Cultural Evolution

Next Factor in Drake Equation: f_c

- f_c: fraction of planets with intelligent life that develop a technological phase, during which there is a capability for and interest in interstellar communication
- No significant biological evolution in last 40,000 to 200,000 years
- Evolutionary Takeover
  - Cultural evolution instead of biological
  - Much shorter timescale

What is Cultural Evolution?

- No longer changes in genes (biological)
- Extra-somatic information
  - Information stored outside the body
- Changes in knowledge of group
  - Passed on by learning from others
- Allows combination of “lessons learned” from many individuals

Example

- Culture in primates other than humans?
  - Differences in behavior of groups
- Example: Orangutans in Kluet swamp in Sumatra
  - Make and use tools (bark-stripped twigs) to get honey and seeds from fruit
  - Genetically similar group across Alas river do not
  - River too wide to cross
  - Key feature is high density: observe each other's behavior and learn

Concepts

1. Timescales
2. Origin of agriculture
3. Extra-somatic information storage
4. Tools, technology
5. Interactions: written language, cities, taxes, classes, technology
6. Interest in communication
7. World view evolution
8. Coupling between technology and world view

Timescales

- On next slide (which we will look at in more detail later) notice the timescales
- MUCH shorter than the previous kinds of evolution
- And accelerating!

Oral language	400,000?	Cooperative hunting?
Oral historians	30,000?	Traditions and Lore
Clay tokens	~ 8500 B.C.	Sumeria (record keeping)
Clay tablets	~ 3000 B.C.	Business, Taxes
Paper	~ 100 A.D.	China
Printing press	1456 A.D.	Europe
Radio	1895	Italy
Television	~ 1936	First “strong” broadcast
Computers	~ 1950’s	
World-wide-web	~ 1990’s	

Importance of farming

- The rise of civilizations all based on farming
- Understand origins of agriculture
- How likely to arise?
- Did it arise **independently** more than once?

Origin of Agriculture

10,000 years ago within 50-100 miles of Dead Sea
Natufian culture - well built houses & signs of rank
Harvested wild wheat, barley - used flint sickles,
Stone mortars, and hunted

Climate becomes hotter, drier
Overcrowding, shortages led to need for food source
favors annuals over perennials shorter cycle
larger seeds in husks - easier to collect
Save, plant, harvest
Evidence: seeds in settlements of Natufians successors

Mutant: fatter, adheres to husk better

$\Rightarrow$ domestication, selection without forethought

leads to rapid evolution of wheat

and hunting decreases rapidly

Domestication (and farmers?) spread northward

at ~ 1 km/year

Hole & McCorriston *American Anthropology*

~ April 1991

Agriculture leads to higher level political organization

	Band	*Tribe*	*Chiefdom*	*State*
Religion				
Justifies kleptocracy?	no	no	yes	yes → no
Economy				
Food production	no	no → yes	yes → intensive	intensive
Division of labor	no	no	no → yes	yes
Exchanges	reciprocal	reciprocal	redistributive ("tribute")	redistributive ("taxes")
Control of land	band	clan	chief	various
Society				
Stratified	no	no	yes, by kin	yes, not by kin
Slavery	no	no	small-scale	large-scale
Luxury goods for elite	no	no	yes	yes
Public architecture	no	no	no → yes	yes
Indigenous literacy	no	no	no	often

A horizontal arrow indicates that the attribute varies between less and more complex societies of that type.

J. Diamond, Guns, Germs, and Steel

TABLE 14.1 Types of Societies

	Band	*Tribe*	*Chiefdom*	*State*
Membership				
Number of people	dozens	hundreds	thousands	over 50,000
Settlement pattern	nomadic	fixed: 1 village	fixed: 1 or more villages	fixed: many villages and cities
Basis of relationships	kin	kin-based clans	class and residence	class and residence
Ethnicities and languages	1	1	1	1 or more
Government				
Decision making, leadership	"egalitarian"	"egalitarian" or big-man	centralized, hereditary	centralized
Bureaucracy	none	none	none, or 1 or 2 levels	many levels
Monopoly of force and information	no	no	yes	yes
Conflict resolution	informal	informal	centralized	laws, judges
Hierarchy of settlement	no	no	no → paramount village	capital

J. Diamond, Guns, Germs, and Steel

Information

Genes $\longrightarrow$ 10^{10} bits (or less)

Brains $\longrightarrow$ 10^{14} bits

$\longrightarrow$ 1400 cm^3 in humans

$\Downarrow$

Extra-somatic information

leads to communication: information passed between individuals.

Allows **societies** to evolve.

Information and Intelligence

- Can we think of extra-somatic information as intelligence?
- Collective “intelligence” of the species
- But cannot be assimilated by any individual
- Collective knowledge does lead to ability to engage in interstellar communication

Oral language	400,000?	Cooperative hunting?
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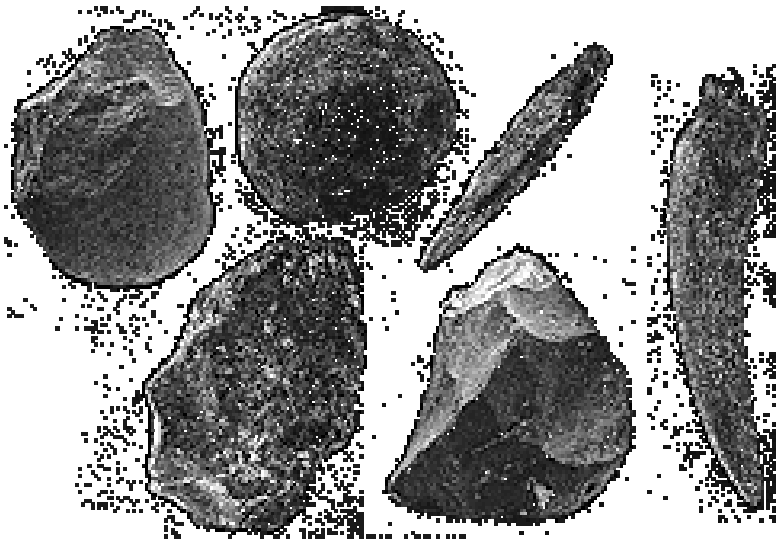
Tools and Technology

Stone

Oldowan	2.4 Myr	H. habilis
Acheulian	1.6 Myr	H. erectus
Mousterian	200,000 yr	Neanderthals
Paleolithic	90,000 yr	H.sapiens (Africa)
Paleolithic	40,000 yr	H.sapiens (Europe)
Pottery	7,000 BCE	
Wheel	6,500 BCE	Sumeria

Oldowan Tools



- OLDOWAN TOOLS (left to right): end chopper, heavy-duty scraper, spheroid hammer stone (Olduvai Gorge); flake chopper (Gadeb); bone point, horn core tool or digger (Swartkrans).

From http://www.handprint.com/LS/ANC/stones.html

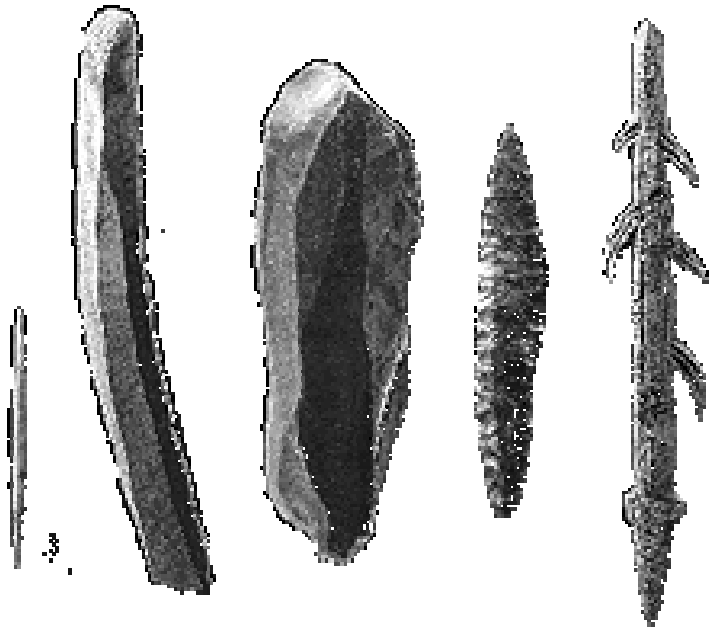
Acheulian

- ACHEULEAN TOOLS (left to right): cleaver stone (Bihorei oest, France); lanceolate hand ax (Briqueterie, France); large hand ax (Olduvai Gorge).

Mousterian

- MOUSTERIAN TOOLS (left to right): cutter or point, Levallois core and point, Aterian point with base tang, double-sided scraper (various sites in France).

Upper Paleolithic



- UPPER PALEOLITHIC TOOLS (left to right): biconical bone point, Perigordian flint blade, prismatic blade core, Soluterean Willow leaf point, double-row barbed harpoon point (various sites in France).

Tools and Technology

Metal

Copper Tools	4,000 BCE	
Bronze Tools	2,800 BCE	
Iron Tools	1,500 BCE	
Industrial Revolution		
Mass Production		

Silicon

Transistor	1948	U.S.
Microchip	1959	
Internet	1990’s	

Metal Tools

Copper

Bronze

Iron

Uniqueness

1. Agriculture

   At least 5 (and maybe 9) independent origins

   Southwest Asia, China, Mesoamerica, Andes, Eastern U.S.

2. Written language

   2-4 independent origins

   Sumer, Mesoamerica, China(?), Egypt (??)

   Only after farming

From Guns, Germs, and Steel Jared Diamond

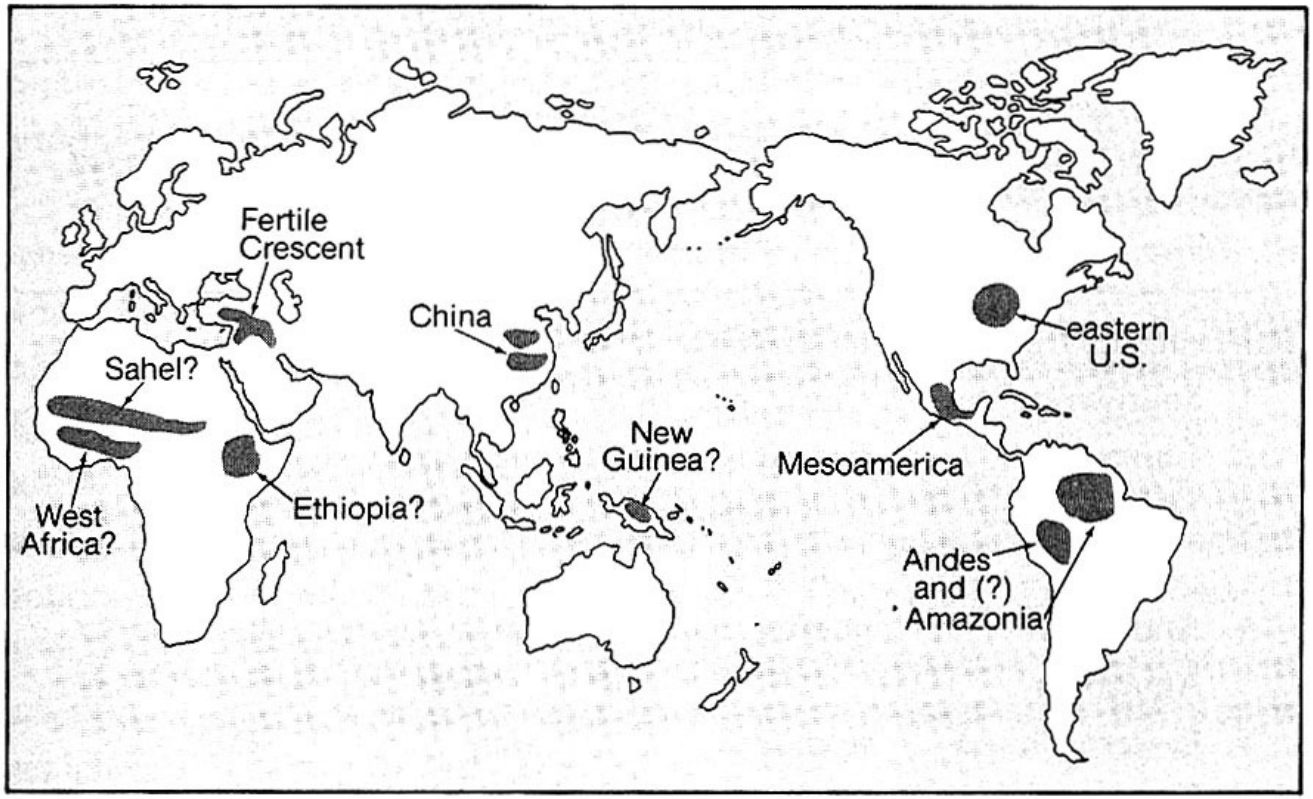


Figure 5.1. Centers of origin of food production. A question mark indicates some uncertainty whether the rise of food production at that center was really uninfluenced by the spread of food production from other centers, or (in the case of New Guinea) what the earliest crops were.

From Guns, Germs, and Steel Jared Diamond

TABLE 5.1 Examples of Species Domesticated in Each Area

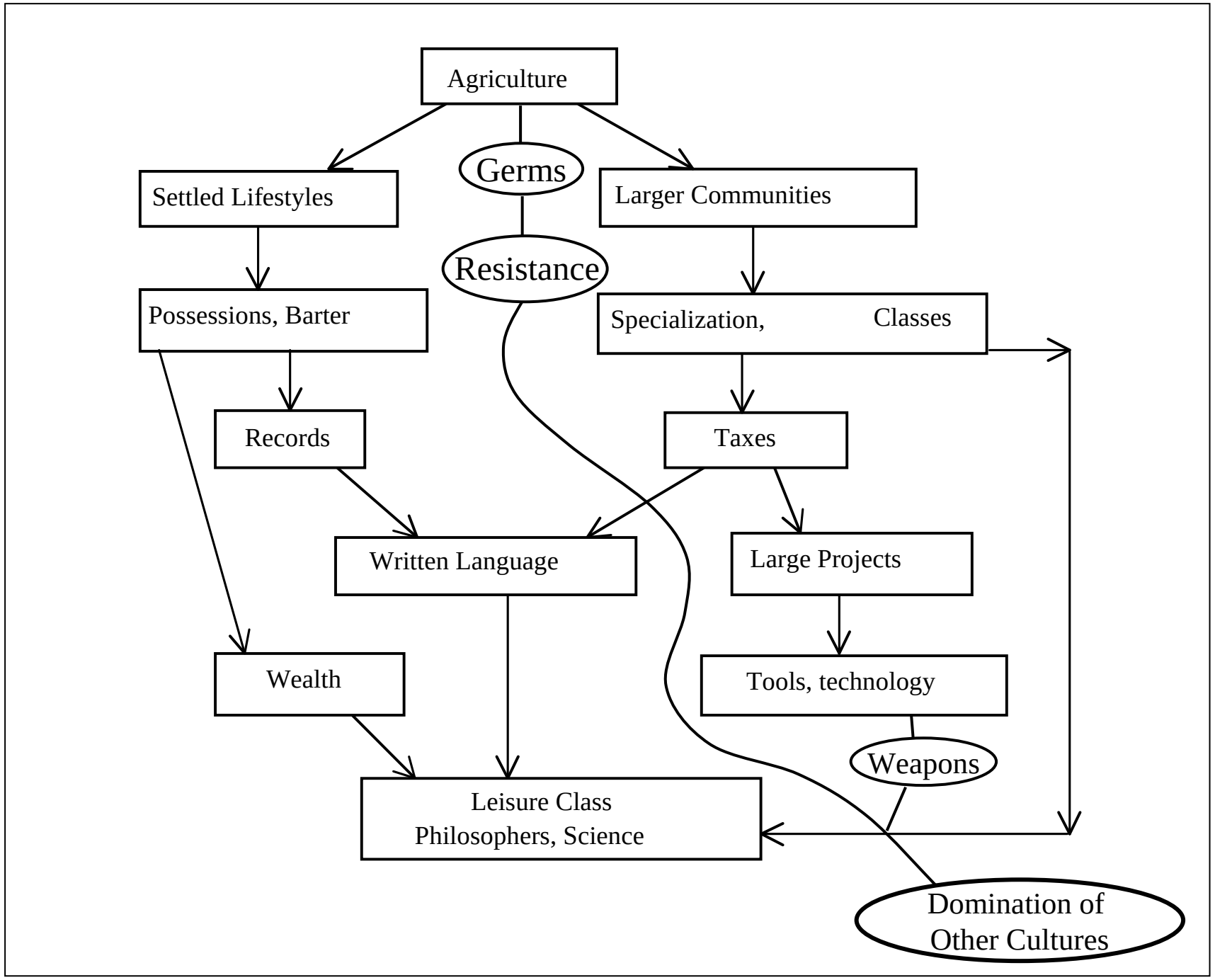
	Area	*Domesticated*		*Earliest Attested Date of Domestication*
		Plants	*Animals*	
Independent Origins of Domestication				
	1. Southwest Asia	wheat, pea, olive	sheep, goat	8500 B.C.
	2. China	rice, millet	pig, silkworm	by 7500 B.C.
	3. Mesoamerica	corn, beans, squash	turkey	by 3500 B.C.
	4. Andes and Amazonia	potato, manioc	llama, guinea pig	by 3500 B.C.
	5. Eastern United States	sunflower, goosefoot	none	2500 B.C.
?	6. Sahel	sorghum, African rice	guinea fowl	by 5000 B.C.
?	7. Tropical West Africa	African yams, oil palm	none	by 3000 B.C.
?	8. Ethiopia	coffee, teff	none	?
?	9. New Guinea	sugar cane, banana	none	7000 B.C.?
Local Domestication Following Arrival of Founder Crops from Elsewhere				
	10. Western Europe	poppy, oat	none	6000–3500 B.C.
	11. Indus Valley	sesame, eggplant	humped cattle	7000 B.C.
	12. Egypt	sycamore fig, chufa	donkey, cat	6000 B.C.

Uniqueness

3. Centralized states, specialization
   Several independent origins
   Only after farming

4. Metal use
   Near East
   New World (Andes) mostly decorative

5. Industrial Revolution, modern electronics
   (no test possible - all world in contact)


Agriculture
Germs
Settled Lifestyles
Larger Communities
Resistance
Possessions, Barter
Specialization, Classes
Records
Taxes
Written Language
Large Projects
Wealth
Tools, technology
Weapons
Leisure Class
Philosophers, Science
Domination of
Other Cultures

Questions

How does cultural evolution differ from biological evolution?

Does “natural selection” operate in cultural evolution?

If so, is technology an “advantageous trait”?

Is “cultural evolution” a valid description of “history”?

Evolution of Concept of Universe

"Interest" part of f_c

Requires the following:

1. Understand the size and nature of Universe
2. Understand place in Universe (*not* the center)
3. Optimistic Drake Equation

Are ability and interest linked?

Both very recent

Is this a coincidence?

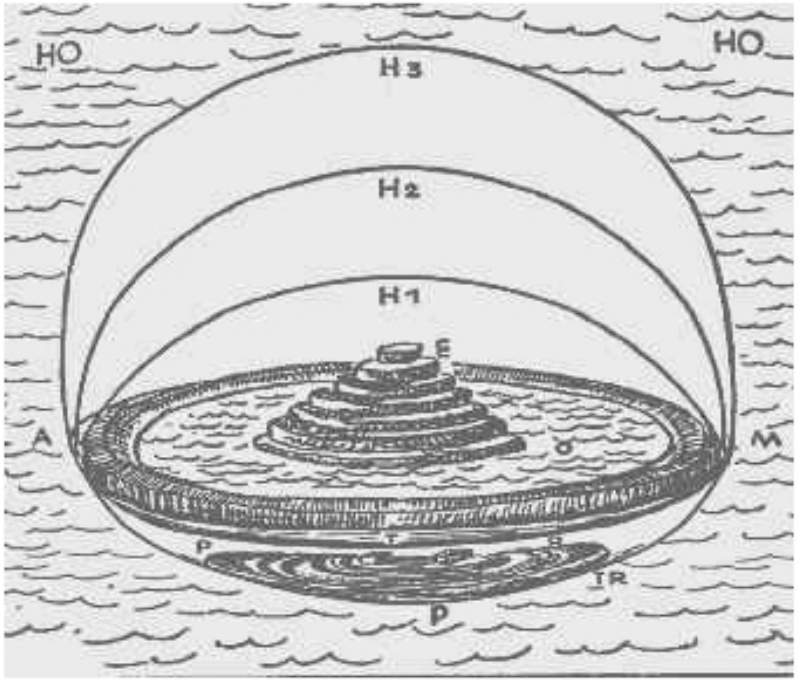
Evolution of Worldview

- Early astronomy had dual nature
  - Calendar Astronomy (observations)
    - Precise calendars in agricultural societies
    - Dates back to at least 3800 BCE
    - Mayans: length of year to 0.001% accuracy
  - Cosmic Myth (theory)
    - Tied to religion, origin stories

Oyster World

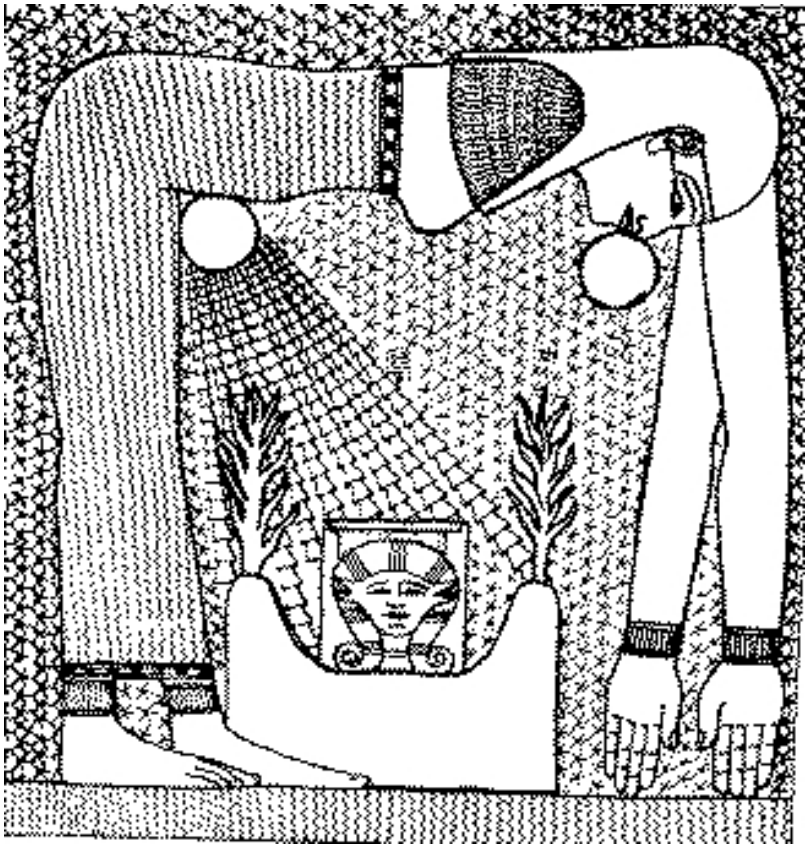
- Flat Earth
- Dome of Heavens
- Waters above
- Waters below
- Stars fixed to the dome
- Sun moves across

Late Babylonian World



- Three heavens
- Underworld
- Babylon is center
- Created by Marduk
  - City god of Babylon
  - Sliced up Tiamat
  - Separated waters above and waters below

Egyptian World



- God of the Air (Shu)
- Separated his parents
- Sky and Earth
- Mother was sky
  - Unusual choice

Origin of Natural Philosophy

- Around 500 BCE, Greeks on Ionian islands
- Thales and others
- Search for universal substance
  - Tried water, air, earth, fire
- Key feature is search for **natural** explanation
- Distinguished planets from stars
- Began to think about larger Universe

One group of Greek philosophers (the Atomists) believed in other worlds.

Epicurus 4th Century BCE

Infinite atoms implies infinite worlds, living creatures

In contrast: Aristotle

"The world must be unique"

Lucretius (Roman poet and philosopher)

"It is in the highest degree unlikely that this Earth and sky is the only one to have been created…"

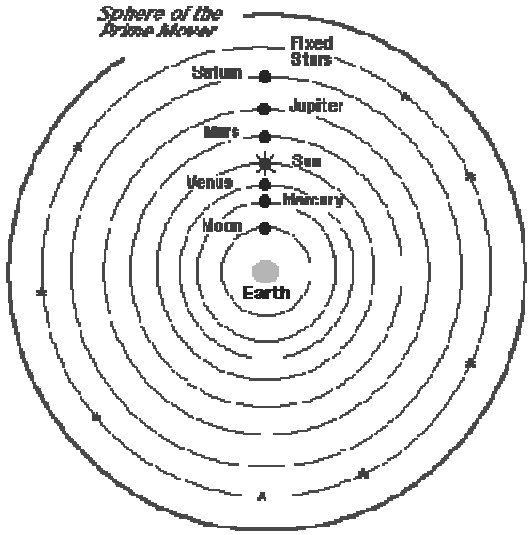
But even the Atomists did not have a correct vision of the nature of the Universe, stars

Plato and the dominance of the circle

- Plato chose the circle – the most symmetric
  - "And he gave the universe the figure which is proper and natural…"
  - "… he made it move with circular rotation"
    - Both from Timaeus

Aristotle and the two spheres

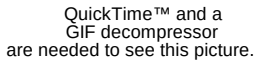
- Aristotle distinguished the two spheres
  - Sub-lunary
    - Four elements, natural motion dictated by nature
    - Unnatural motion requires constant force
  - Celestial
    - Quintessence
    - Eternal, uniform, circular motion
    - Crystalline spheres
    - Moved by Prime Mover
    - All motion centered on Earth



Aristotle's Universe

Saving the phenomena

- Ptolemy's Earth Centered model
  - Size: 19,865 Earth Radii
    - No voids (but cheated)
  - To match observed motions of planets,
    - Eccentrics, epicycles, equants
    - Extremely contrived



Ptolemy's model

For moving models, check
http://faculty.fullerton.edu/cmcconnell/Planets.html - 7

Astronomy & Religion

Augustine (420 CE)

- Neo-platonism incorporated into Christianity
- Ignore Observation
- World-view regressed

Aquinas (13th Century)

- Aristotle incorporated into Christianity
- Ptolemaic system

- Heretics
  - e.g. Giordano, Bruno
  - Stars are Suns with Planets, Life

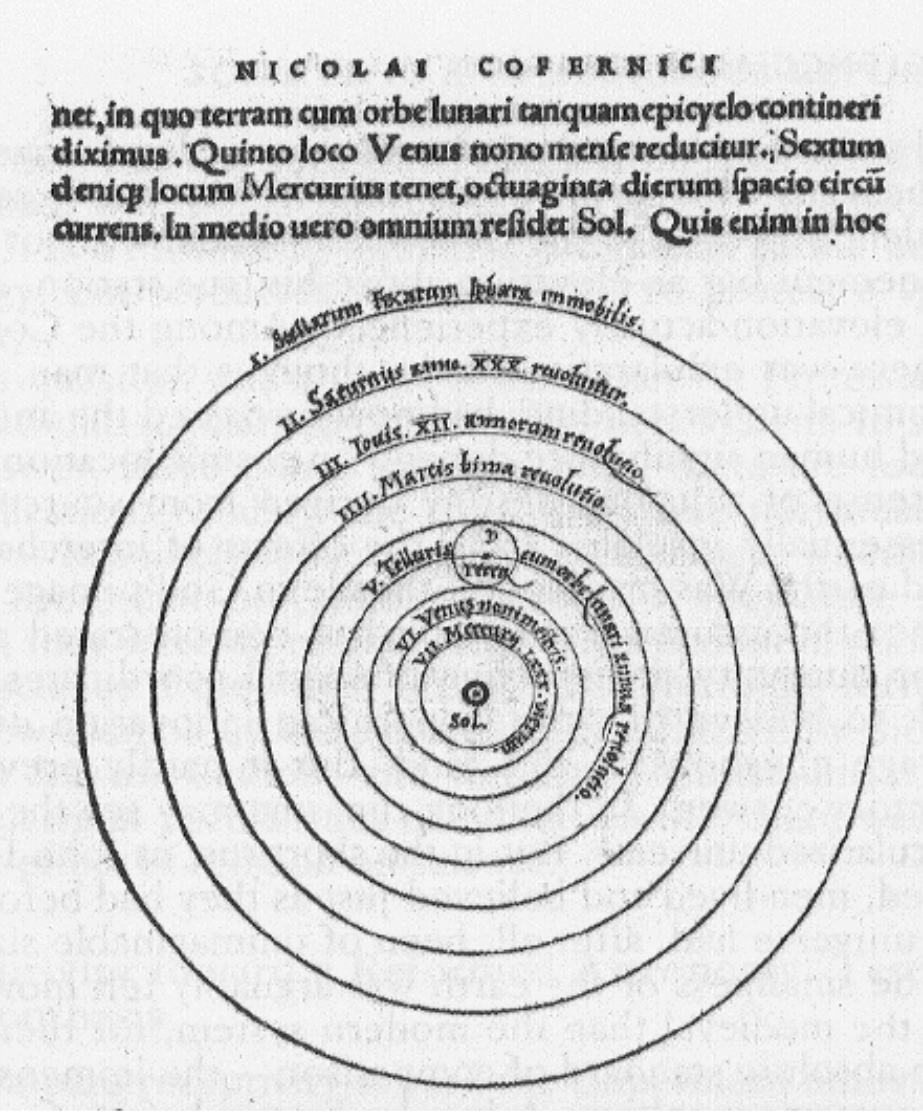
Two Thousand Years of Error

"There is perhaps no other example in the history of thought of such dogged, obsessional persistence in error, as the circular fallacy which bedevilled astronomy for two millennia."

Arthur Koestler, in The Sleepwalkers, pg. 58)

Example: the supernova of 1054 was recorded in China, American southwest, …, but NOT in Europe. It did not fit the theory.

Copernican Model (1540)

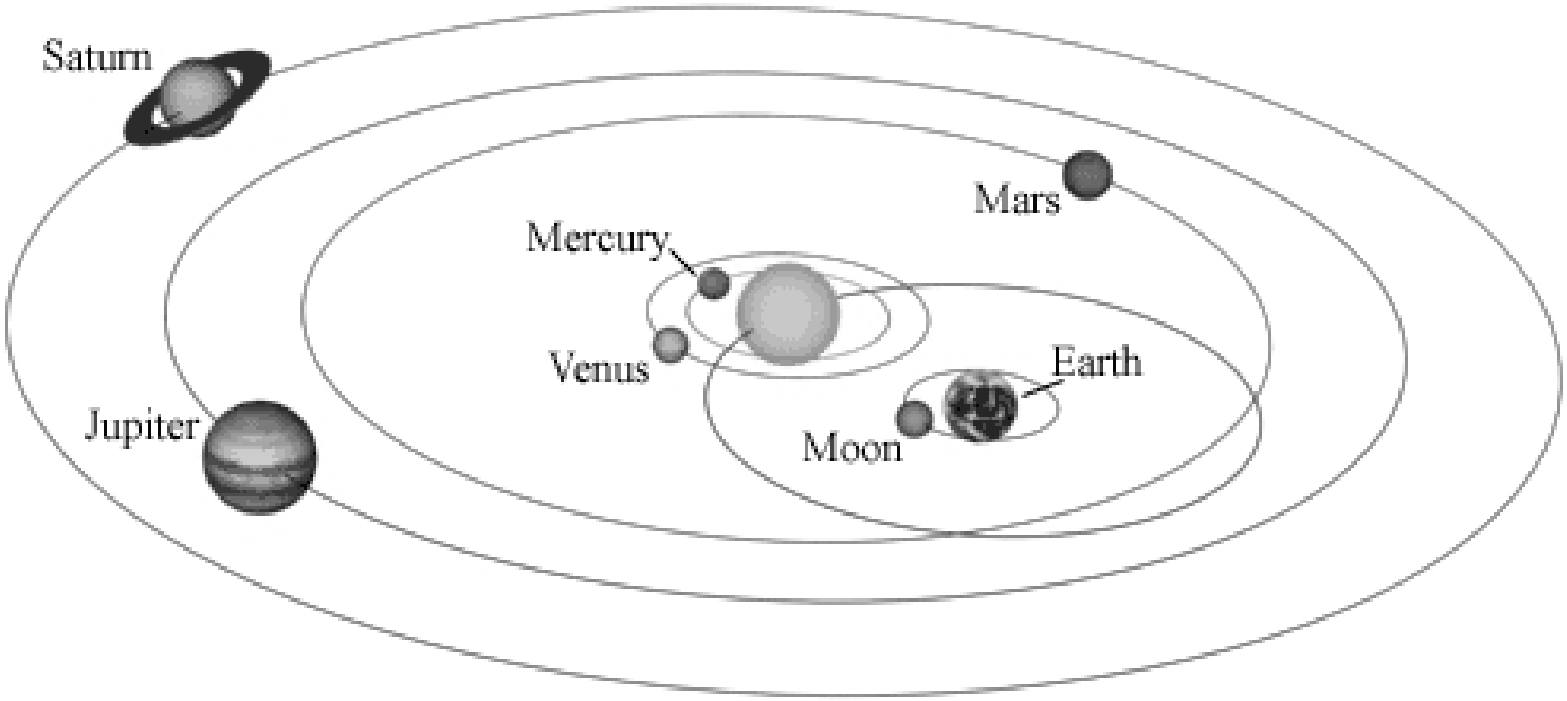


- Sun at center
- All planets orbit around Sun
- Circular motion
- Uniform speed
- To explain planets:
  - Still need:
  - Epicycles
- To avoid apparent motion of stars
  - Much bigger universe
  - 7,850,000 Earth radii
  - voids

Tycho Brahe (late 1500s)

- Before the telescope
- Very large circles for sighting positions of planets
- Observed supernova
- Careful records
- Hired Kepler
- Compromise world view

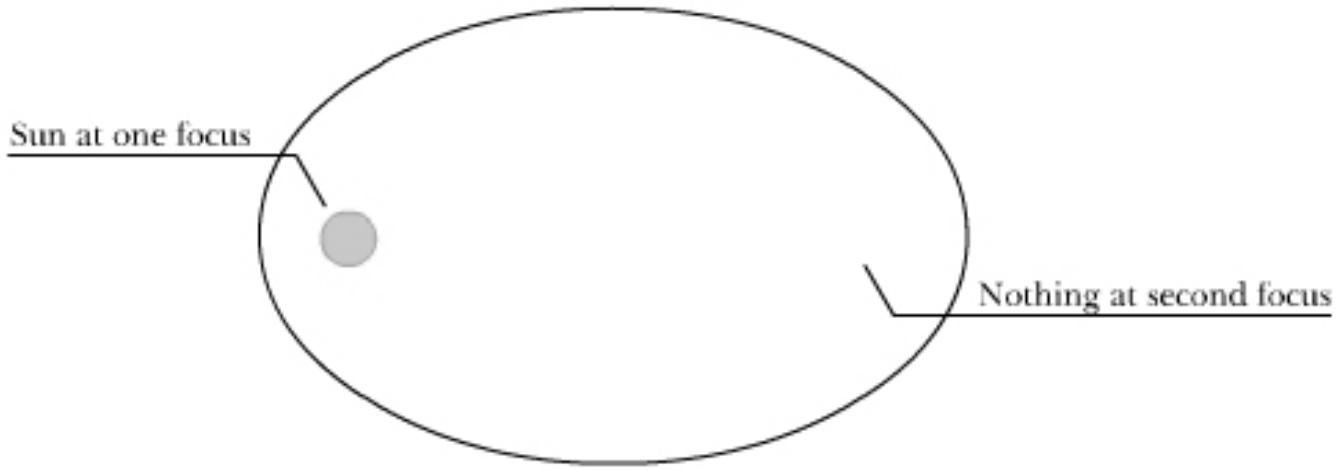
Brahe's Compromise World View



Kepler

- Worked with Brahe's data
- Found that he could fit the Mars data if
  - 1. Planets moved in elliptical orbits
  - 2. At different speeds at different places
  - 3. $P^2 = a^3$
    - P is period (how many years to complete orbit)
    - a is semi-major axis ~ radius or orbit
    - P in Earth years, a in earth orbit radii (AU)

Elliptical Orbits



The size of the Sun is greatly exaggerated in this diagram

This would be an extremely elliptical orbit.
In fact, orbits in Solar system are nearly circles.

Galileo

- Used telescope (recently invented)
  - New “planets” (moons of Jupiter)
  - Sunspots
  - Craters on Moon
  - Many more stars
- New physics
  - No force needed to keep a body in motion

Newton completes the revolution

- Newton (1687, Principia)
  - Unifies celestial and sublunary physics
  - Newton's Laws of motion
  - Theory of Universal Gravitation
  - Together these explain both
    - Motion of planets
    - Motion on Earth

Newton's Laws of Motion

- 1. A body in motion tends to remain in motion unless acted upon by external forces.
  - Momentum ($p = m v$) remains constant
- 2. The rate of change of momentum with time is equal to the force.
  - $F = (dp/dt) = m (dv/dt) = m a$, if m constant
- 3. An object exerting a force on a second object experiences an equal and opposite force.
  - $F_{12} = - F_{21}$

Newton's Law of Gravity

- Every object with mass exerts a force on every other object with mass.
  - The force is proportional to the product of the two masses
  - The force is inversely proportional to the distance between the two masses.
  - $F = (GM_1M_2)/r^2$

The Copernican Revolution

- Copernicus (heliocentric but circular)
- Tycho Brahe (meticulous observations)
- Kepler (ellipses, not circles!)
- Galileo (constant motion needs no force)
  - The Earth can move but we don’t feel it.
  - The inquisition was not persuaded.
  - “eppur, si muove”
- Newton (unified physics)

Copernican Principle

- Removal from the center
  - geocentric before 1543 (Copernicus)
  - heliocentric 1543 to 1915 (Shapley)
  - galactocentric 1915 to 1923 (Hubble)
  - nowherecentric 1923 to present (Einstein, …)
- Nothing special about us
- No “fine-tuning” to allow us

The Universe as we see it now

- The Observable Universe (Horizon)
- Very large (about 13 billion light years)
- Very clumpy on “small” scales
  - planets, stars, galaxies, clusters, superclusters
- Very empty on average
  - about one atom every 40 cubic meters
- Expanding (galaxies moving apart)
  - velocity proportional to distance

Evolution of World View

- Need for a correct world view
  - If solar system is whole Universe
  - No possibility of other civilizations
  - Need to learn how big Milky Way is
  - (Note that we consider only the Milky Way)
    - Time to communicate with other galaxies is too long

Evolution in other fields

- Geology
  - Earth much older than 4500 yrs
    - Lyell (1860s)
  - Radioactive dating
- Biology
  - Species all evolved from common ancestor
    - Darwin (1859)
  - Natural origin of life
    - Miller Urey experiment (1953)

Connections

Time	Information	Technology	World View
2 Myr ago		Stone tools	
??	Oral Language	Collective hunting	
6500 B.C.	Clay tokens	Agriculture, cities	
6500 B.C.		Wheel	
4000 B.C.		Copper tools	
3000 B.C.	Clay tablets		Oyster World
3000 B.C.	Syllabic alphabet		
2800 B.C.		Bronze tools	
1500 B.C.	Letter alphabet	Iron tools	
500 B.C.			Natural Philosophy
200			Ptolemaic Model
1456	Printing Press		
1540			Copernican Model
1610		Telescope	Kepler, Galileo
1665			Newton
1700s		Industrial Revolution	
1859			Darwin
1895	Radio		
1924			Other galaxies
1936	First TV Broadcast		
1950s	Computers	Transistors, microchips	Miller-Urey
1960			First Search for Signals
1990s	Internet		

How to Estimate f_c

Consider both “capability” & “interest”

Are these coupled?

Yes - Science implies Technology

No - Technology without Astronomy?

Cloudy planet?…

Does correct worldview favor a civilization?

Yes - European domination

No - Germs more important than weapons?