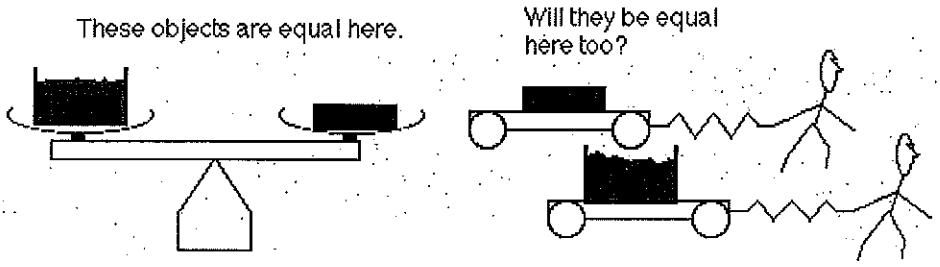
Inertial Mass and Gravitational Mass

The method of determining mass by pulling it with a spring and measuring acceleration seems very inconvenient. It is more convenient to compare two masses by putting them on a balance. If an object with unknown mass on one side exactly balances a standard kilogram mass on the other side, then the object has a mass of one kilogram. But you might not see the logical connection between balancing two masses in earth's gravity and comparing how hard it is to accelerate them with an applied force. You would be right! One property of all objects is that the earth exerts a force on them downward. This forces seems to be larger the more material there is. This is what the balance compares and it has no obvious connection with the measure of how difficult it is to get them moving. The casual observation that both properties seem to grow larger with the amount of material is no guarantee that they grow larger in the same proportion for all materials.



To see this consider a balance with a lump of iron on one side and a plastic bottle of water on the other. Iron and water are very different materials. We know that water is made of light elements oxygen and hydrogen and the bottle has some carbon in it which is also light. Iron is a relatively heavy element, very different from water. If I pour enough water in the bottle so that the force of earth's gravity on it is the same as the force of gravity on the iron bar, then they balance. Can you be absolutely certain that these two quantities of water and iron will also have equal resistance to being accelerated by an applied force (i.e, the same inertia)? You really have to try it and see. When it has been tried it has always been found that when the force of gravity is equal, then the inertia is equal. This has been checked to a very high degree of accuracy!

Because these two properties are logically different, we should call them by different words. The property that resists acceleration is called inertial mass. The property of an object that causes earth to exert a force on it is called gravitational mass. It is only from experiments that we can say that the number we get for one property can be also used for the other property. Is this a coincidence?

In order to find a system where the equivalence of these two properties follows logically we really have to envision strange things. Einstein's theory of general relativity is an attempt to "explain" this equivalence. In this theory all bodies travel between two points along the path of least distance: a geodesic. The way gravity comes about is that a mass causes nearby space and time to curve. Then an object travelling through curved space along the shortest path will be appear to be attracted to the other mass which is causing the space to be curved. Of course each of the masses causes space around it to curve. In this way the amount of gravitational attraction between two objects is proportional to the amount inertial mass in both objects. This gets ahead of our subject because we haven't even learned Newton's theory of gravitation, let alone Einstein's.