after the dark ages...
600’s BC: something happened

Kouros, Greek, ~6th century B.C.

Polymedes of Argos, Greek, ~615–590 B.C.

they began to practice

unsafe art
“Professor Hanfmann, who succinctly sums up the prevailing view: “When classical sculptors and painters discovered a convincing method of representing the human body, [then] they set up a chain reaction which transformed the character of Greek narration.

Gombrich notes:

I feel prompted to put forward the opposite hypothesis: when classical sculptors and painters discovered the character of Greek narration, [then] they set up a chain reaction which transformed the methods of representing the human body—and indeed more than that.

he goes on...
For what is the character of Greek narration as we know it from Homer? Briefly, it is concerned not only with the “what” but also with the “how” of mythical events.

~600 BC the beginning of us.
our scientific parents:

“presocratics”

Ionians (Milesians)
Pythagoreans (from Italy)
Eleatics (Elea, IT)
Pluralists (IT and Asia Minor)
let me make a point:

nobody works in isolation in science

The last 3 pages of a couple of hundred from our experiment at Fermilab in Illinois

109 references.
this just floors me:

Ionian's Bibliography:

nobody ever thought like them before
now everyone thinks like them
the big cheese:

Thales of Miletus (ca 624-547BC)
May 28, 585 B.C

typical academic?
everything around you is different

yet, he asked:
what is the fundamental common structure of the Universe

water
not crazy

think about it

what’s most noticeable about Life?

moisture and water are a necessity

so, pretty good guess, right?

But, aren’t all of the unique events in the world due to the capriciousness of the deities?

That was the presumption of Thales! - to ask what was uniform about Nature and expect to be able to understand it!
this is new thinking
for Thales

the universe is regularly structured
and it’s knowable

students and followers

others came after Thales
but,
the “research problem” was the same
the details
were different

Anaximander & Anaximenes

the pied piper
Pythagoras of Samos (ca 582-497BC)
abstract mathematics
proofs in number theory...
but not what you’re thinking!
All things have form, all things are form; and all forms can be defined by numbers.

Pythagoras

music

4 strings of a lyre

tuned to pleasurable tones

lengths:

the octave \(1:2\)

the fourth \(2:3\)

the fifth \(3:4\)
Number

a fundamental entity of Nature

integers: sacred

harmony: tones themselves
orderliness in Nature

= orderliness in Number

world as number
still a part of our heritage
And, nope; it’s not necessarily his theorem:

Egyptians knew: \(3^2 + 4^2 = 5^2\)

Babylonian cuneiform: \(119^2 + 120^2 = 169^2\)

\(3367^2 + 3456^2 = 4825^2\)

Maybe the idea of mathematical proof from him.
They were the first to represent geometrical figures with numbers

The first to represent geometrical figures with numbers

square numbers

$1 + 3 = 2^2$

$1 + 3 + 5 = 3^2$

$1 + 3 + 5 + 7 = 4^2$

and rectangular numbers

$2 + 4 = 2 \times 3$

$2 + 4 + 6 = 3 \times 4$

divide by 2:

$1 + 2 + 3 + \ldots + N = \frac{N(N + 1)}{2}$

in particular, for $N = 4$... this was a magical number: the tetraktys

But look:

As the story goes, a shocking development

*it’s a secret*

$1^2 + 1^2 = (\sqrt{2})^2$

irrational
Pythagoreanism

directly influential on:

Plato, Kepler
modern day theoretical physics

MSU = 150 years old

Pythagoras’ school: 300 years after his death

a distinction

Milesians: fundamental structure:

substance or matter

Pythagoreans: fundamental structure:

mathematical form
I'm easily amused*

in about a century:

1. fundamental Substance and Process
2. recognition of permanence + change
3. beginnings of mathematical analysis
4. myth is gone as an explanation for natural phenomena

*I find this absolutely amazing

Greek

invention of art.

a creative act
preGreek: liturgical

symbolism
especially, Egyptian
can’t change
autocratic
(notsomuch, the Minoans)

Greek gods?

frat boys
connected with humans
mingled in every sense
They didn’t know that Clapton is God.

Greek painting... survives largely on vases and their evolution can be followed contemporaneous with Pythagoras. Two kinds: black figure and red figure.
Neck Amphora, Exekias, Greek, ca 540 B.C.

Calyx Krater, Euphronios, Greek, ca 515 B.C.

painting like you see it

510BC Foreshortening

Euthymedes, 510 BC
a spark of divinity

in humans

Greek art seems to have set out to find it

the perfection in the human form

Kritios

is and isn’t a natural rendering

interpretation

of a universal
four defining moments

1. government...occasionally democratic

2. Persian wars
   including destruction of Athens
Perikles

The individual can be trusted. Let him alone.

3. Peloponnesian war
Greek against Greek
4. subjugation by Macedonia

pre-Alexander
explosion of creativity

mid-5th C BC
civics, medicine, literature, drama, sculpture, architecture, philosophy

balance

“Nothing in excess.”
on the Delphi shrine
The dodecahedron was special (universe) even in Pythagoras' time. Take a pentagon face...

By this time, reliance on proportion was explicit...and known to be psychologically pleasing.

The dodecahedron was special (universe) even in Pythagoras' time.

Take a pentagon face...

"divine proportion" (Kepler):

\[
\frac{AP}{PQ} = \frac{AQ}{AP} = \frac{1 + \sqrt{5}}{2} = 1.61803...
\]

"Golden Rectangle"...an especially pleasing (tested!) shape
Classical Doric architecture

The Parthenon was constructed after 480 B.C. (while Socrates was a child) by Perikles

Look at the columns - the taper at the top and the almost muscular structure. Perfectly suited to hold the roof of this perfectly proportioned building.

There are no straight lines!

a part of the reason this building is so pleasing?

the Golden Rectangle.
Kritos’ Boy, Greek, ca 490-80 B.C.
The Poseidon of Artemision, ca 460 B.C.
Charioteer, ca 475 B.C.
Anavyssos Kouros, Greek, ca 480 B.C.

Discobolos, Myron, ca 450 B.C.
model, Athena Parthenos, Pheidias, ca 5th B.C.

style
The Master

Polykleitus
“wrote the book” kanon (or canon)

Architect
theater at Epidaurus

Theater at Epidaurus, Polycleitus, ca 440 B.C.
still used today. Upper part added 2nd B.C.

Doryphorus (spear bearer)
Polycleitus, ca 440 B.C.

head, 1/8 of height
crown-eyebrows, 3/8; eyebrow-chin, 5/8

The Master

tension
change vs permanence
think about it

Both Milesians & Pythagoreans
stressed permanence

“One” permanent thing?

How...
do you get stuff??
an essential tension:
  permanence
  change

the Riddler
Heraclitus (ca 540-480 BC)
aphorisms:

We step and do not step in the same river twice.
Praying to a statue is like chatting with your house.
Nature likes to hide.

"That which is in opposition is in concert...and from that and from things that differ comes the most beautiful harmony."

Heraclitus
importance for H:

Process

change is the only constant

balance

birth of fire -> death of air,
d of air -> b of water,
d of water -> earth -> fire -> etc

everything is in balance through tension between opposites
Process
very modern idea

note:
change is a threat
to those trying to account for unity
but it’s hard to argue away “change”
the antidote:

Parmenides of Elea
the first Eleatic
all change is....
 illusion

the first reasoning from logic
before?

Pronouncements
one poem

Reality is One Permanent thing

change?

because our senses are fallible

Reality: (true, permanent, knowable through rational thought)

Opinion: (senses...that’s where change lives)
before the current reality?

Nope. There was no reality before our reality so, our reality must be unchanging because nothing can come from nothing he said.

“Be” vs “Becoming”

“becoming” = motion is impossible requiring somewhere for something to move to and a “void” is impossible
Zeno

was his personal posse
“What is, is. What is not, is not.”

Parmenides

the first logical proof
Thou canst not know what is not – that is impossible – nor utter it: for it is the same thing that can be thought and that can be.

Parmenides
you cannot think

of what does not exist

“Nothing” cannot exist:

That which is cannot have come from anything, since it would have previously been in a state of Not.
so, creation is impossible

Creation of something that IS implies creation from something *different from* what IS

Something *different from what IS* is something that... IS-NOT!

**But**, what is NOT cannot be

Therefore, Creation cannot be

“Nor will the force of belief allow for anything else to arise from *what is, besides itself*. For this reason justice does not relax the fetters to free it either to begin or to cease, **but keeps it**...

For, if it once arises, it is not, nor if sometime it is going to be.

So **development is extinguished and destruction silenced**.

Parmenides

So, **there**.
importance

impossible to overestimate:
invented logical argument

Heraclitus

hot and cold
Parmenides

cold does not exist

just not-hot

he's wrong

in at least one way:

can we think about what might exist?

essential to science

don’t have to believe in the conceived ideas
the permanence idea has legs

Conservation “laws”
physics equivalent of Parmenides

Pluralists
Leucippus (ca 470-?BC)
Democritus (ca 460-352BC)

antidote to the Parmenides and Heraclitus
allow the “void”

have only:

matter and the void

motion and permanence

the void is where things move to

plus: atoms are permanent
empiricism?

Democritus: the senses can deceive.

“By convention hot, by convention cold, but in reality atoms and void, and also in reality we know nothing, since the truth is at bottom”

We perceive sensual impressions, but must interpret them with the intellect.
having your cake

and eating it too
the vacuum

how did that go for him?

Plato: no
Aristotle: no
Renaissance: no
19th/20th century positivists: no
Nature: yup...um...well, no. er...

thanks to Parmenides!

the disgust with atoms
persisted until the beginning of the 20C

in part.
modern ideas
and problems
we think: matter is lumpy
planets, atoms, nuclei, quarks
& spacetime is a stretchable fabric
continuous

this is bothersome
we need to reconcile energy
as appearing as gravitation
and as matter
two incompatible theories now
Impact of the Ionians, Eleatics, Pythagoreans, and Pluralists: far-reaching

trying to understand the universe as substance and process
trying to reconcile variety with permanence, *Particulars and Universals*

laying logical tensions between a view of the universe as particulate or continuous
single-handedly, beginning the mathematization of physics
pre-Socrates

well...before Socrates

why that division?

before S: The World; after S: How to Live

‘cant live with ‘em

can’t live without ‘em

Plato and Aristotle said nothing about physics that was correct

responsible for 1.5 millennia of problems

gotta consider Plato and his student, Aristotle.