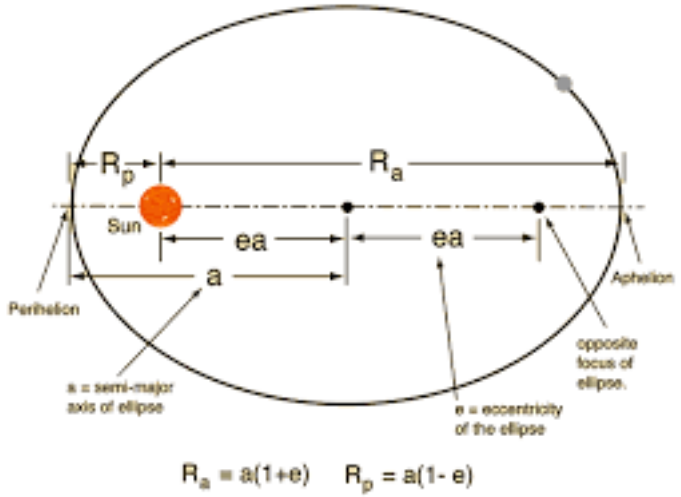
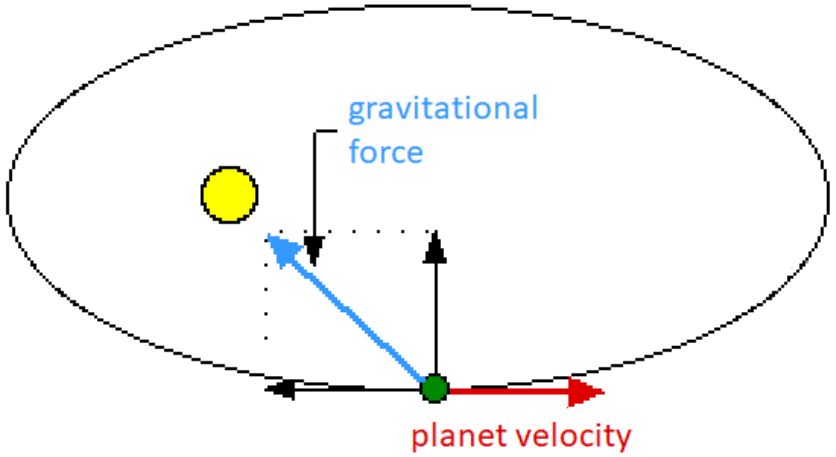




Kinematics and Mechanics

The *How* and the *Why* of Motion

- **Kinematics**: describe *how* a thing changes with time. What is the *shape* of the motion?
  - E.g. Copernicus' heliocentric theory, Kepler's theory of elliptical orbits, evolution of life.

- **Mechanics**: *Why* does it move that way? Appeal to forces, causes, laws of motion, etc.
  - Aristotle's theory of natural motions
  - Newton's gravitational force and laws of motion
  - Descartes' vortices
  - mutations, drift, recombination, natural selection.

- N.B. *Kinêsis* is the ancient Greek for motion or change.

Forces and Causes in Evolutionary Theory

"The traditional view of evolutionary theory asserts that we can usefully understand natural selection, drift, mutation, migration, and the system of mating as forces that cause evolutionary change."

(Christopher Stephens, UBC philosopher)

- I.e. evolution itself is a *kinematic* claim – what happened, and when. When and where did reptiles appear? What were they descended from?
- Mechanisms such as natural selection, mutation and drift are *mechanical* claims, proposed as *causes* of evolution.

Kinematics and Mechanics in Astronomy

- In early modern astronomy, the kinematic and mechanical issues were closely related.
  - If the earth moves, then what *causes* it (such a heavy object) to move?
  - If the earth moves, then why don't things that aren't nailed down fly off sideways?
  - In Tycho's model, why do the planets (other than the sun and moon) completely ignore the earth?

Kinematics and Mechanics in Astronomy

- It wasn't possible to fully accept Copernicus's heliocentric model until a new mechanics was developed, relative to which it made sense.
- This was finally accomplished by Newton, in *Philosophiae Naturalis Principia Mathematica* (The Mathematical Principles of Natural Philosophy), published 1687.
- But some of the key details were earlier developed by Descartes and Galileo, and even by Medieval philosophers Oresme and Buridan.

Aristotelian mechanics

- For Aristotle “motion” meant *change* of any kind. For example, the growth of an acorn into an oak tree was “motion”.
- What we call “motion” was called *local* motion, i.e. change of location. The task of explaining local motion was just a piece of the broader task of explaining motion. (‘Locomotion’ = local motion)
- Also, Aristotle was very interested in living things, and explaining their motions. Why does a snake slither? Why does a bird fly?

Natural and Unnatural Motion

- The most important distinction in Aristotle's mechanics is between natural and unnatural (or forced, compulsory) motions. A natural motion is one that comes from within, produced by the object's own nature. An unnatural motion is imposed on it by external forces.

- Newton and Descartes didn't like to use Aristotelian terms like 'natural motion'. But in effect they regarded uniform motion in a straight line as natural, and anything else as forced.

Aristotelian natures

- Why does the horse run, the snake slither, and the bird fly?

Due to the *nature* of each type of animal.

Aristotelian natures

- It's in the nature of a horse to run. (It has legs, after all, and they're made for running.) Birds have wings, and snakes have neither legs not wings.
- Each object has a certain nature, an inner cause which make it move in certain specific ways.

Forced motions

- An object does not always move according to its nature.
  - For example, a snake will fly if it is picked up and thrown.
  - In such cases, the motion is due to an external cause, and is described as *forced* or *compulsory* or *contrary to nature*.
- An animal in captivity may display “unnatural” behaviour, which never occurs in the wild. This is also a case of forced motion.
- Science is, according to Aristotle, the study of natural motions rather than compulsory ones.

Lesbian lizards?

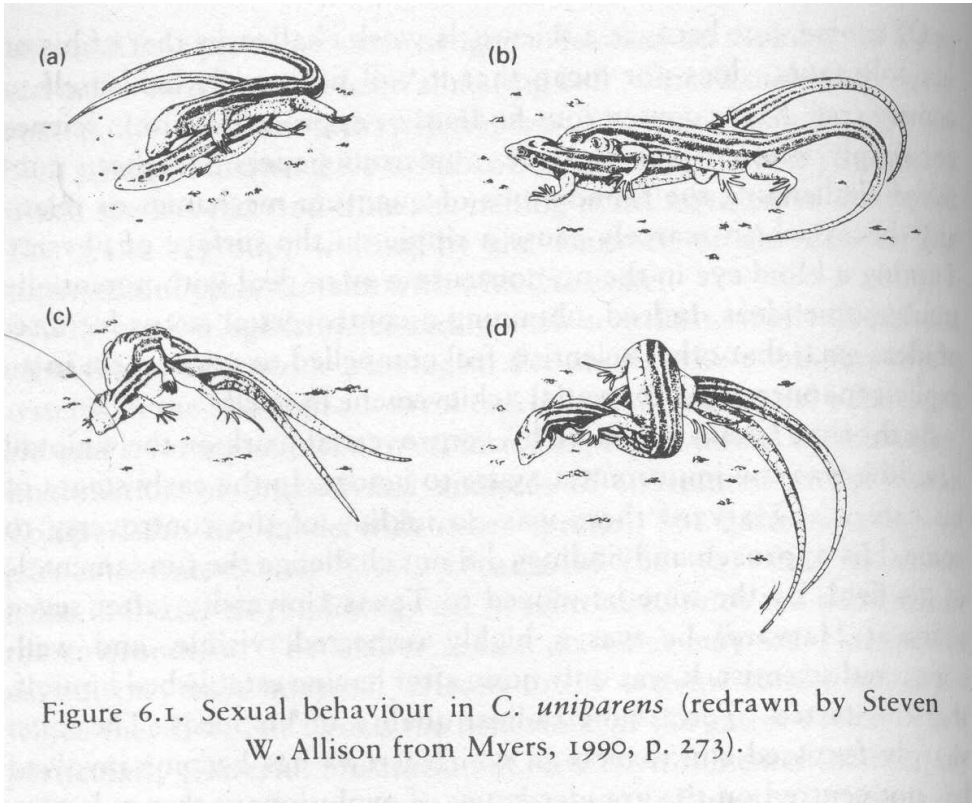


Figure 6.1. Sexual behaviour in C. *uniparens* (redrawn by Steven W. Allison from Myers, 1990, p. 273).

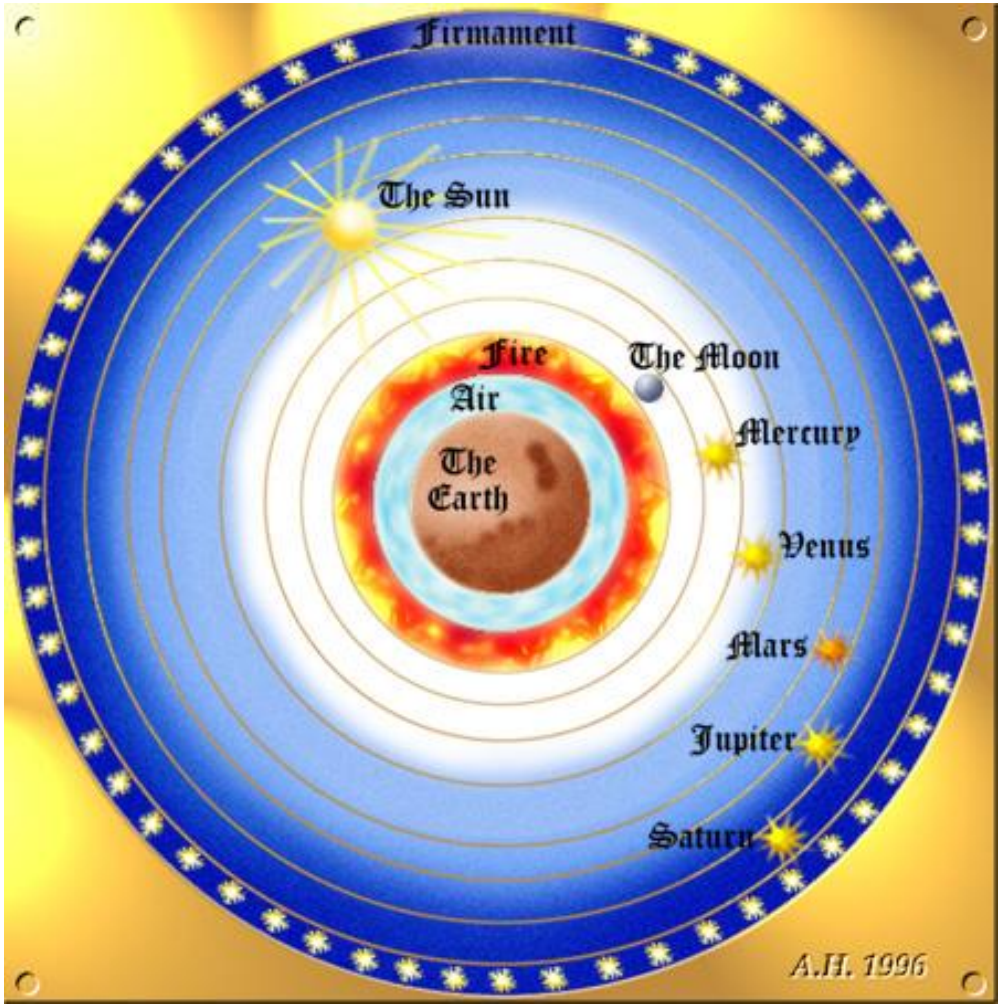
What does an Aristotelian ask about this?

Qu.: *Does this behaviour occur "in nature", or is it a mere artifact of captivity?*

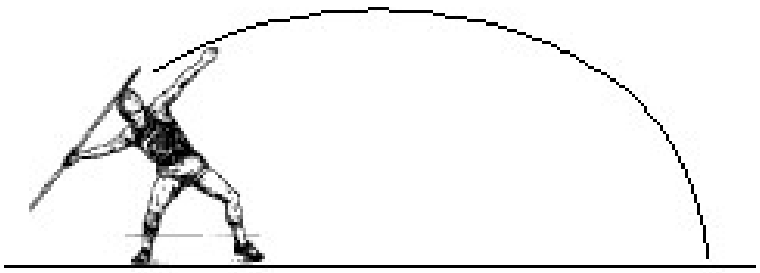
The mechanics of simple bodies

- The four terrestrial elemets have very simple natures, basically to move up or down.
- The nature of earthy objects, such as stones for example, is to gravitate downward toward their natural place, which is the centre of the universe. That's why the earth is stationary at the centre – it's heavy.
- The nature of aether (quintessence) is to move perpetually in a circle.

A layered universe



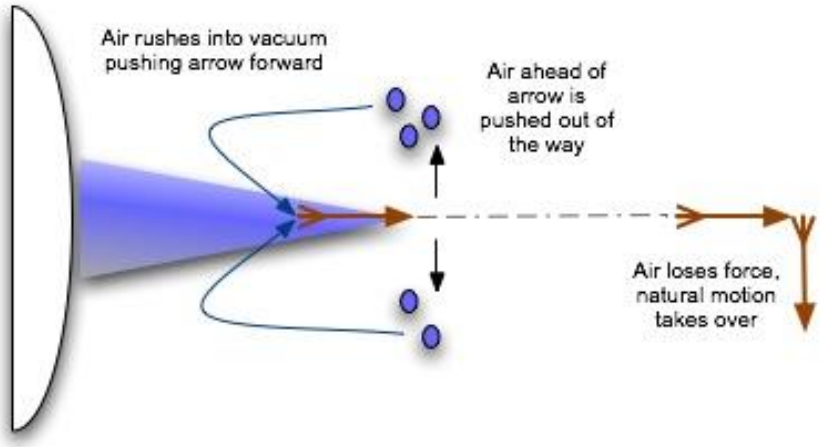
The projectile problem



- Why does a projectile (javelin, arrow, stone, etc.) fly sideways through the air? It's made of earth, and so *naturally* moves straight down.
- Of course while it's in the thrower's hand it is forced to move sideways. But *why does that sideways motion continue after it's been released*?

“antiperistasis”

- Aristotle’s theory was that air displaced in front of the projectile somehow rushes round it and pushes from behind, thus propelling the projectile along.



- Antiperistasis was criticised as early as 550 AD (or so) by **John Philoponus**, in his *Commentary on Aristotle's Physics*.

"Furthermore, how can this air, in so turning about, avoid being scattered into space, but instead impinge precisely on the notched end of the arrow and again push the arrow on and adhere to it? Such a view is quite incredible and borders rather on the fantastic."

The theory of impetus

- Philoponus suggested that:

  "Rather is it necessary to assume that some incorporeal motive force is imparted by the projector to the projectile …"

  This is known as the theory of **impetus**.

- The theory of impetus was later developed and popularized by Jean Buridan (1300-1360ish) .

"after leaving the arm of the thrower, the projectile would be moved by an impetus given to it by the thrower, and would continue to be moved as long as the impetus remained stronger than the resistance, and would be of infinite duration were it not diminished and corrupted by a contrary force resisting it or by something inclining it to a contrary motion" (QM XII.9: 73ra).

Buridan also contends that impetus is a variable quality whose force is determined by the **speed and quantity of the matter** in the subject, so that the acceleration of a falling body can be understood in terms of its gradual accumulation of units of impetus.

Oresme (1320-1382)

- Nicole Oresme, another Frenchman, even argued that a moving earth was theoretically possible. Since things "resting" on the earth would share the earth's impetus, they would all move along together. Nothing would fly off.

- Yet Oresme agreed with Aristotle that the earth is stationary in fact.

The concept of *inertia*

- The theory of impetus departed from the details of Aristotle's mechanics. But it agreed with Aristotle that any motion of dense matter (other than straight down) was unnatural, and so required a force acting on the body. **Impetus was some kind of force** that pushed the body along, keeping it in motion.

- Galileo disagreed with Aristotle more fundamentally, taking a step towards the theory of *inertia*.

‘Neutral motion’

- To Aristotle’s division between **natural** and **forced** motions, Galileo added a third, namely ‘**neutral**’ motion.
- E.g. a stone moving downward is *natural* and requires no force.
- A stone moving upward is *repugnant* and requires a constant force to make it happen.
- A stone moving horizontally is *neutral* (or indifferent). It requires a gentle force to get it started, but then the motion continues indefinitely on its own.

"And therefore, all external impediments being removed, a heavy body on a spherical surface concentric with the earth will be indifferent to rest or to movement toward any part of the horizon. And it will remain in that state in which it has once been placed; that is, if placed in a state of rest, it will conserve that; and if placed in movement toward the west, for example, it will maintain itself in that movement."

- Galileo, *History and Demonstrations Concerning Sunspots*, 1613.

- Note that Galileo's theory of neutral motion, like Oresme's impetus theory, predicts that the earth will appear to us to be at rest.
- Objects that are presently on the surface of the earth will continue to move rapidly with the earth's own motion, and so remain at rest with respect to the earth. No applied force is needed to maintain this motion.

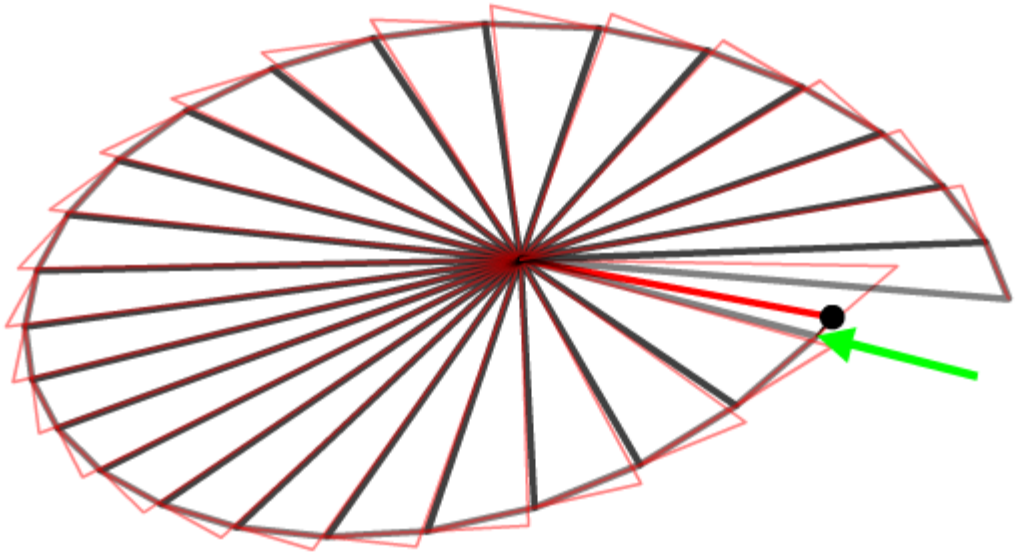
Newton and the Apple

Newton and the Apple

Newton and the Apple

- According to Newton, gravitation isn't a natural motion at all, but a forced motion. **Gravity is a *force*!!**
- Newton extended Galileo's idea of inertia to all directions in space, so that *every change of velocity requires a force*.
- Inertia causes every body to move uniformly in a straight line, unless acted upon by a force.

Explaining planetary orbits



- Newton's theory of inertia, and the gravitational force, **predicted elliptical orbits** for the planets.