Title: Rob @ 10am

Date: Oct 14, 2011 10:00 AM

URL: http://pirsa.org/11100102

Abstract:

Symmetries of spatial configurations

A spatial configuration has a particular transformation as a symmetry if it is invariant under that transformation

Types of spatial transformations:

Translations

Rotations

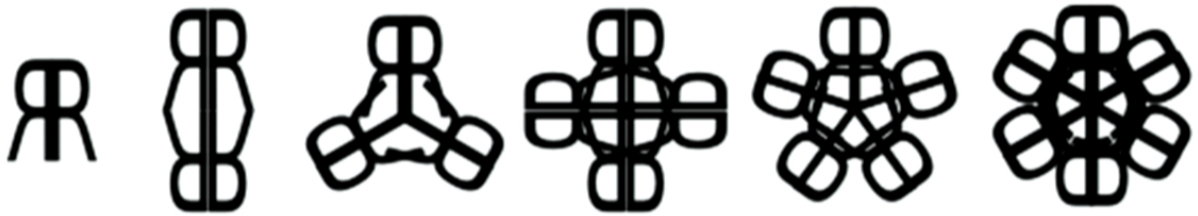
Reflections

Scalings

Rotation in a plane – the cyclic groups

R_1 R_2 R_3 R_4 R_5 R_6

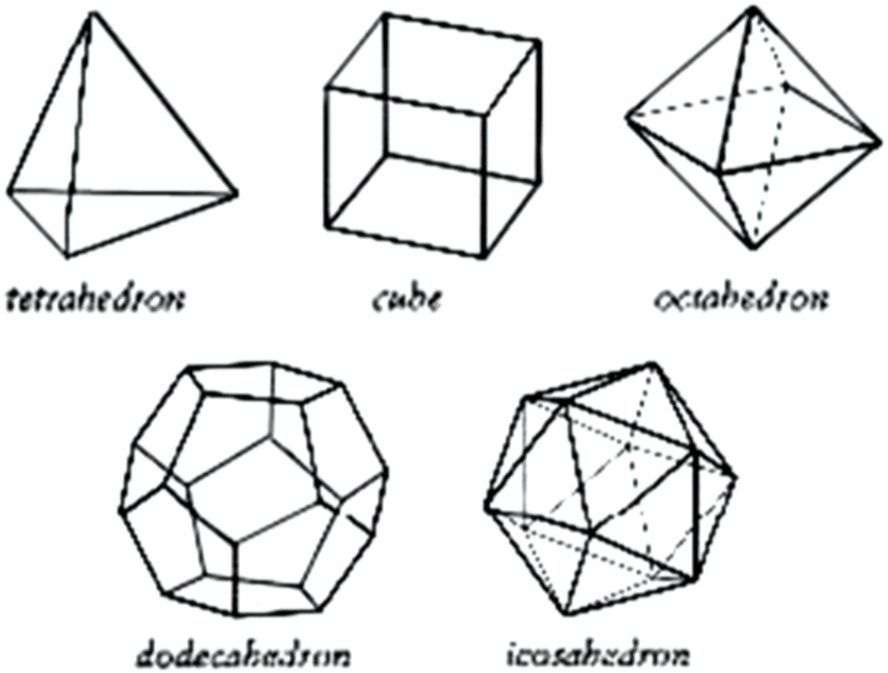
Rotations in a plane with reflections – the dihedral groups



D_1 D_2 D_3 D_4 D_5 D_6

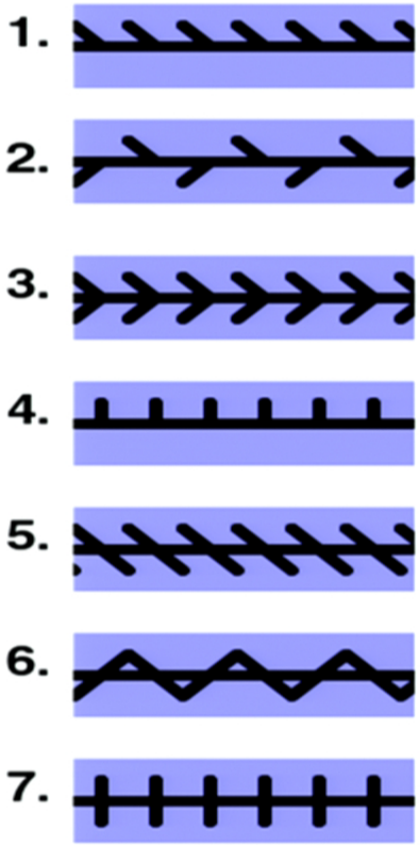
Rotations in three-dimensional space with reflections

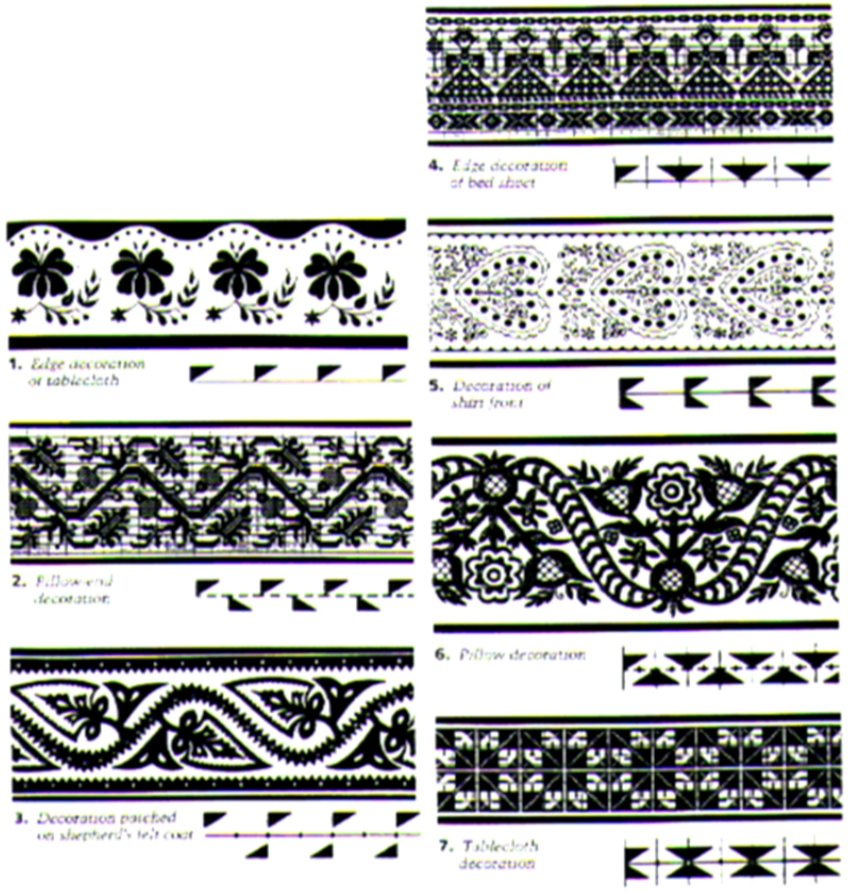
Includes: -planar symmetries
- symmetries of the Platonic solids



Frieze groups

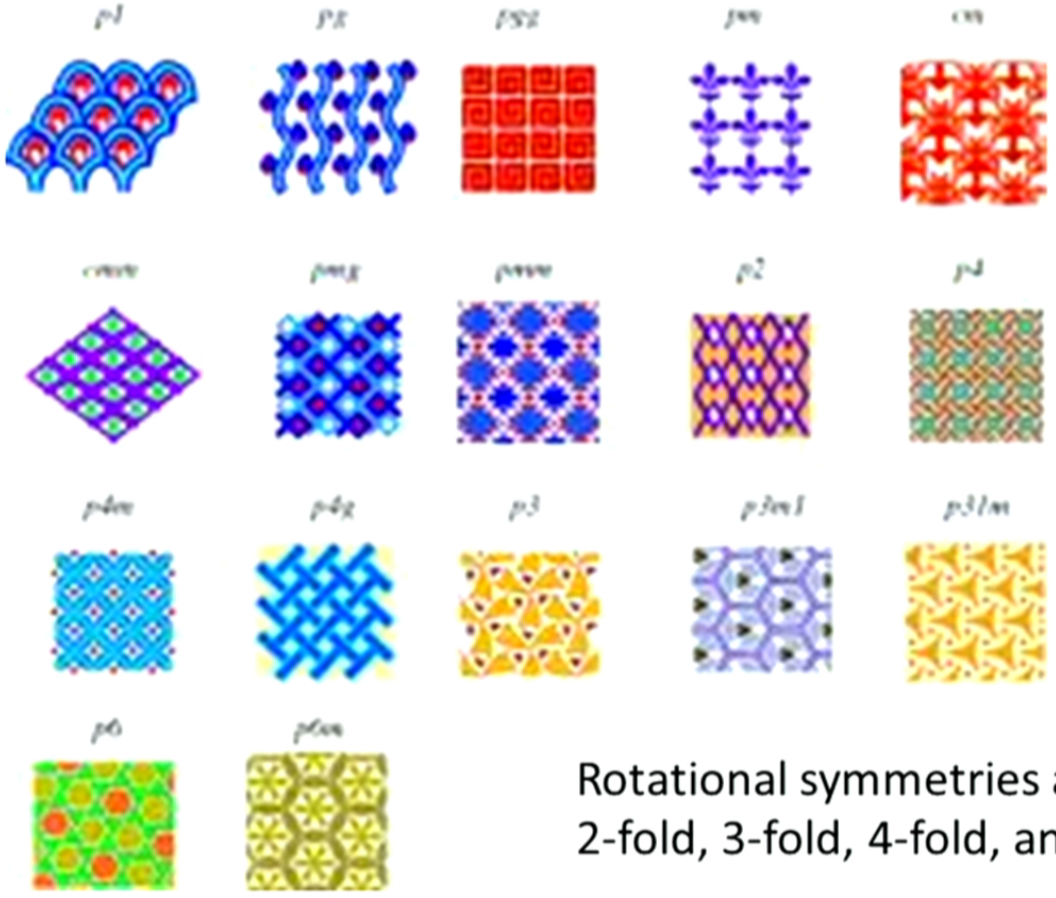
Symmetries of designs on **two-dimensional** surfaces which are repetitive in **one** direction





Wallpaper groups

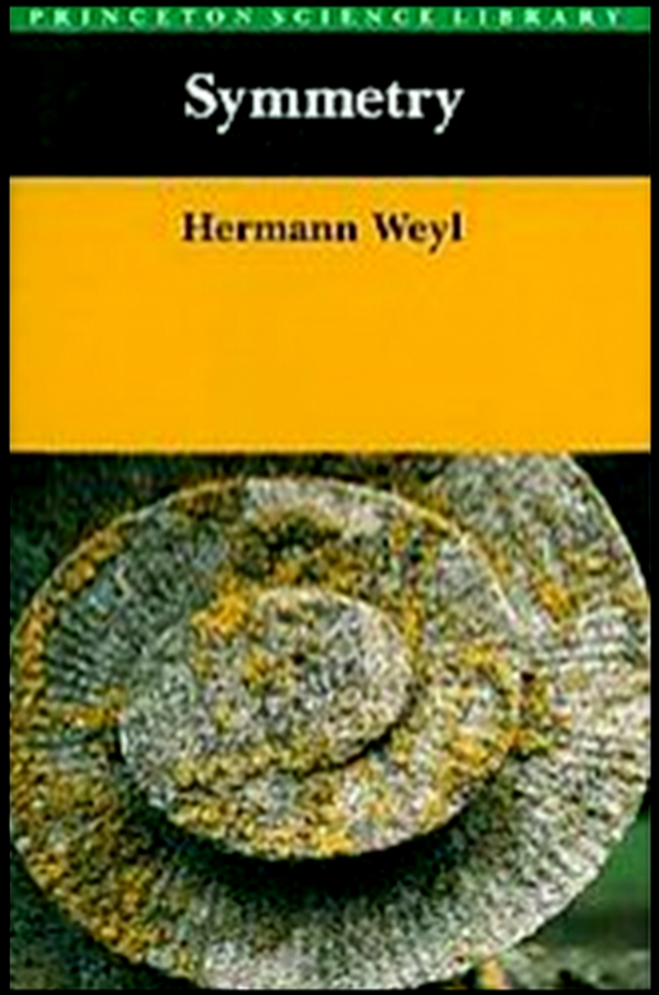
Symmetries of designs on **two-dimensional** surfaces which are repetitive in **two** directions



17 in total

Rotational symmetries are limited to 2-fold, 3-fold, 4-fold, and 6-fold.

Hermann Weyl
(1885 –1955)



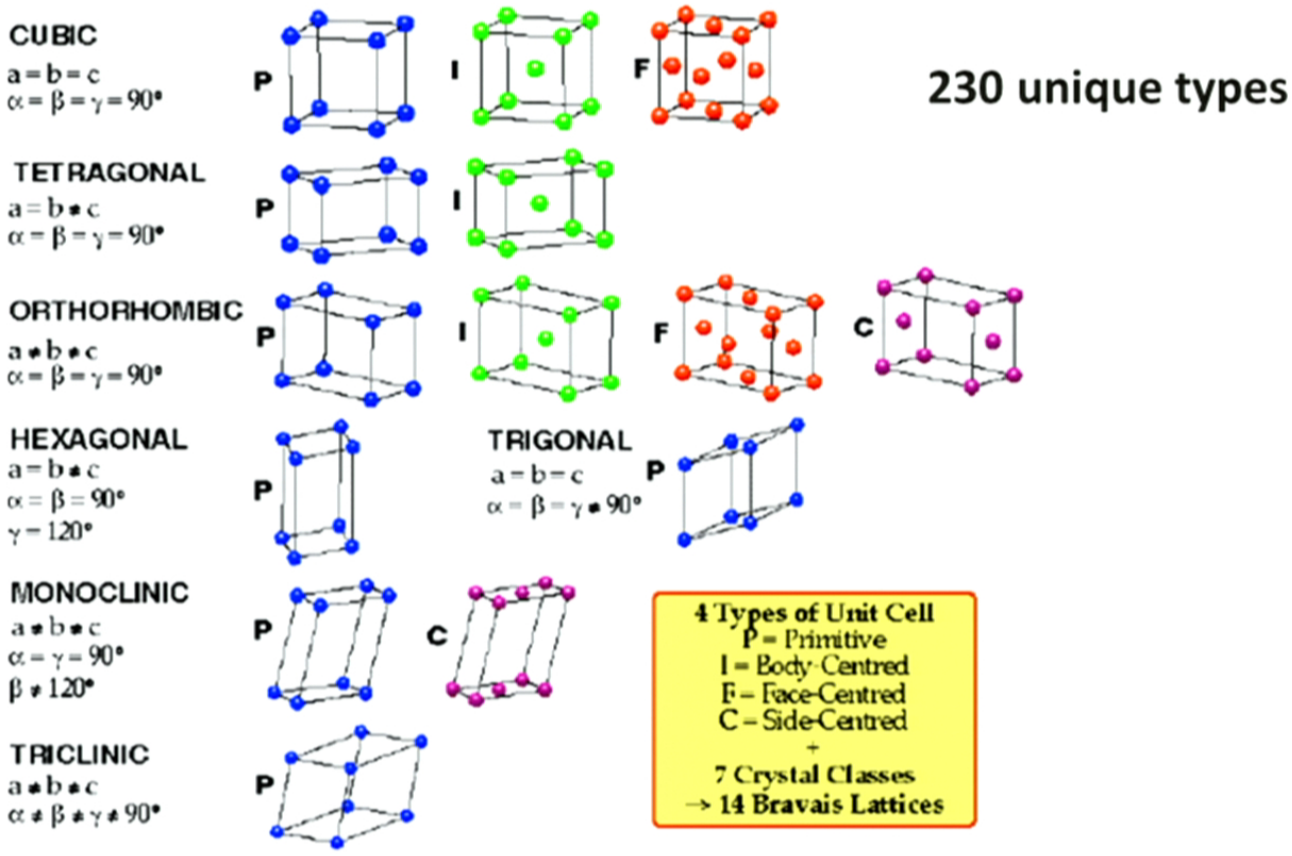
Hermann Weyl
(1885 –1955)

""Examples for all 17 groups of symmetry are found among the decorative patterns of antiquity. […]The art of ornament contains in implicit form the oldest piece of mathematics known to us."

"The arabs fumbled around much with the number 5 but they were of course never able honestly to insert a central symmetry of 5 in their ornamental designs of double infinite rapport."

Crystallographic groups

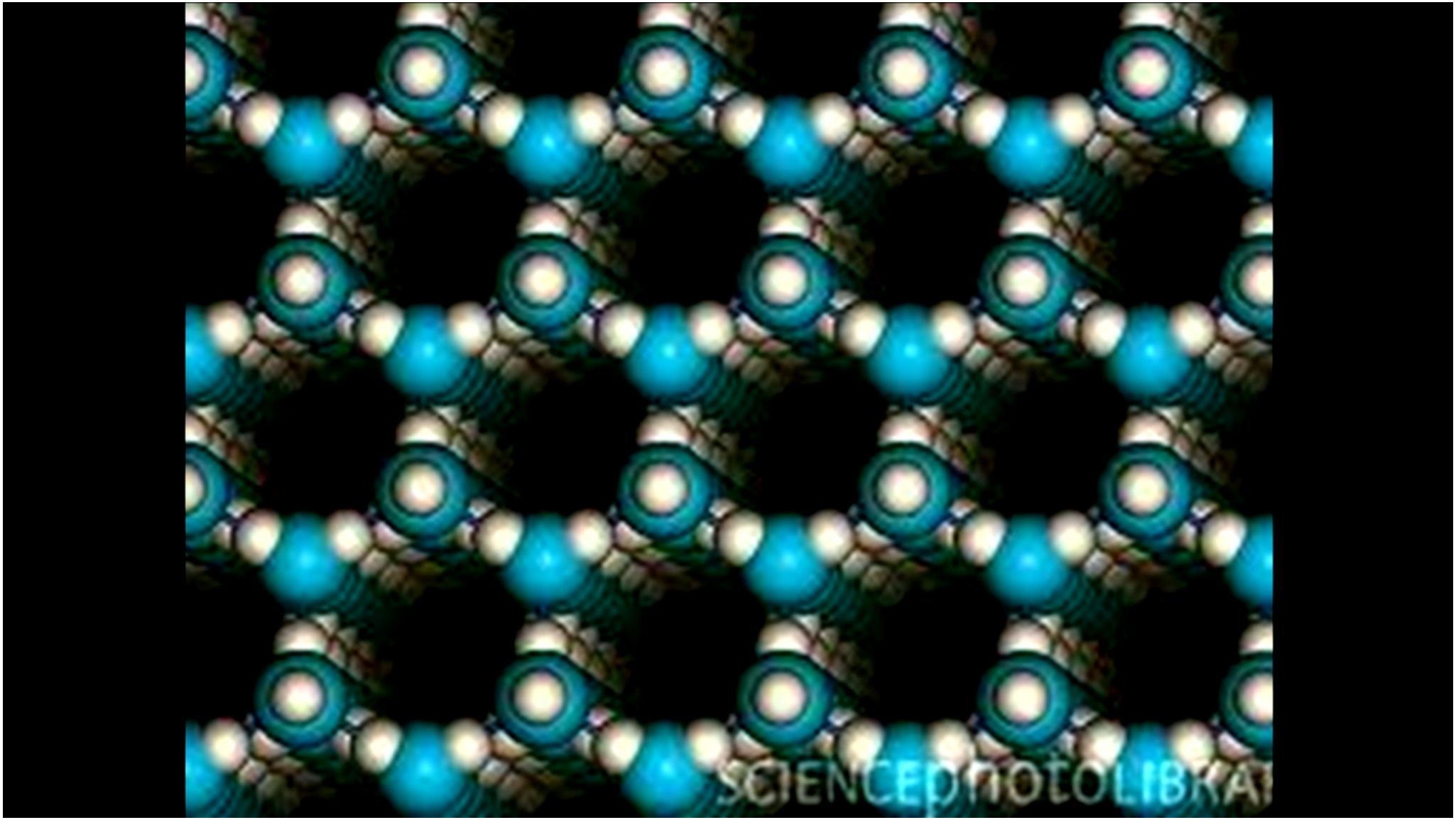
Symmetries of designs in **three-dimensional** spaces which are repetitive in **three** directions



230 unique types

Hermann Weyl
(1885 –1955)

"Artists don't go in much for three-dimensional ornaments."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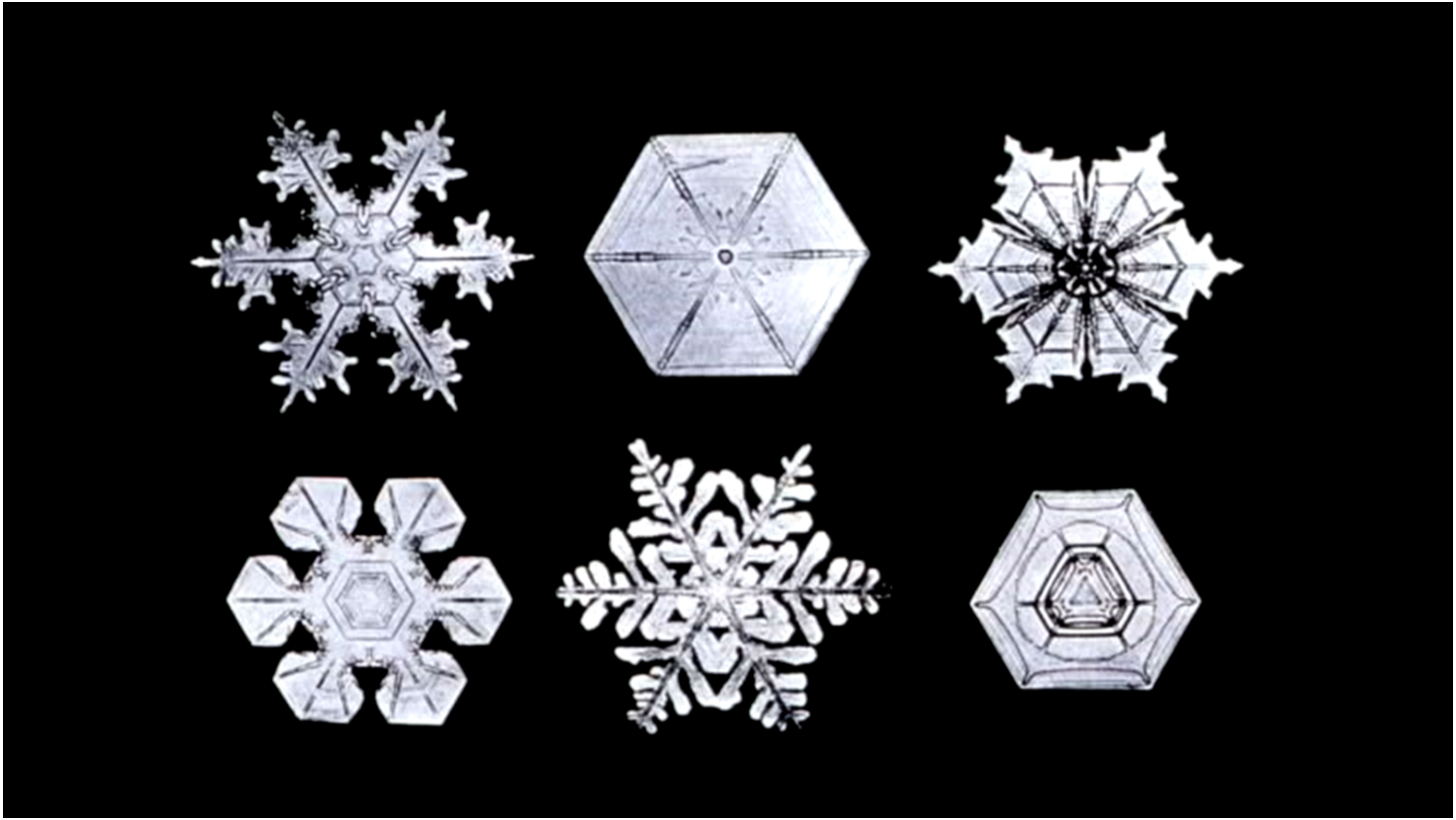

Pierre Curie
(1859 –1906)

Curie's principle

"The symmetry elements of the causes must be found in their effects, but the converse is not true; that is, the effects can be more symmetric than the causes."

Or

Any asymmetry in an effect must be found in its causes

Or

Only asymmetry can beget asymmetry


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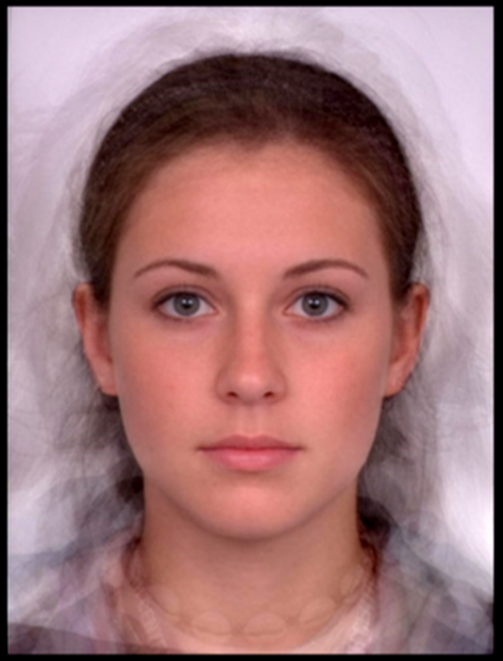
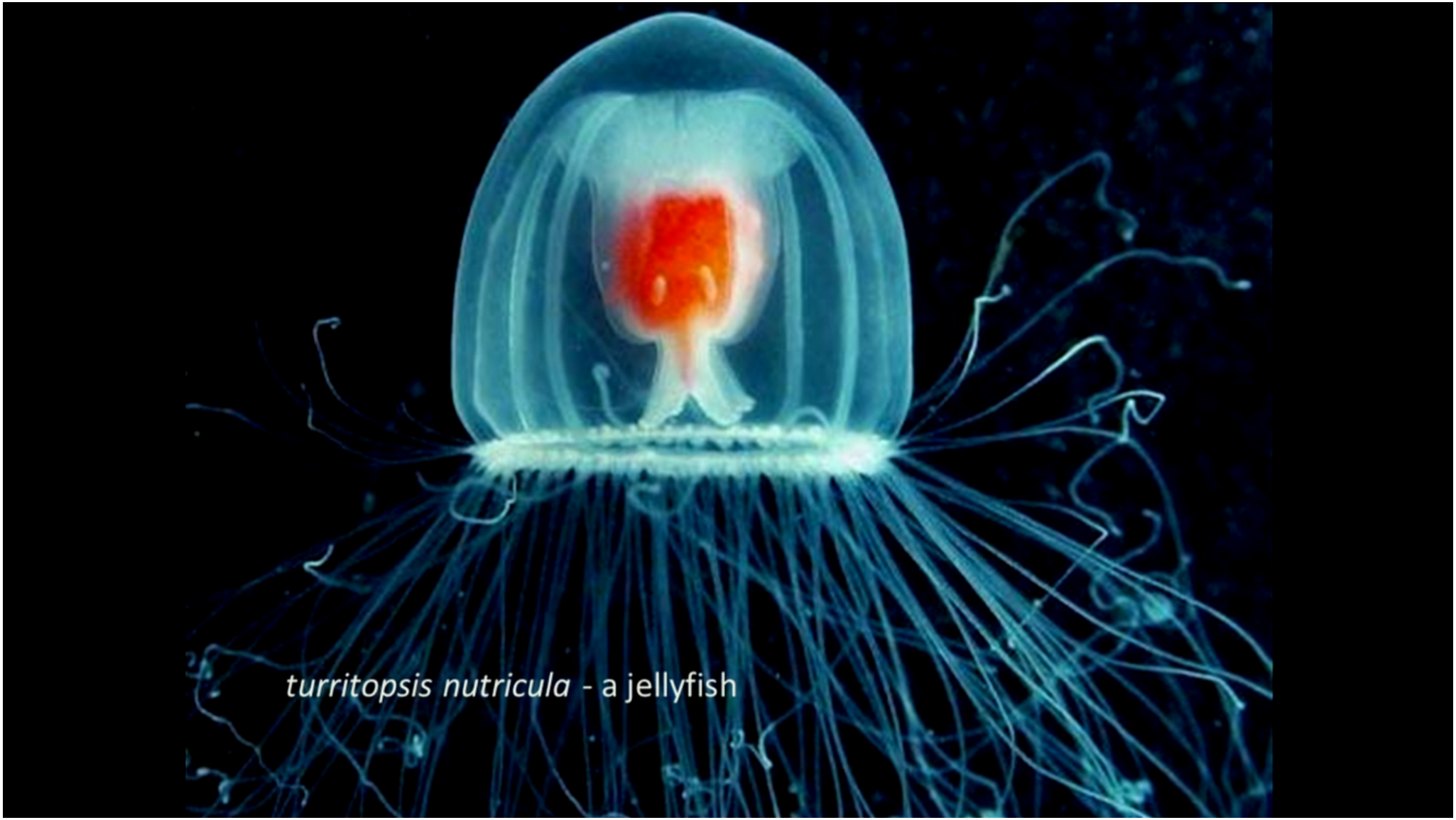
Bilateral symmetry



Rather than asking:
Why do we find this symmetry?

Ask:
Why do we find this **a**symmetry?

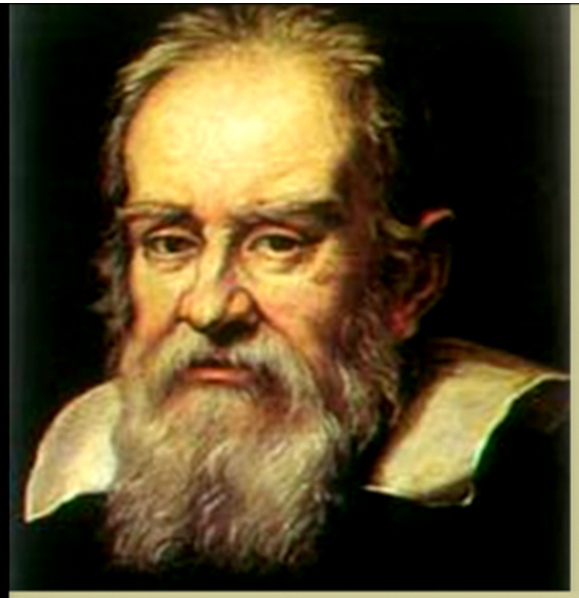

Actinophrys sol—a heliozan
20 µm


turritopsis nutricula - a jellyfish


Meganyctiphanes norvegica -- a krill

Symmetries of laws

A law has a particular transformation as a symmetry if it is invariant under that transformation

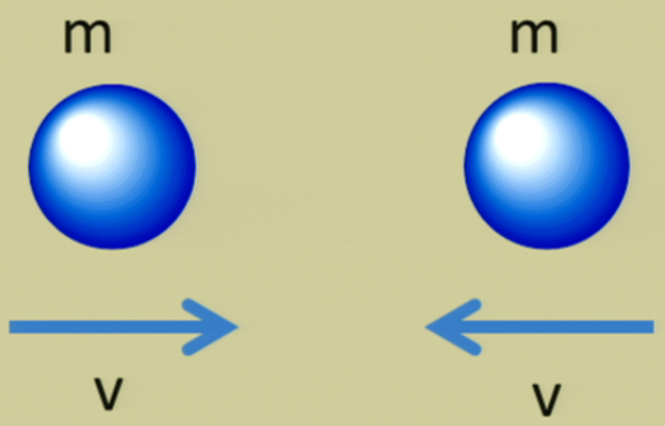


Galileo Galilei
(1564 –1642)

Galilean Relativity

Shut yourself up with some friend in the main cabin below decks on some large ship, and have with you there some flies, butterflies, and other small flying animals. Have a large bowl of water with some fish in it; hang up a bottle that empties drop by drop into a wide vessel beneath it. With the ship standing still, observe carefully how the little animals fly with equal speed to all sides of the cabin. The fish swim indifferently in all directions; the drops fall into the vessel beneath; and, in throwing something to your friend, you need throw it no more strongly in one direction than another, the distances being equal; jumping with your feet together, you pass equal spaces in every direction. [Now] have the ship proceed with any speed you like, so long as the motion is uniform and not fluctuating this way and that. You will discover not the least change in all the effects named, nor could you tell from any of them whether the ship was moving or standing still.

Rene DesCartes
(1596-1650)



Rene DesCartes
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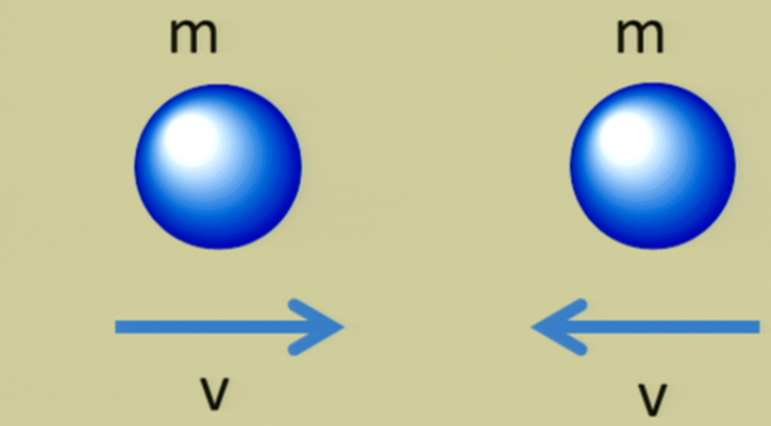
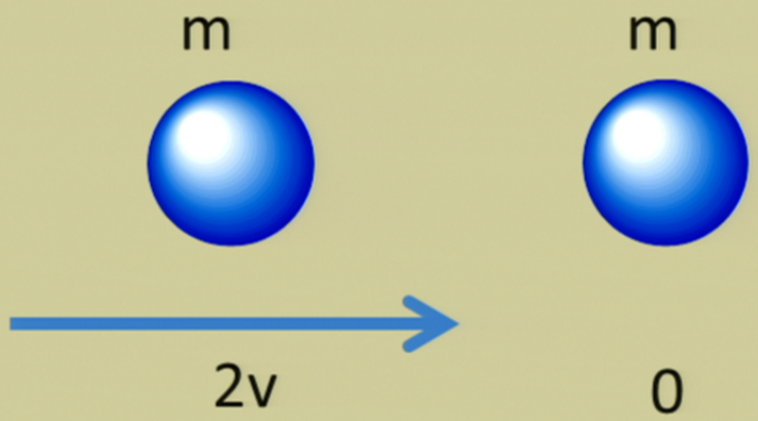
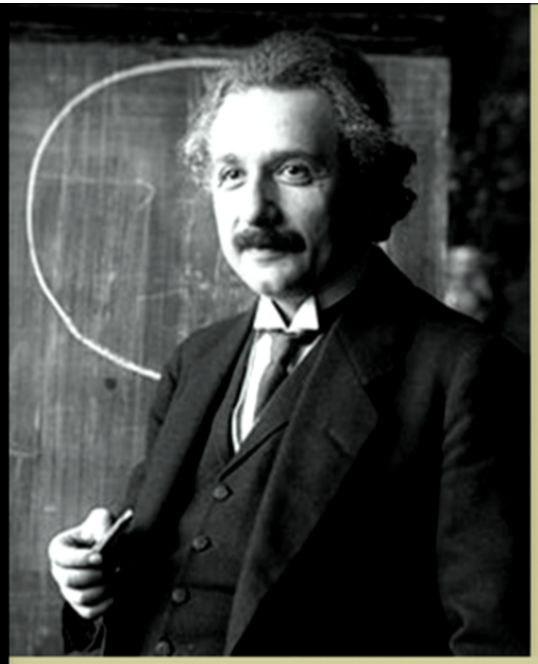




Christiaan Huygens
(1629 – 1695)



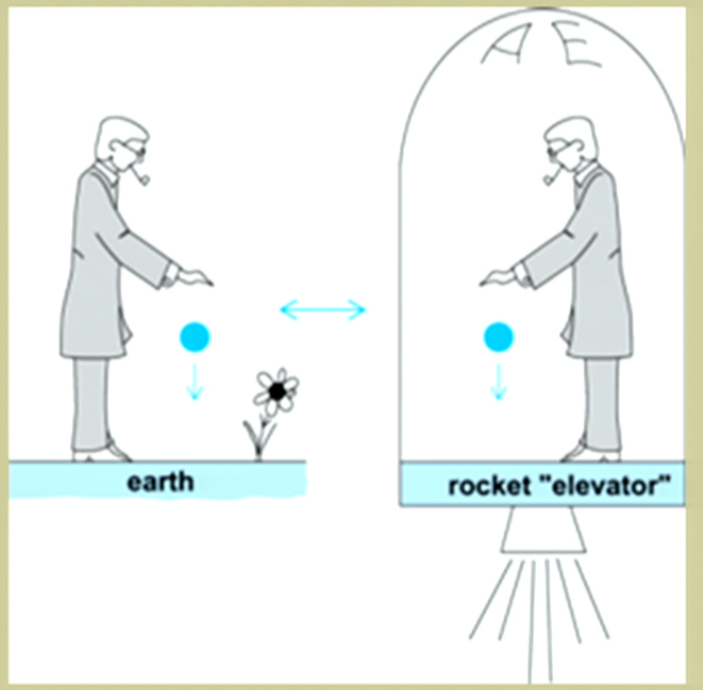
Albert Einstein
(1879 – 1955)

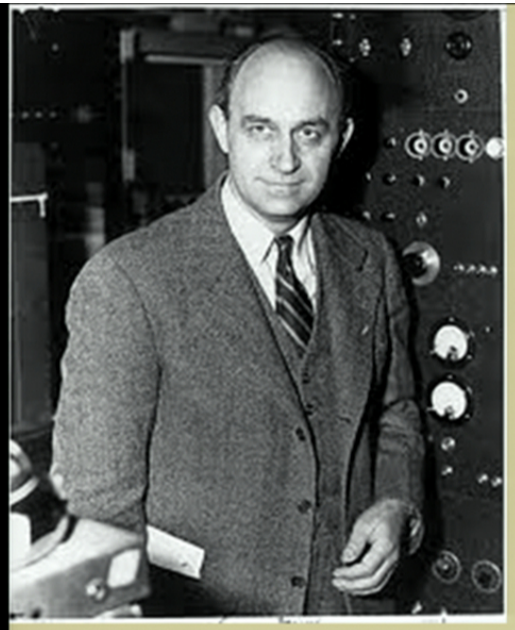
The special theory of relativity

uses the relativity principle of Galileo

The general theory of relativity

uses the equivalence principle





Eugene P. Wigner
(1902 – 1995)

"[Einstein's work marks] the reversal of a trend: until then, the principles of invariance were derived from the laws of motion … It is now natural for us to derive the laws of nature and to test their validity by means of the laws of invariance, rather than to derive the laws of invariance from what we believe to be the laws of nature"

Symmetries of information

A state of knowledge has a particular transformation as a symmetry if it is invariant under that transformation

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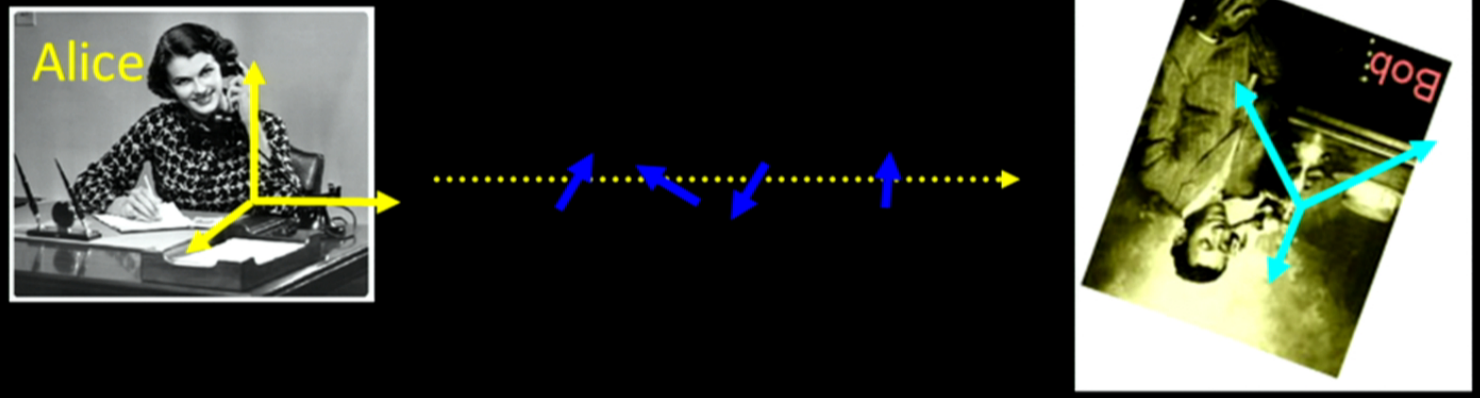
Alice
Bob

Metrology

Quantum theory can provide an advantage!

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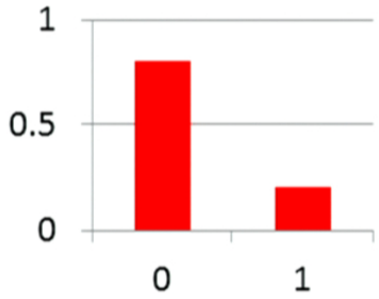
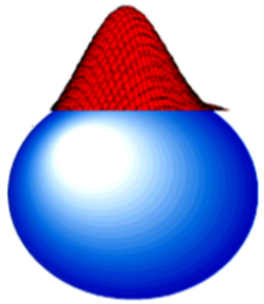
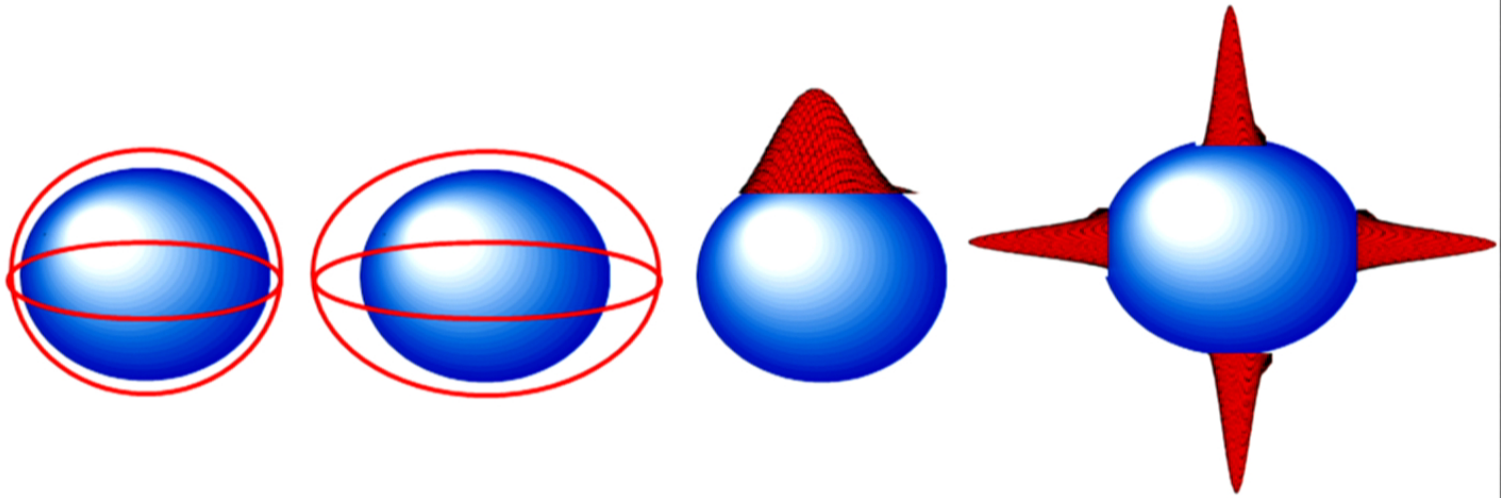


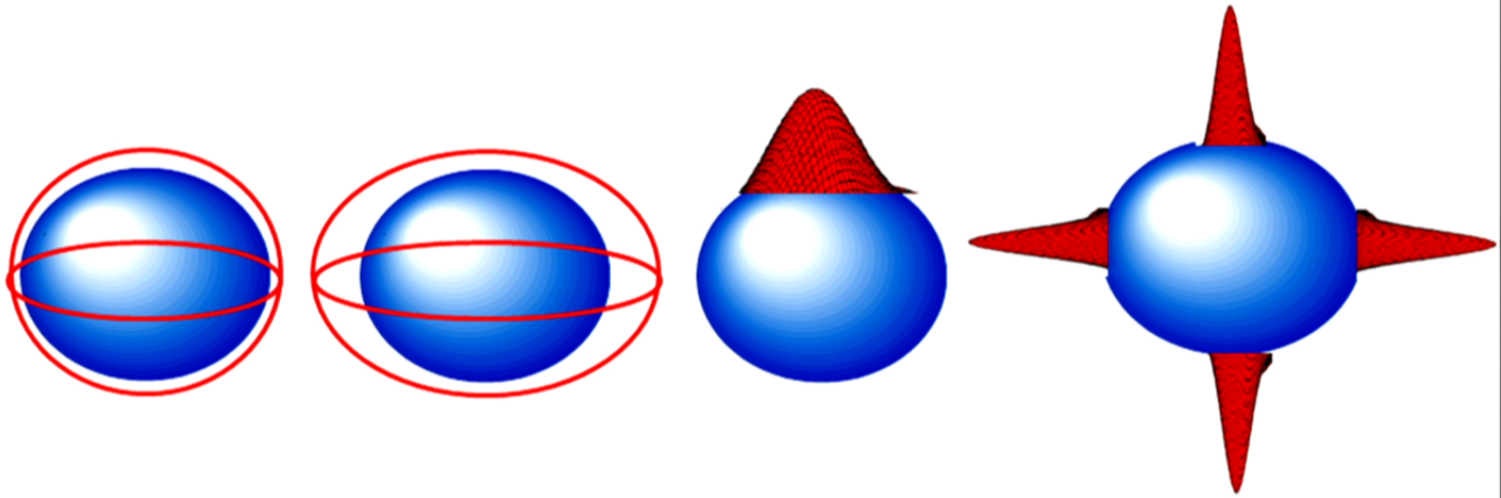


A states of knowledge = a probability distribution

Note: quantum states are states of knowledge

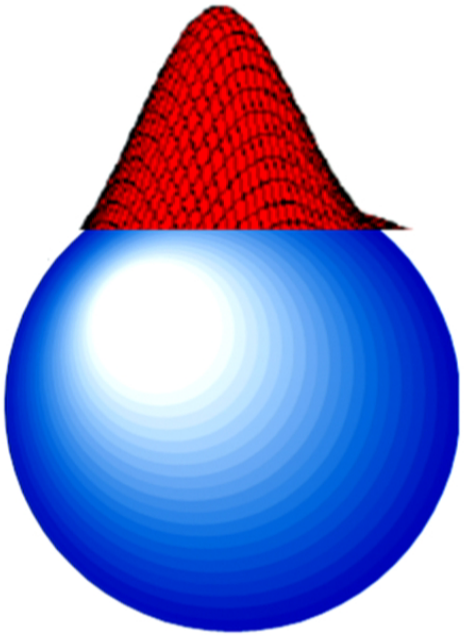


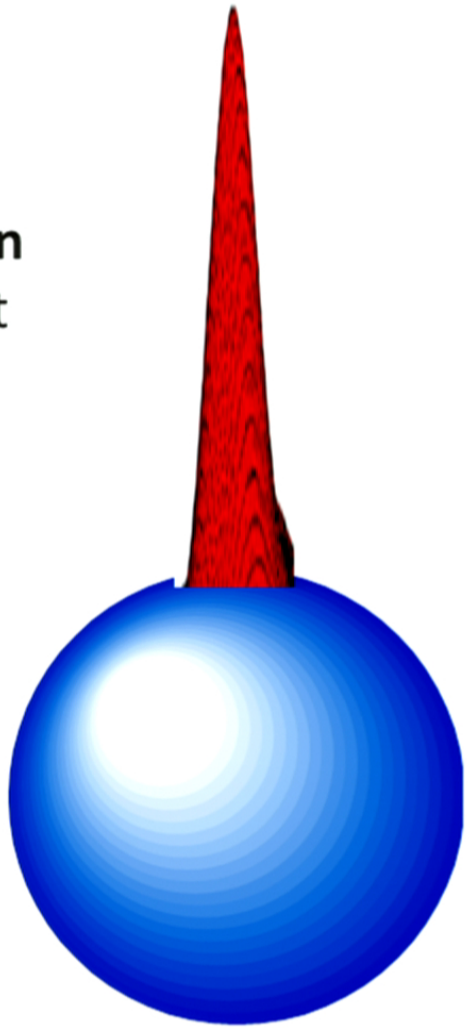
States of knowledge with different symmetries



States of knowledge with different symmetries

We can define a
measure of asymmetry
of a state of knowledge by
a measure of the information
that can be extracted from it





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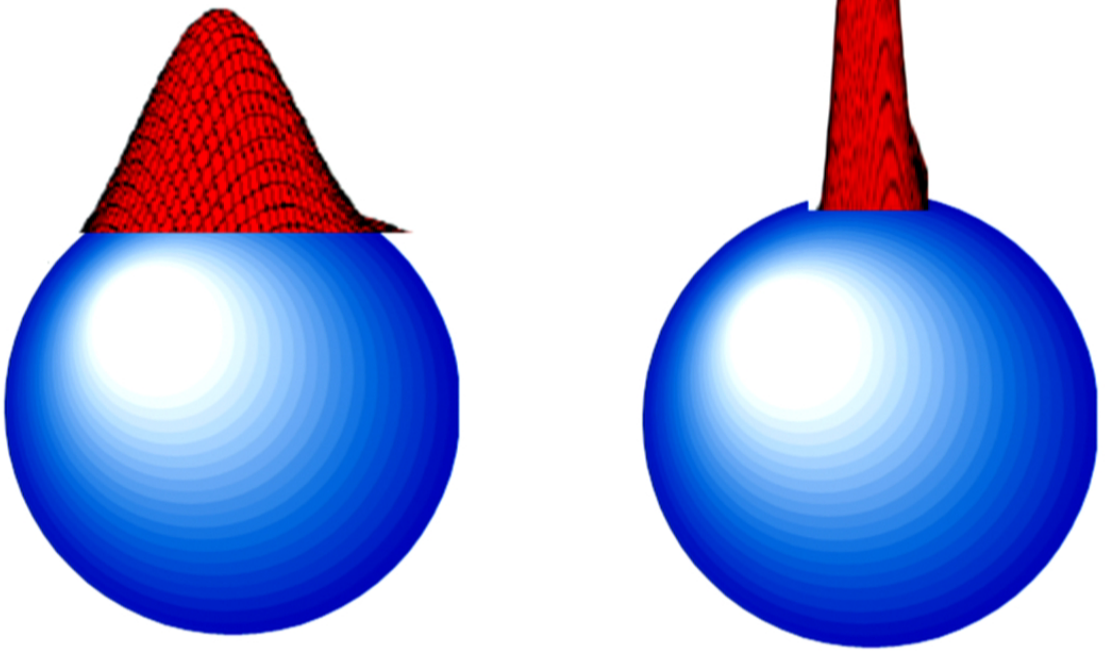

The principle of "Conservation of information":
The amount of information in a set of signals cannot be increased by processing

is equivalent to

A principle of "Conservation of asymmetry":
The amount of asymmetry in a state cannot be increased by processing

or

The measure of asymmetry of the signal cannot be greater than the measure of asymmetry of the source
A quantitative version of Curie's principle