MATH IN NATURE

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HISTORY OF THE FIBONACCI SEQUENCE

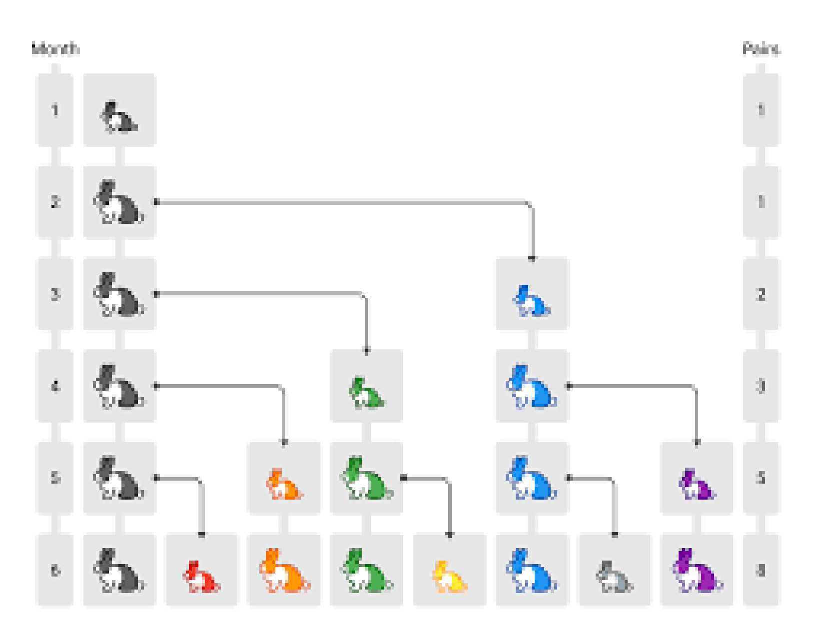
- First appeared in the book *Liber Abaci* by Fibonacci; used to calculate the growth of rabbit populations in an idealized (biologically unrealistic) setting

The conditions are as follows:

1. A newly born breeding pair of rabbits (1 male & 1 female) are put in a field
2. Each breeding pair mates at the age of 1 month
3. Each month, they always produce another pair of rabbits (1 male & 1 female)
4. Rabbits never die and continue breeding forever

So… how many pairs will there be in one year?

HISTORY OF THE FIBONACCI SEQUENCE CONTINUED

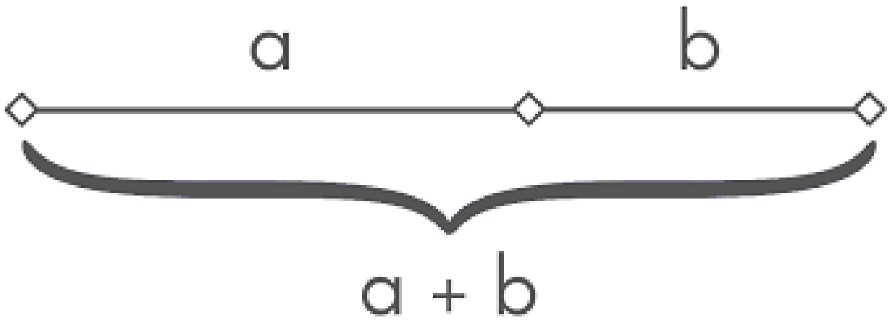


https://youtu.be/sjQlW6cH3Ko?si=rx28gysiLfi12Nbv&t=36

At the end of the *n*-th month, the number of pairs of rabbits is equal to the number of mature pairs (that is, the number of pairs in month $n - 2$) plus the number of pairs alive last month (month $n - 1$). The number in the *n*-th month is the *n*-th Fibonacci number.

THE GOLDEN RATIO

Also known as phi, the golden ratio is equal to approximately 1.618. It is the ratio of a line segment cut into 2 pieces of different lengths such that the ratio of the whole segment to that of the longer segment is equal to the ratio of the longer segment to the shorter segment.



THE GOLDEN RATIO

It is strongly associated with the Fibonacci sequence such that the ratio of each number with its previous number gradually approaches 1.618.

Fibonacci Numbers:	1	1	2	3	5	8	13	…	55	89	…
Ratios:		1	2	1.5	1.67	1.6	1.625	…	1.618		…

“Math is often described ... as a language or a tool that humans created to describe the world around them, with precision.

But there's another school of thought which suggests math is actually what the world is made of; that nature follows the same simple rules, time and time again, because mathematics underpins the fundamental laws of the physical world.

Instead, if we think of math as an essential component of nature that gives structure to the physical world, it might prompt us to reconsider our place in it rather than reveling in our own creativity.”

- Philosopher Sam Baron, Australian Catholic University

FIBONACCI NUMBERS IN FLOWER PETALS

1 petal - Calla Lily

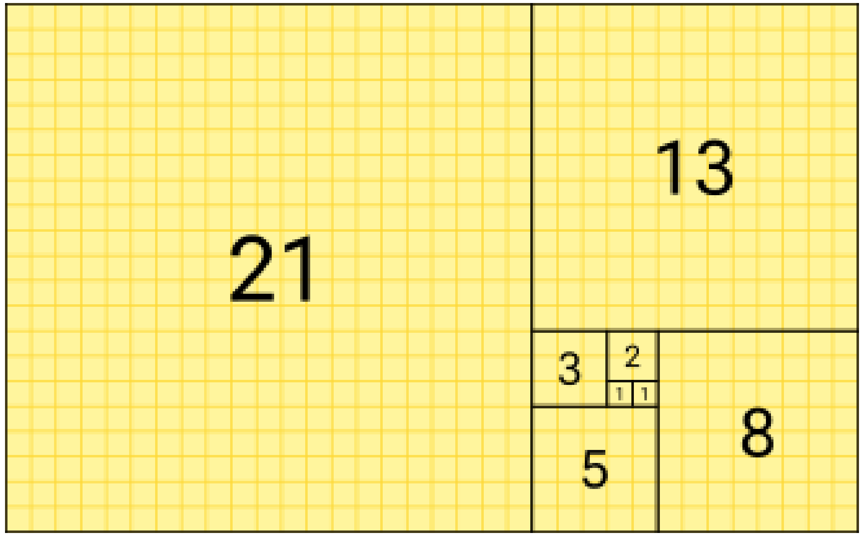
2 petals- Euphorbia Millii

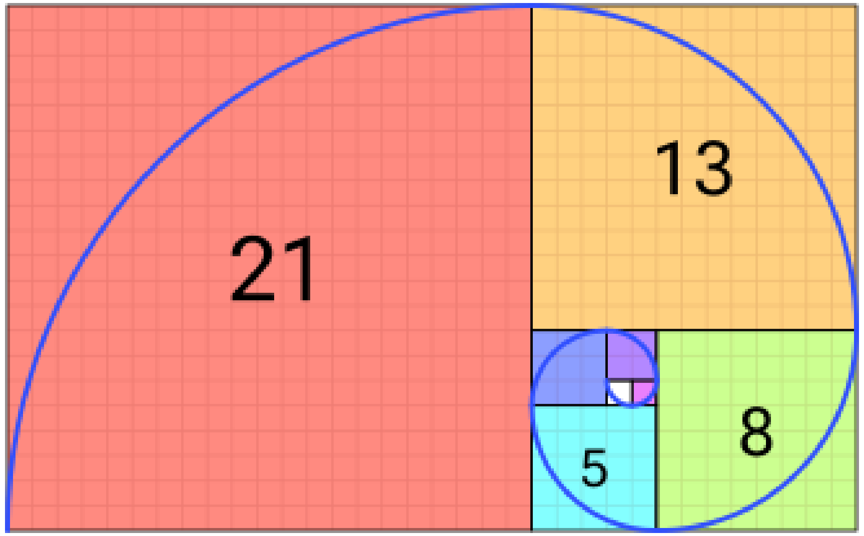
3 petals - Trillium

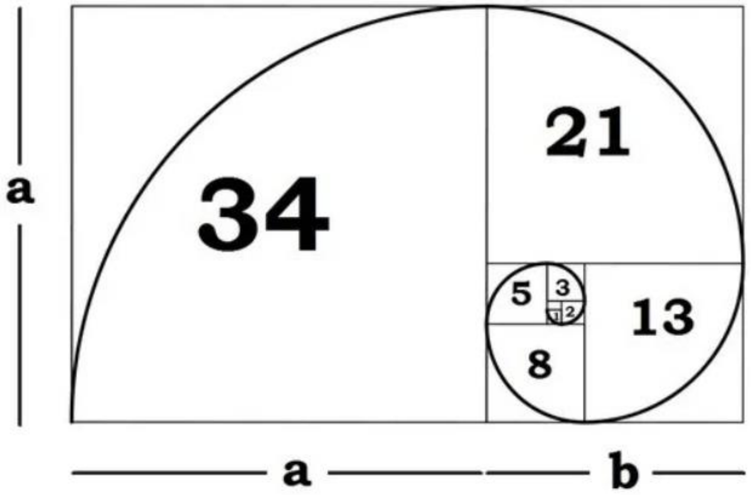
5 petals - Buttercup

8 petals - Bloodroot

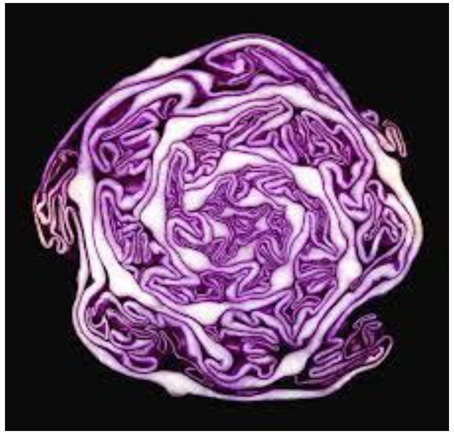
THE FIBONACCI SPIRAL







FIBONACCI SPIRALS IN NATURE



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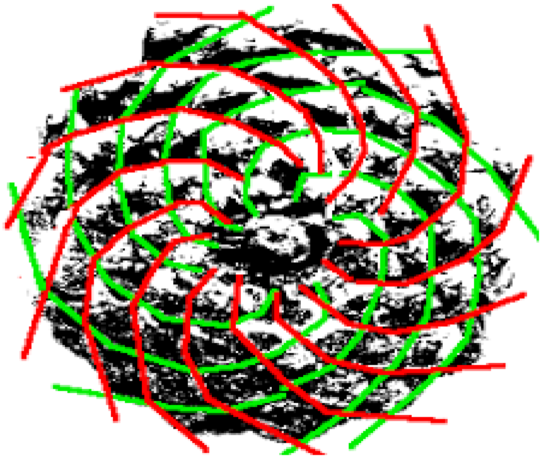
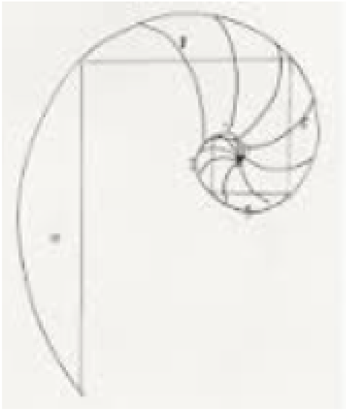
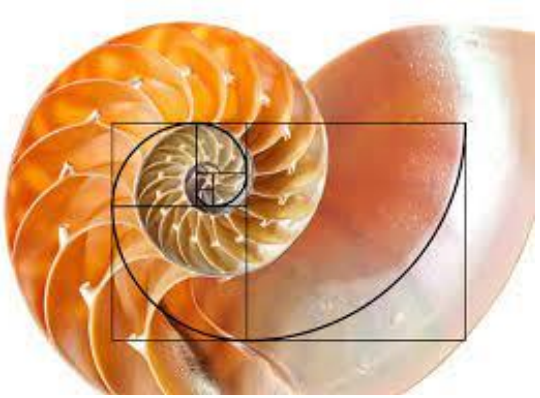
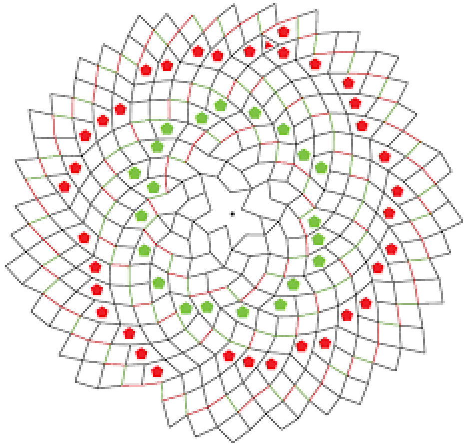


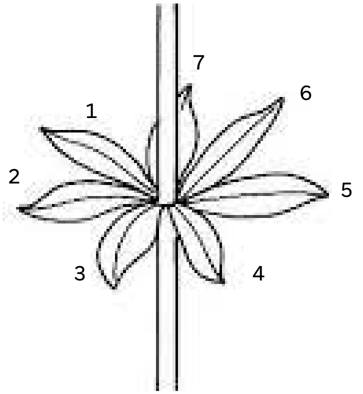


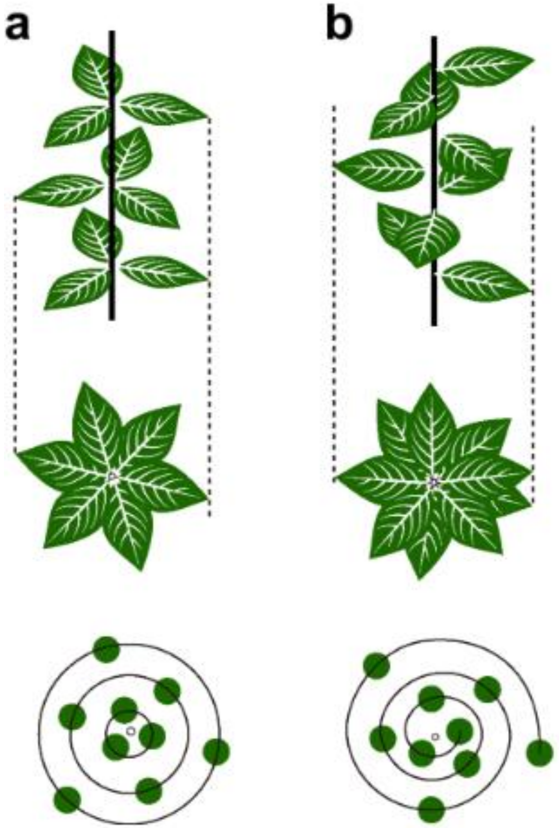


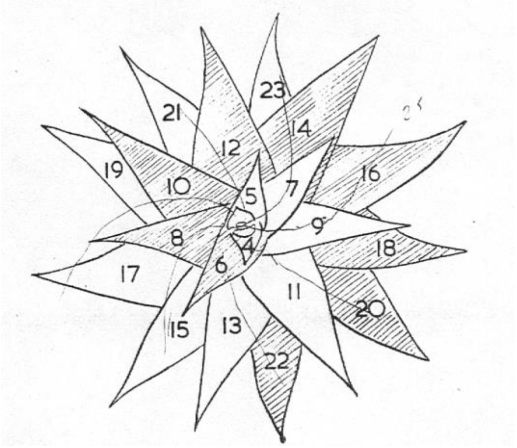


PHYLLOTAXIS:

THE ARRANGEMENT ON LEAVES ON A PLANT STEM







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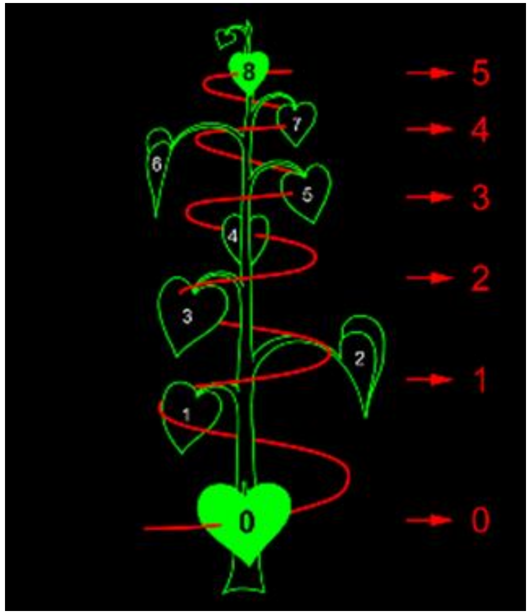


1/3 - Hazel

2/5 - Apricot

3/8 - Sunflower

5/13 - Willow

WHY DO WE SEE THE FIBONACCI SEQUENCE AND GOLDEN RATIO SO MUCH IN NATURE?

- In animals, researchers still are not certain why the growth and renewal of some tissues give rise to these patterns of Fibonacci numbers
- Genetic, evolutionary, and environmental factors all play a part
- Some believe that it is due to asymmetric cell division
  - Cells divide asymmetrically to create a mature and immature cell
  - Model output on the number of cells generated over time fits specific Fibonacci sequences depending on the maturation time

WHY DO WE SEE THE FIBONACCI SEQUENCE AND GOLDEN RATIO SO MUCH IN NATURE?

- It is the most efficient way for something to grow; i.e. some argue that maintaining the same shape through each successive turn of the spiral uses the least amount of energy

- Plants have made use of spirals to ensure that leaves have maximum light exposure or ensure maximum seed arrangement
  - The spiral happens naturally because each new cell is formed after a turn
  - The golden ratio creates a round shape with no gaps… But how can the golden ratio do this?

HOW DOES THE GOLDEN RATIO CREATE THIS COMPACT SHAPE?

- The golden ratio is an *irrational number*, meaning that it cannot be approximated by a fraction
- In fact, the golden ratio is as far as you can get from being near any fraction
- Any other ratio that is a simple fraction would eventually turn into a pattern of stacked lines - meaning *gaps* (fig 1)
- The corresponding golden angle is 137.5 degrees
    - Creates the same spacing between all seeds → optimal filling (fig 3)
- Only when the angle is exactly 137.5, 2 families of spirals (one in each direction) are visible

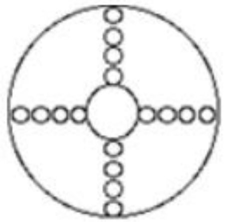


fig.1

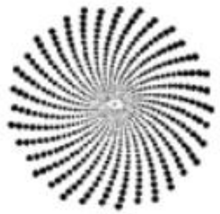


fig.2

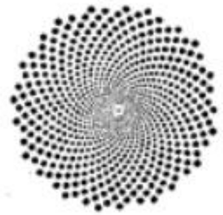
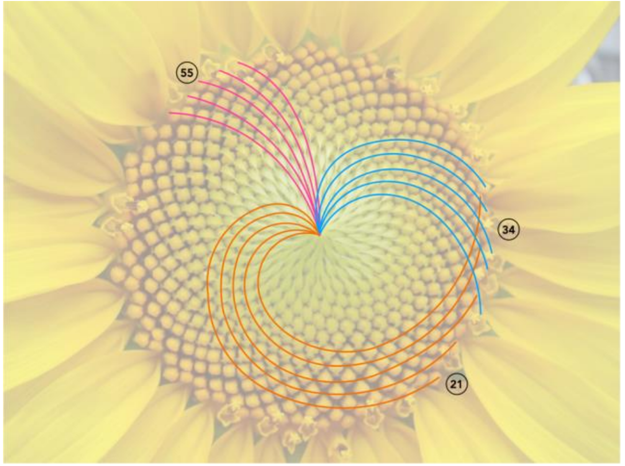
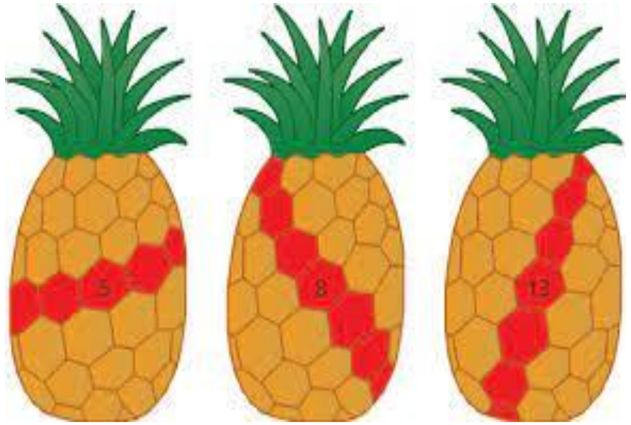


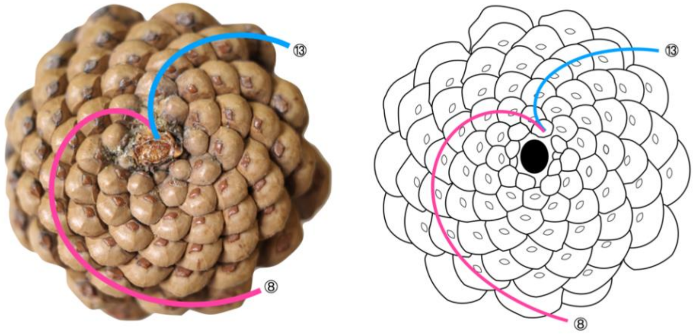
fig.3

FIBONACCI NUMBERS IN SPIRALS

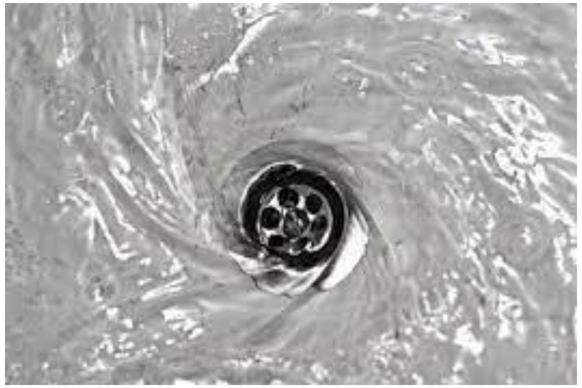
- The number of spirals in either direction correspond to the numerator and denominator of one of the fractions which approximates the golden ratio







OTHER EXAMPLES OF NATURAL SPIRALS



HOW DO WE KNOW THAT ALL OF THESE EXAMPLES IN NATURE RELATE TO THE FIBONACCI SEQUENCE?

WE DON'T!