Recurring Designs and Patterns in Nature

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About This Presentation

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Tree Stump vs. Human Fingerprint

Patterns in nature arise from natural processes, growth in particular

> We see the same patterns repeated in different contexts and on different scales

Near-perfect match between growth rings & fingerprints is what got me interested in studying this topic

A tree stump and a human fingerprint.



3. Spiral Patterns











Where Do Spirals Come From?

The Fibonacci spiral: 1, 1, 2, 3, 5, 8, 13, 21, ... The ratio F(n + 1) / F(n) tends to $\phi = (1 + \sqrt{5})/2 \sim 1.618$

The Golden Ratio plays a role in how things grow

On a rose, each new petal grows a factor of ϕ away from last petal (pine cone is similar)

On a sunflower, the spiral arrangement is the best way to house the most seeds



Fibonacci Spirals: Branches, Petals, Leaves

Suppose a branch must grow for two months before it is strong enough to support a new branch, then it branches every month

The number of petals in flowers 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, ... Lucas Numbers play a role too 2, 1, 3, 4, 7, 11, 18, 29, 47, 76, ...

Leaves grow with increasing spacing from one another to allow more sunlight to reach them





Recurring Designs and Patterns in Nature

Two References and Two Relevant Books

ON GROWTH

AND FORM







SCALE

The Universal Laws of Growth, Innovation, Sustainability, and the Pace of Life, in Organisms, Cities, Economies, and Companies



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More Sources, including Books on Fractals



SHAPE



THE HIDDEN GEOMETRY OF INFORMATION, BIOLOGY, STRATEGY, DEMOCRACY, AND EVERYTHING ELSE

JORDAN ELLENBERG

New York Times Bestselling Author of How Not to Be Wrong

THE deepest and most realistic finance book ever published." --Nassim Nicholas Taleb, author of The Black Seean (MIS)BEHAVIOR OF MARKETS A Fractal View of Financial

Financial Con THE FINANCIAL Turbulence

Author of THE FRACTAL GEOMETRY OF NATURE & RICHARD L. HUDSON



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Recurring Designs and Patterns in Nature

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1. Symmetry









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More Examples of Symmetry













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4. Flow and Chaos



5. Waves and Dunes



All about sand dunes: https://www.facebook.com/itsokaytobesmart/videos/662474401744279

6. Bubbles and Foam



7. Arrays and Tiling







8. Cracks



Dried mud



Cooled basalt



Palm trunk

Cracks in Desert, Glaze, Paint, Lava



9. Spots and Stripes



Mathematician Alan Turing was one of the first people to observe that spots & stripes can form when certain genes are switched on or off

And Here Are Some Stripes













Fractals Are Abundant in Nature





Benoit Mandelbrot, "Fractals and the Art of Roughness"

17-minute TED talk

https://www.ted.com/talks/benoit_mandelbrot_fract als_and_the_art_of_roughness?language=en





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Marble and Its Exquisite Patterns

Composed of limestone and various carbonate minerals Colorful veins are created by different substances





Marble Formation and Varieties

Found mostly in Italy, China, India, and Spain Formed under extreme heat and pressure in Earth's crust Different material impacted differently, hence the veins



River Basin, Tree, Leaf, Blood Vessels



Branching Patterns



Einstein: Physics | Mandelbrot: Geometry

Ben Weiss, "Fractals: A World in a Grain of Sand"

15-minute TED talk, https://www.ted.com/talks/ben_weiss_fractals_a_world_in_a_grain_of_sand



The Parameter c in $z \rightarrow z^2 + c$



Fractals Art: GIFs



Zooming in on a Section of a Coastline



Length of Coastline Is III-Defined



How Long is the US Pacific Coastline?

US State Department: 2131 km = 1324 mi Nat'l Oceanic & Atmospheric Admin.: 3288 km = 2043 mi



How Long is the California Coastline?

California Research Service: 1352 km = 840 mi Nat'l Oceanic & Atmospheric Admin.: 5115 km = 3427 mi

What fraction of the US Pacific coastline is in California?



Fractal Dimensions

What does it mean for a curve to be 1.5-dimensional?





straight line

fractal dimension = $\log(20/10)/\log(2) = 1$



27 squares





60 squares

fractal dimension = log(60/27)/log(2) = 1.152...

Sierpinski Triangle







https://mathigon.org/course/fractals/sierpinski







Number Patterns in the Pascal Triangle



Multiples of 2











Multiples of 11

2 3 3 1 Multiples of 7 Multiples of 10 4 6 4 1 10 10 5 5 6 15 20 15 6 35 35 21 21 1 7 7 8 28 56 70 56 28 8 36 84 126 126 84 36 1 9 9 120 210 252 210 120 10 45 45 10

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Questions?

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