would change?

Many things. Among them:

- A miniaturized person’s vocal cords would vibrate faster, making the pitch of speech higher.
- Nerve impulses would have a shorter distance to travel through the nervous system, so reflexes would be a lot faster (and insects have faster reflexes than we do).
- Muscular strength goes up (or down) with the square of the size change, so smaller animals are proportionately stronger. A flea can jump an immense distance compared to its own size, and ants can carry many times their own weight.
- Small objects are more affected by air resistance, so a miniaturized person falling from a great (relative) height should not be injured by the landing.
The bottom line? Size *does* matter...

...and good science fiction should recognize that.

It is possible to write SF in a way that keeps enough of the science intact to make the story seem more real. Not everyone goes to all that trouble.
Next week: Time Travel