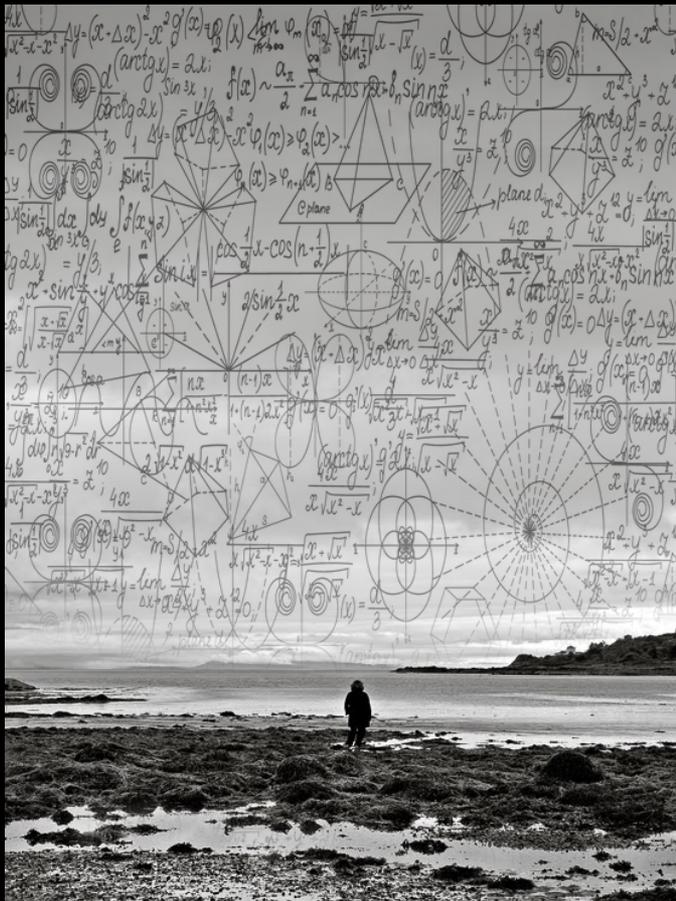


# Science & Art: Self-Entangled Pathways Toward Inner & Outer Truths

2017 Humanities and Technology Association Conference



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<http://www.sudden-stillness.com>

# Science & art: *separate, but entwined processes...*

<http://www.creativecriminals.com/images/mercedesleftrighbrain1.jpg>

## Left brain

I am the left brain.  
I am a scientist. A mathematician.  
I love the familiar. I categorize. I am accurate. Linear.  
Analytical. Strategic. I am practical.  
Always in control. A master of words and language.  
Realistic. I calculate equations and play with numbers.  
I am order. I am logic.  
I know exactly who I am.

## Right brain

I am the right brain.  
I am creativity. A free spirit. I am passion.  
Yearning. Sensuality. I am the sound of roaring laughter.  
I am taste. The feeling of sand beneath bare feet.  
I am movement. Vivid colors.  
I am the urge to paint on an empty canvas.  
I am boundless imagination. Art. Poetry. I sense. I feel.  
I am everything I wanted to be.

 Mercedes-Benz  
The best or nothing

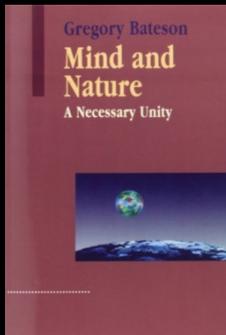
# Science & art: *what do they have in common?*

$$e^{i\pi} + 1 = 0 \quad \sum_i F_i = ma \quad \left\{ \begin{array}{l} \nabla \cdot \mathbf{E} = \frac{\rho}{\epsilon_0} \quad \nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t} \\ \nabla \cdot \mathbf{B} = 0 \quad \nabla \times \mathbf{B} = \mu_0 \left( \mathbf{J} + \epsilon_0 \frac{\partial \mathbf{E}}{\partial t} \right) \end{array} \right. \quad (i\partial - m)\psi = 0$$

$$x_{n+1} = \lambda x_n (1 - x_n) \quad \frac{\partial^2 u}{\partial t^2} = v^2 \nabla^2 u$$

$$\delta \int_{t_1}^{t_2} L dt \quad S = k_B \ln W \quad E = mc^2 \quad \left( \frac{-\hbar^2}{2m} \nabla^2 + V \right) \Psi = i\hbar \frac{\partial \Psi}{\partial t} \quad G_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

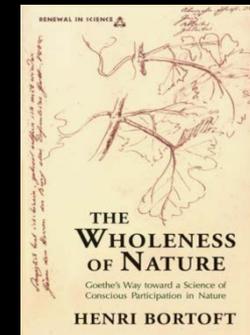
$$F = G \frac{m_1 m_2}{r^2}$$



## Beauty

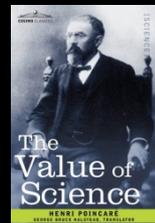
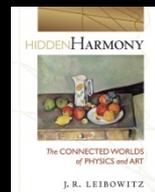
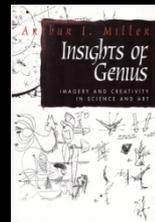
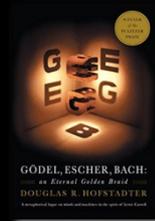
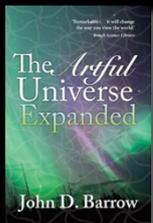
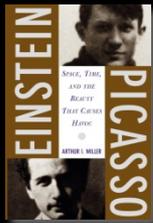
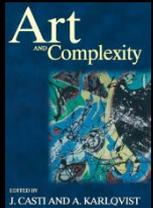
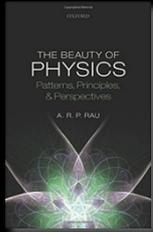
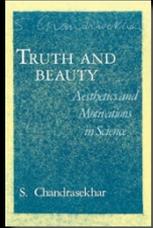
“Seeing the pattern of patterns that connects; Seeing the *metapattern*.”

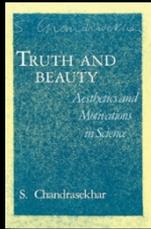
— Gregory Bateson  
(1904 – 1980, Anthropologist)



# Beauty in science and art

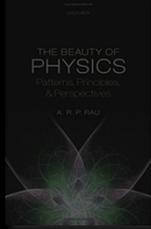
Dozens of books have examined beauty in science & art ...





“One may ask the question as to the extent to which the quest for beauty is an aim in the pursuit of science. . . . It is, indeed, an incredible fact that what the human mind, at its deepest and most profound, perceives as beautiful finds its realization in external nature. What is intelligible is also beautiful...**Beauty is that to what the human mind responds at its deepest and most profound.**”

– S. Chandrasekhar (1910 – 1995, *Astrophysicist*)

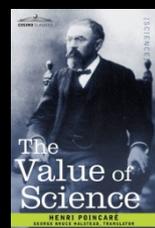
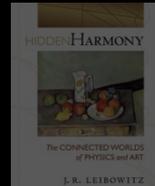
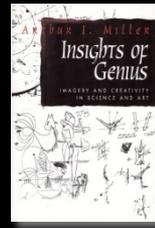


“For there are 'made' laws, 'discovered' laws, but also *laws* – a truth for all time. These are more or less hidden in the reality which surrounds us and do not change. Not only science but art also, shows us that **reality, at first incomprehensible, gradually reveals itself, by the mutual relations that are inherent in things.**”

– Piet Mondrian (1872 – 1944, *Artist*)

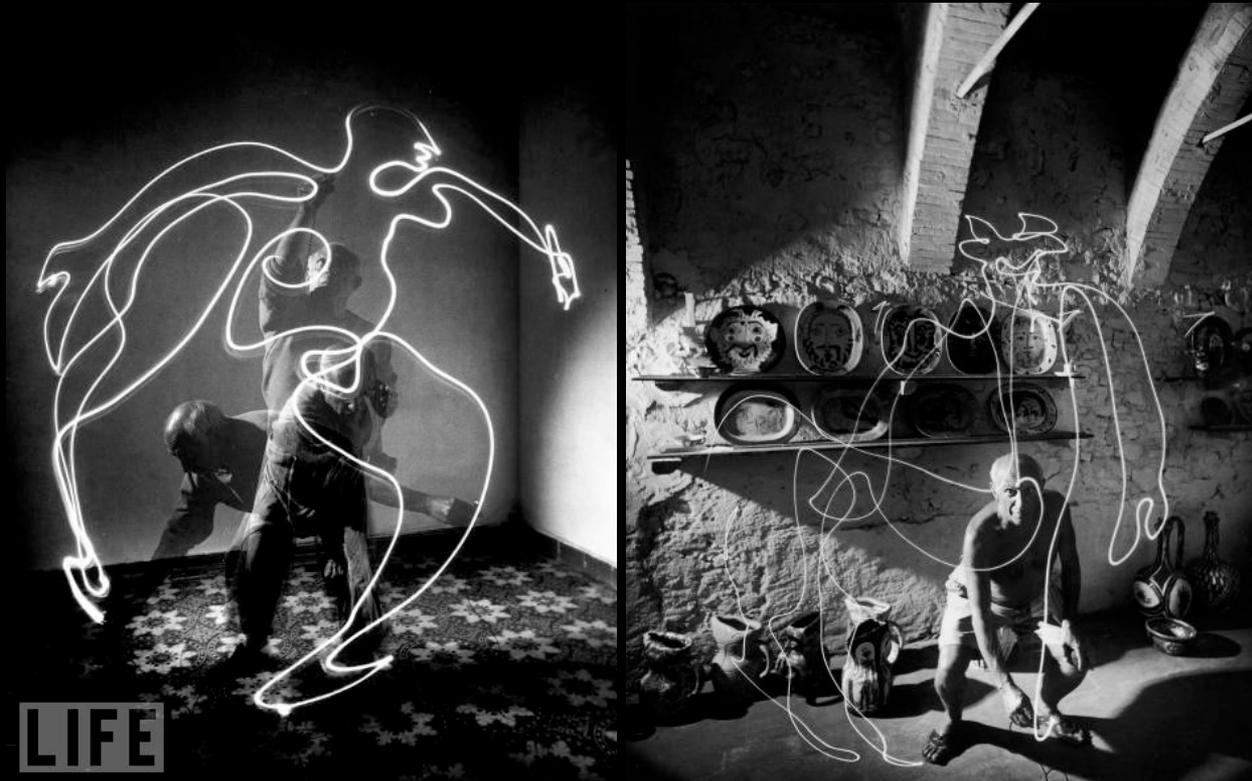
“The scientist does not study nature because it is useful to do so. He studies it because he takes pleasure in it; and he takes pleasure in it because it is beautiful...I mean the **intimate beauty that comes from the harmonious order of its parts** and that a pure intelligence can grasp.”

– Henri Poincare (1854 – 1912, *Physicist/Mathematician*)



Physics and photography both define and revel in *categories, divisions, groupings, labels, orders, and partitions*

An artist is a meta-pattern of “subjective order”

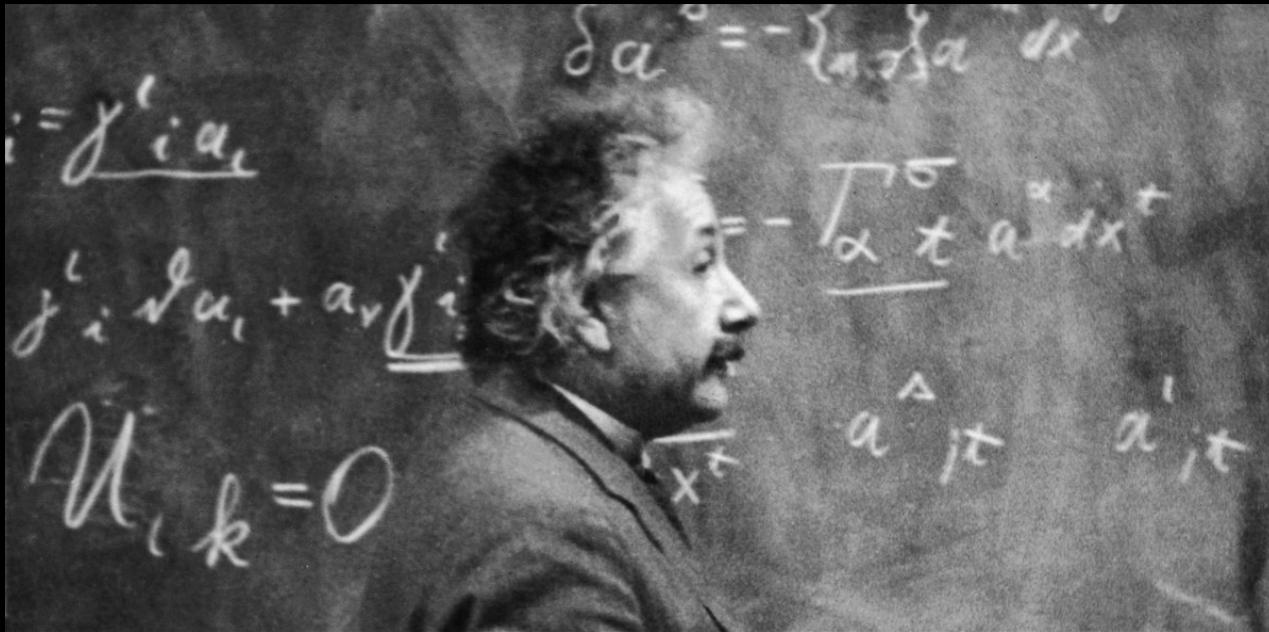


LIFE

Gjon Mili, *Life Magazine* (1949)

Physics and photography both define and revel in *categories, divisions, groupings, labels, orders, and partitions*

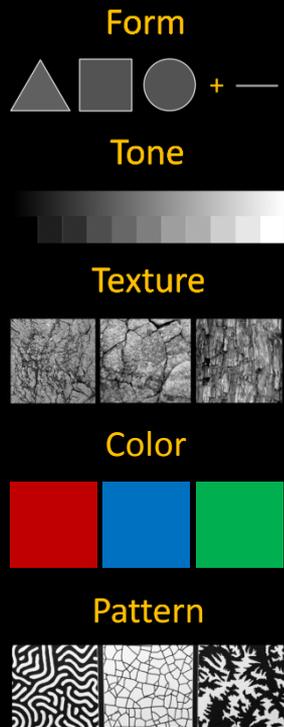
A **physicist** is a meta-pattern of “objective order”



<http://img.timeinc.net/time/2007/einstein/cuts/03.jpg>

Physics and photography both define and revel in *categories, divisions, groupings, labels, orders, and partitions*

**Art** is the transcendence of subjective categories

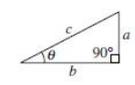


Wassily Kandinsky, *Improvisation 28* (1912)

# Physics and photography both define and revel in categories, divisions, groupings, labels, orders, and partitions

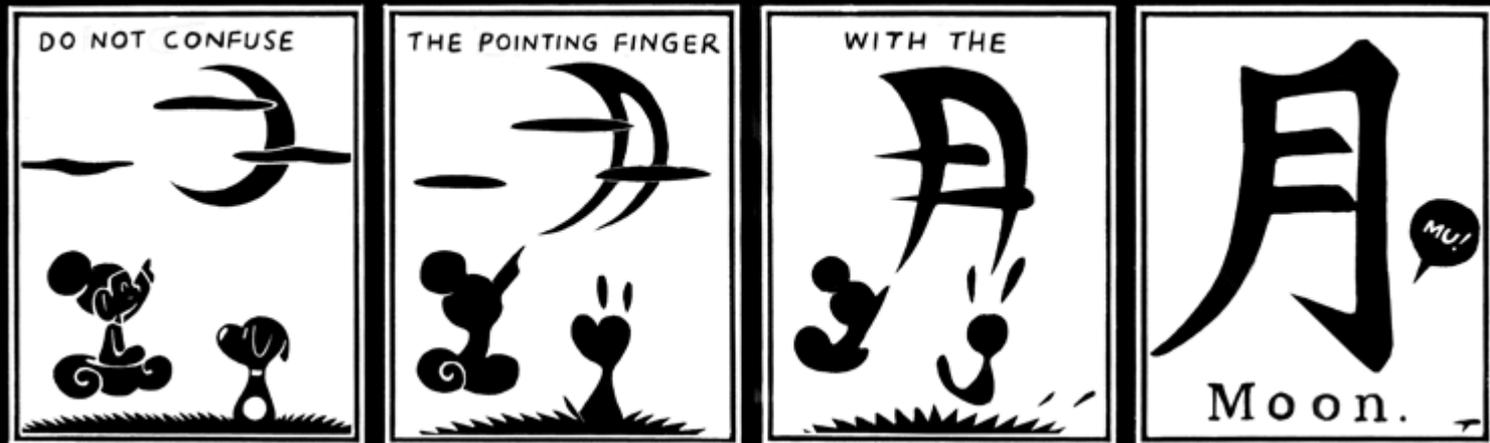
## Physics is a reduction / distillation of "objective categories"

NEWTONIAN MECHANICS	ELECTRICITY AND MAGNETISM	FLUID MECHANICS AND THERMAL PHYSICS	WAVES AND OPTICS
$v = v_0 + at$ $x = x_0 + v_0t + \frac{1}{2}at^2$ $v^2 = v_0^2 + 2a(x - x_0)$ $\Sigma \mathbf{F} = \mathbf{F}_{net} = ma$ $F_{fric} \leq \mu N$ $a_c = \frac{v^2}{r}$ $\tau = rF \sin \theta$ $p = mv$ $\mathbf{J} = \mathbf{F}\Delta t = \Delta p$ $K = \frac{1}{2}mv^2$ $\Delta U_g = mgh$ $W = F\Delta r \cos \theta$ $F_{avg} = \frac{W}{\Delta t}$ $P = Fv \cos \theta$ $F_s = -kx$ $U_s = \frac{1}{2}kx^2$ $T_s = 2\pi\sqrt{\frac{m}{k}}$ $T_p = 2\pi\sqrt{\frac{\ell}{g}}$ $T = \frac{1}{f}$ $F_G = -\frac{Gm_1m_2}{r^2}$ $U_G = -\frac{Gm_1m_2}{r}$	$F = \frac{kq_1q_2}{r^2}$ $E = \frac{F}{q}$ $U_E = qV = \frac{kq_1q_2}{r}$ $E_{avg} = -\frac{V}{d}$ $V = k\left(\frac{q_1}{r_1} + \frac{q_2}{r_2} + \frac{q_3}{r_3} + \dots\right)$ $C = \frac{Q}{V}$ $C = \frac{\epsilon_0 A}{d}$ $U_C = \frac{1}{2}QV = \frac{1}{2}CV^2$ $I_{avg} = \frac{\Delta Q}{\Delta t}$ $R = \frac{\rho \ell}{A}$ $V = IR$ $P = IV$ $C_p = C_1 + C_2 + C_3 + \dots$ $\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \dots$ $R_2 = R_1 + R_2 + R_3 + \dots$ $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$ $F_B = qvB \sin \theta$ $F_B = BI\ell \sin \theta$ $B = \frac{\mu_0 I}{2\pi r}$ $\phi_m = BA \cos \theta$ $\mathcal{E}_{avg} = -\frac{\Delta \phi_m}{\Delta t}$ $\mathcal{E} = B\ell v$	$\rho = m/V$ $P = R_0 + \rho gh$ $F_{buoy} = \rho Vg$ $A_1v_1 = A_2v_2$ $P + \rho gy + \frac{1}{2}\rho v^2 = \text{const.}$ $\Delta \ell = \alpha \ell_0 \Delta T$ $H = \frac{kA\Delta T}{L}$ $P = \frac{F}{A}$ $PV = nRT = Nk_B T$ $K_{avg} = \frac{3}{2}k_B T$ $v_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3k_B T}{\mu}}$ $W = -P\Delta V$ $\Delta U = Q + W$ $e_c = \frac{T_H - T_C}{T_H}$	$v = f\lambda$ $n = \frac{c}{v}$ $n_1 \sin \theta_1 = n_2 \sin \theta_2$ $\sin \theta_c = \frac{n_2}{n_1}$ $\frac{1}{s_i} + \frac{1}{s_o} = \frac{1}{f}$ $M = \frac{h_i}{h_o} = -\frac{s_i}{s_o}$ $f = \frac{R}{\lambda}$ $d \sin \theta = m\lambda$ $x_m = \frac{m\lambda L}{d}$
		$A = \text{area}$ $B = \text{magnetic field}$ $C = \text{capacitance}$ $d = \text{distance}$ $E = \text{electric field}$ $\mathcal{E} = \text{emf}$ $F = \text{force}$ $I = \text{current}$ $\ell = \text{length}$ $P = \text{power}$ $Q = \text{charge}$ $q = \text{point charge}$ $R = \text{resistance}$ $r = \text{distance}$ $t = \text{time}$ $U = \text{potential (stored) energy}$ $V = \text{electric potential or potential difference}$ $v = \text{velocity or speed}$ $\rho = \text{resistivity}$ $\theta = \text{angle}$ $\phi_m = \text{magnetic flux}$	$d = \text{separation}$ $f = \text{frequency or focal length}$ $h = \text{height}$ $L = \text{distance}$ $M = \text{magnification}$ $m = \text{an integer}$ $n = \text{index of refraction}$ $R = \text{radius of curvature}$ $s = \text{distance}$ $v = \text{speed}$ $x = \text{position}$ $\lambda = \text{wavelength}$ $\theta = \text{angle}$
		$A = \text{area}$ $e = \text{efficiency}$ $F = \text{force}$ $h = \text{depth}$ $H = \text{rate of heat transfer}$ $k = \text{thermal conductivity}$ $K_{avg} = \text{average molecular kinetic energy}$ $\ell = \text{length}$ $L = \text{thickness}$ $m = \text{mass}$ $M = \text{molar mass}$ $n = \text{number of moles}$ $N = \text{number of molecules}$ $P = \text{pressure}$ $Q = \text{heat transferred to a system}$ $T = \text{temperature}$ $U = \text{internal energy}$ $V = \text{volume}$ $v = \text{velocity or speed}$ $v_{rms} = \text{root-mean-square velocity}$ $W = \text{work done on a system}$ $y = \text{height}$ $\alpha = \text{coefficient of linear expansion}$ $\mu = \text{mass of molecule}$ $\rho = \text{density}$	<b>GEOMETRY AND TRIGONOMETRY</b> Rectangle $A = bh$ $C = \text{circumference}$ Triangle $A = \frac{1}{2}bh$ $h = \text{height}$ $b = \text{base}$ $S = \text{surface area}$ $V = \text{volume}$ Circle $A = \pi r^2$ $C = 2\pi r$ $\ell = \text{length}$ $w = \text{width}$ $r = \text{radius}$ Rectangular Solid $V = \ell wh$ Cylinder $V = \pi r^2 \ell$ $S = 2\pi r \ell + 2\pi r^2$ Sphere $V = \frac{4}{3}\pi r^3$ $S = 4\pi r^2$ Right Triangle $a^2 + b^2 = c^2$ $\sin \theta = \frac{a}{c}$ $\cos \theta = \frac{b}{c}$ $\tan \theta = \frac{a}{b}$
		<b>ATOMIC AND NUCLEAR PHYSICS</b> $E = hf = pc$ $K_{max} = hf - \phi$ $\lambda = \frac{h}{p}$ $\Delta E = (\Delta m)c^2$	$A = \text{area}$ $C = \text{circumference}$ $V = \text{volume}$ $S = \text{surface area}$ $h = \text{height}$ $b = \text{base}$ $\ell = \text{length}$ $w = \text{width}$ $r = \text{radius}$ $\mu = \text{mass of molecule}$ $\rho = \text{density}$



Physics and photography both define and revel in *categories, divisions, groupings, labels, orders, and partitions*

However, there are good reasons for reminding ourselves of the arbitrariness of divisions, and of the implicit presence of the “I” in making them ...



Tatsuya Ishida (<http://sinfest.net/comikaze/comics/2010-02-01.gif>)

“Physical concepts are free creations of the human mind,  
and are not, however it may seem,  
uniquely determined by the external world.”

– Albert Einstein (1879 – 1955, *Physicist*)

# Let's revisit the separate, but *entwined* processes...

<http://www.creativecriminals.com/images/mercedesleftrighbrain1.jpg>

**Left**  
brain

I am the left brain.  
I am a scientist. A mathematician.  
I love the familiar. I categorize. I am accurate. Linear.  
Analytical. Strategic. I am practical.  
Always in control. A master of words and language.  
Realistic. I calculate equations and play with numbers.  
I am order. I am logic.  
I know exactly who I am.

**Right**  
brain

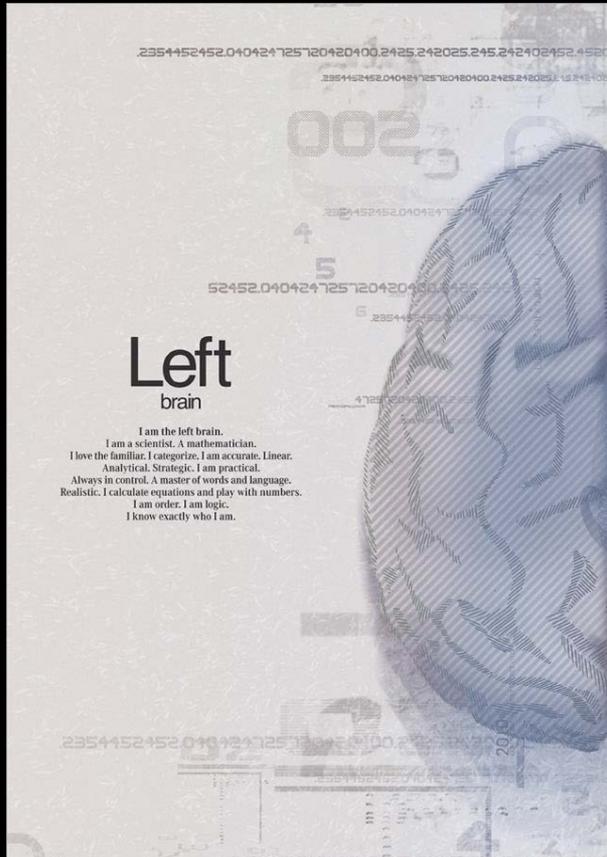
I am the right brain.  
I am extroverted. A free spirit. I am passion.  
Yearning. Sensuality. I am the sound of roaring laughter.  
I am taste. The feeling of sand beneath bare feet.  
I am movement. Vivid colors.  
I am the urge to paint on an empty canvas.  
I am boundless imagination. Art. Poetry. I sense. I feel.  
I am everything I wanted to be.

 Mercedes-Benz  
The best or nothing

# ...my left side

*Physics*: the science of distilling perceived order into simplest possible form  
*Complexity*: self-organized emergence of global order that arises from local simplicity

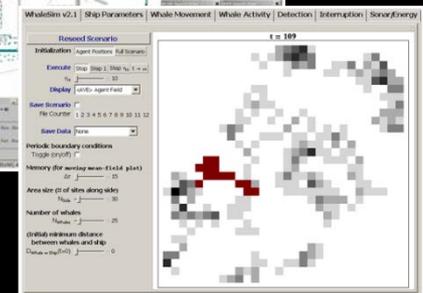
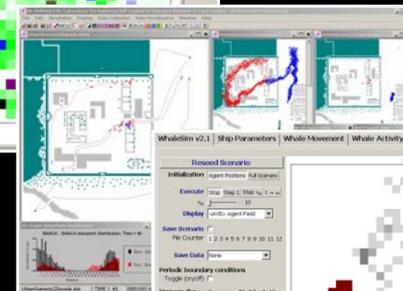
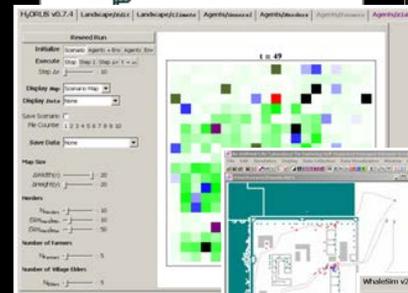
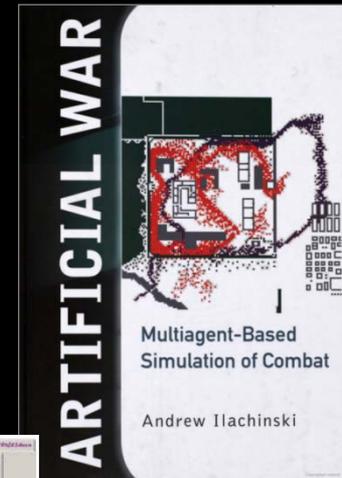
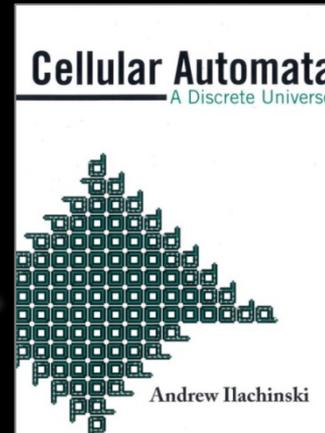
<http://www.creativecriminals.com/images/mercedesleftrighbrain1.jpg>



## By day...

I am a physicist, specializing in chaos, complexity theory, and mathematical modeling

Andy Ilachinski, *Principal Research Scientist*





# Separate, but *entwined* processes...

<http://www.creativecriminals.com/images/mercedesleftrightbrain1.jpg>

## Who am I?

**Left brain**

I am the left brain.  
I am a scientist. A mathematician.  
I love the familiar. I categorize. I am accurate. Linear.  
Analytical. Strategic. I am practical.  
Always in control. A master of words and language.  
Realistic. I calculate equations and play with numbers.  
I am order. I am logic.  
I know exactly who I am.

**Right brain**

I am the right brain.  
I am strong. A free spirit. I am passion.  
Yearning. Sensuality. I am the sound of roaring laughter.  
I am taste. The feeling of sand beneath bare feet.  
I am movement. Vivid colors.  
I am the urge to paint on an empty canvas.  
I am boundless imagination. Art. Poetry. Love. I feel.  
I am everything I wanted to be.

Physicist

Photographer

Complexicologist

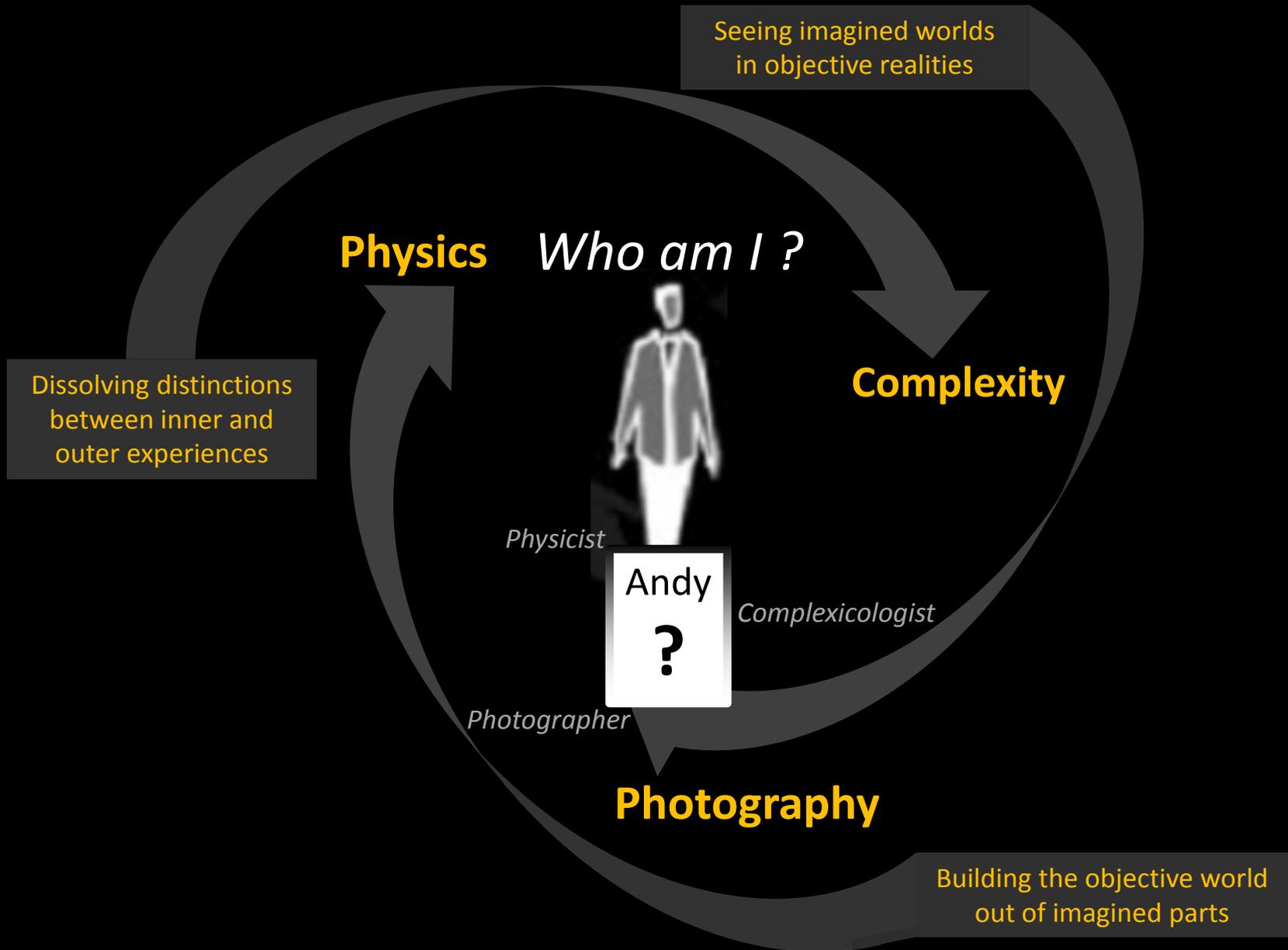
Andy ?

Mercedes-Benz  
The best or nothing.

“The division of the perceived universe into parts and wholes is convenient and may be necessary, but no necessity determines how it shall be done.”

– Gregory Bateson (1904 – 1980, *Anthropologist*)

# Separate, but *entwined* processes...



Seeing imagined worlds  
in objective realities

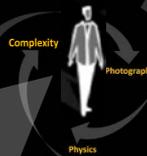
**Physics**

Who am I ?

**Complexity**

Dissolving distinctions  
between inner and  
outer experiences

Photography



Physics

The best way to discover  
this "I" is to examine what it  
has spent a lifetime *creating*

Complexity

"I" am a creature on a  
creative journey, whose  
path is both *informed by*  
– and *shapes* – many  
"subjective" and  
"objective" categories

**Photography**

Building the objective world  
out of imagined parts

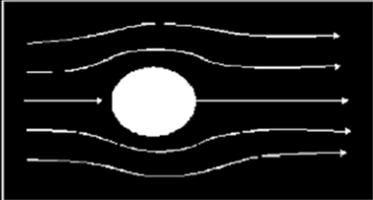
# Sometimes I ponder about physics when something catches my eye...

**Navier-Stokes Equations of Fluid Flow**

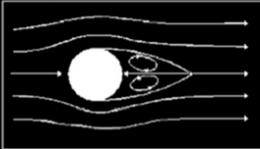
$$\begin{cases} \frac{\partial \vec{v}}{\partial t} + (\vec{v} \cdot \nabla) \vec{v} = -\frac{1}{\rho} \nabla p + \nu \nabla^2 \vec{v}, \\ \nabla \cdot \vec{v} = 0 \end{cases}$$

$\delta \equiv \lim_{n \rightarrow \infty} \frac{\alpha_n - \alpha_{n-1}}{\alpha_{n+1} - \alpha_n} = 4.6692016091$

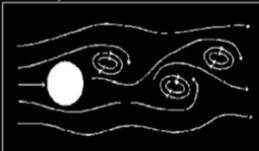
$\Delta \equiv \lim_{n \rightarrow \infty} \frac{d_n}{d_{n+1}} = 2.5029078750 \dots$



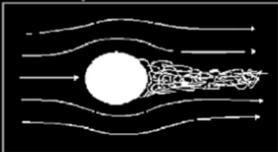
Reynolds Number  $\sim 10^{-2}$



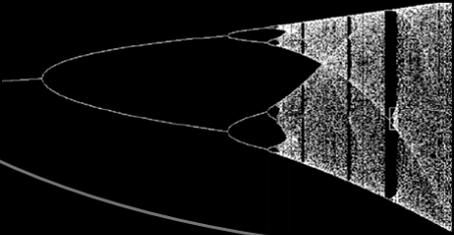
Reynolds Number  $\sim 10$



Reynolds Number  $\sim 100$



Reynolds Number  $\sim 10^5$



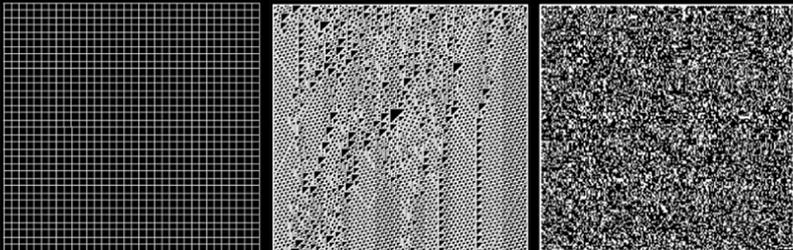
# Sometimes I *ponder about complexity* ...

$$I = -\sum_{i=1}^N p_i \log_2 p_i$$

$$K_U(s) \equiv |\mathcal{P}_U^*|$$

$$K(\mathcal{C}) = \frac{2}{(D+1)(D+2)} \sum_{i=0}^D (i+1)Q_i$$

*Computational complexity*  
*Algorithmic complexity*  
*Logical depth*  
*Thermodynamic depth*



**Order**                      **Complexity**                      **Randomness**

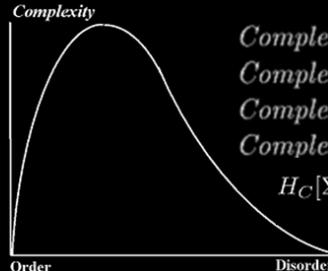
$$\mathcal{C} = \min_{A \in \mathcal{A}} \mathcal{N}_{\mathcal{A}}(f)$$

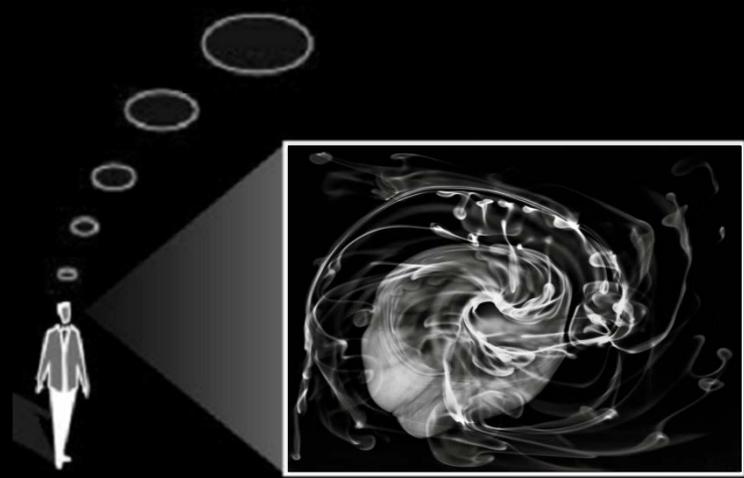
$$\mathcal{D}_U^L(\mathcal{O}) = \tau_U(\mathcal{P}^*)$$

$$\mathcal{C}(T) = \log_2 \{ f(k_T) \prod_{j=1}^k \mathcal{D}(T_j) \}$$

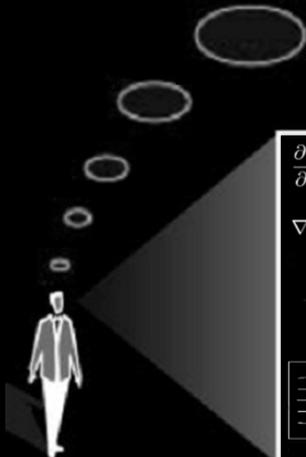
*Complexity as information*  
*Complexity of a graph*  
*Complexity of a simplex*  
*Complexity of a hierarchical system*

$$H_C[\Sigma_N^{(f)}] = \min_{U(\mathcal{P})=\Sigma_N^{(f)}} \tau_U(\mathcal{P})$$





# Sometimes I use my physics to *steer my eye / camera*

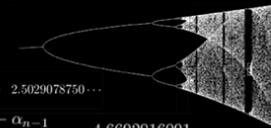


$$\frac{\partial \vec{v}}{\partial t} + (\vec{v} \cdot \nabla) \vec{v} = -\frac{1}{\rho} \nabla p + \nu \nabla^2 \vec{v},$$

$$\nabla \cdot \vec{v} = 0$$

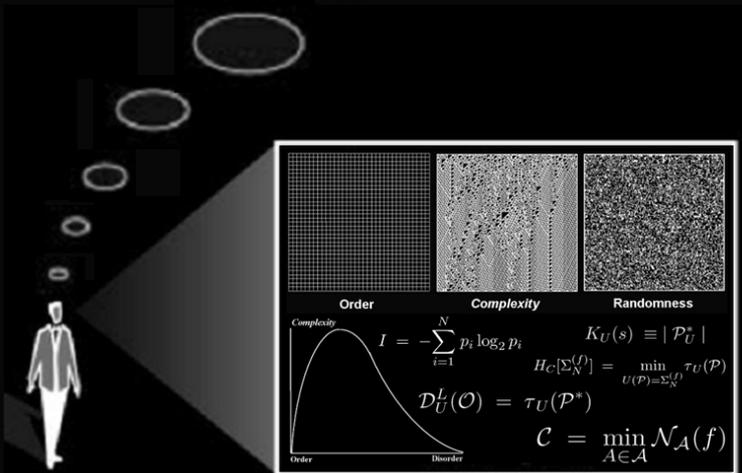
$$\Delta \equiv \lim_{n \rightarrow \infty} \frac{d_n}{d_{n+1}} = 2.5029078750 \dots$$

$$\delta \equiv \lim_{n \rightarrow \infty} \frac{\alpha_n - \alpha_{n-1}}{\alpha_{n+1} - \alpha_n} = 4.6692016091$$



Reynolds Number  $\sim 10^1$       Reynolds Number  $\sim 100$       Reynolds Number  $\sim 10^3$

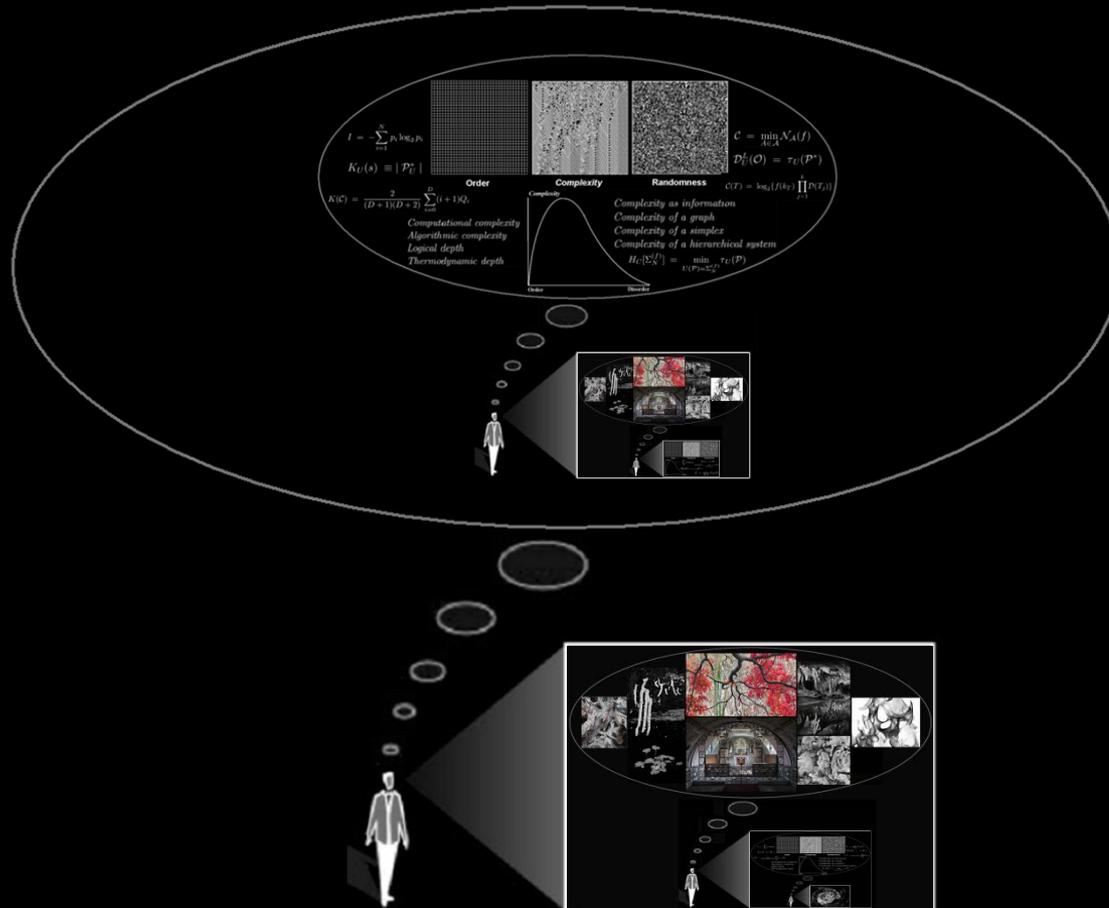
# Sometimes complexity steers my eye / camera...



# In truth, the “I” is a *complex nested creative process*...

[Art is a process] “...in which we give ourselves so deeply to our seeing that we take things right into ourselves and then give forth a new version of them from inside, tinted by all of the possibilities within us, transformed the way an oyster takes grit and makes a pearl.”

— Sean Kernan, *Photographer (Lenswork, May 2004)*



At first, the *photographer* finds the *picture*...

Something about the *photographer* draws him to it



# At first, the *photographer* finds the *picture*...

Something about the *photographer* draws him to it

**Physicist**

Light,  
Entropy,  
Geometry

**Poet**

Romance, History,  
Culture



**Photographer A**

Textures, Landscape

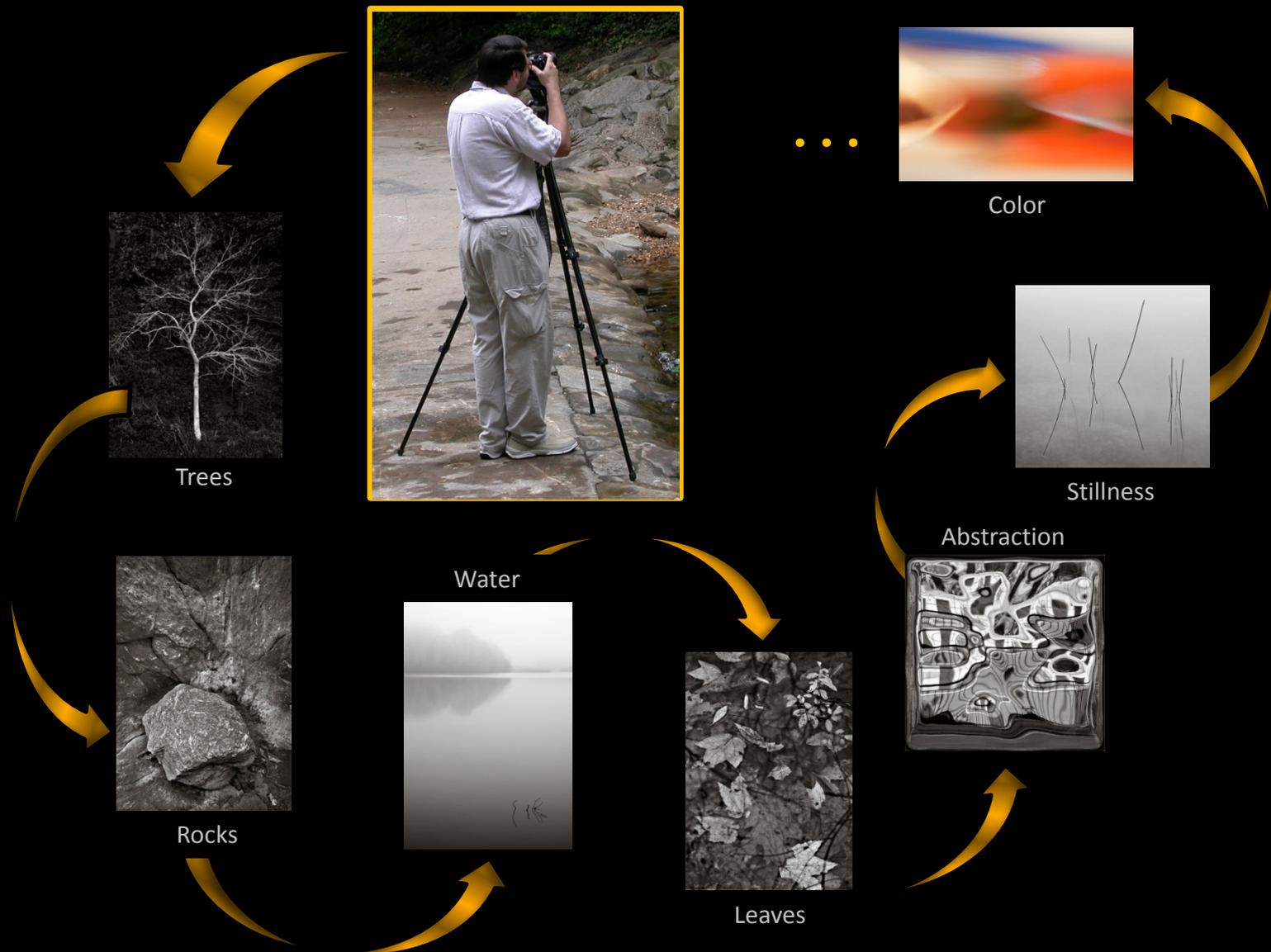
**Photographer B**

Dilapidated door,  
Contrast

**Photographer C**

Tones, Forms

...the *pictures* discover a *path*...



...the path *assembles* itself...

Physics



Complexity

Photography

**Common Theme**

*Relationship between  
the Whole and its Parts*

**Physics**

*Patterns ↔ Order*

**Complexity**

*Micro ↔ Macro*

**Photography**

*Compositional  
Elements ↔ Image /  
Meaning*

*Emergence,  
Transcendence*



# Display/Portfolio: Synesthetic Landscapes

Synesthesia = Greek *syn* (“union”) plus *aisthesis* (“sensation”) → “joined sensation”

Such as when something that is ordinarily “seen” is tasted as well

E.g., Wassily Kandinsky, Vladimir Nobokov, David Hockney, Richard Feynman, and Alexander Scriabin

How someone with *grapheme* → *color* synesthesia might perceive letters and digits



Synesthetic mapping	Freq (%)	Synesthetic mapping	Freq (%)
Graphemes → Colors	66.8	Personalities → Colors	4.4
Time → Colors	19.2	Pain → Colors	4.4
Music → Colors	14.5	Sound → Flavors	2.7
Sounds → Colors	12.1	Sound → Touch	2.7
Notes → Colors	10.4	Temperature → Colors	2.2
Phonemes → Colors	9.6	Sound → Smell	1.1
Flavors → Colors	6.3	Taste → Touch	1.1
Odors → Colors	5.8	Vision → Sound	1.1

*Luminous Landscape*

Online exhibit/essay; May 2015

*Bodzin Art Gallery*

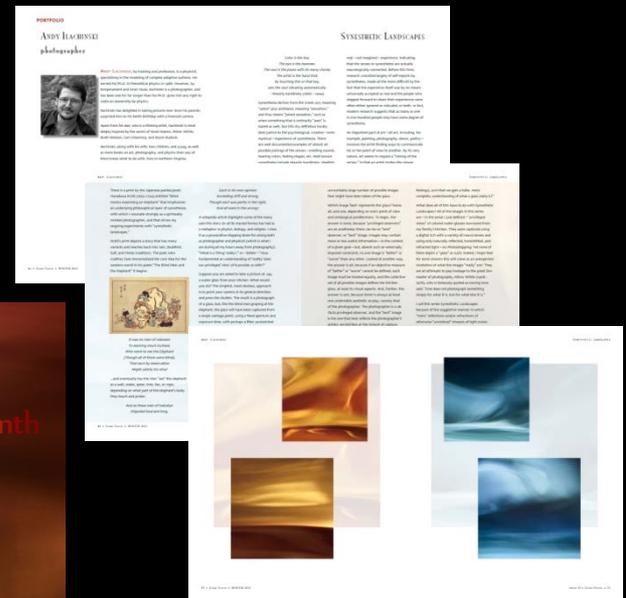
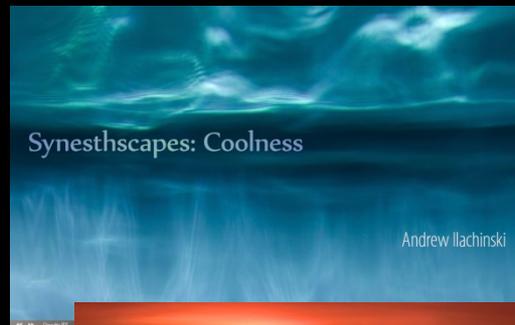
Solo Exhibit, Winter 2015

*Lenzwerk Magazine*

Issue #105, March-April 2013

*Stone Voices Magazine*

Winter 2013





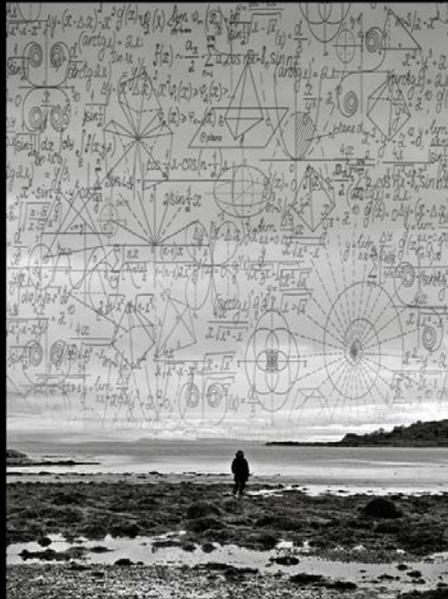
“When words become unclear,  
I shall focus with photographs.  
When images become inadequate,  
I shall be content with silence.”

— ANSEL ADAMS



# Science & Art: Self-Entangled Pathways Toward Inner & Outer Truths

2017 Humanities and Technology Association Conference



Dr. Andy Ilachinski  
Center for Naval Analyses  
703-824-2045  
ilachina@cna.org

<http://tao-of-digital-photography.blogspot.com>  
<http://www.sudden-stillness.com>

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# Questions?

Extra Slides →

# A Lesson from a *Physicist*

“We are not only observers.  
We are participators.  
In some strange sense this is  
a participatory universe...

...no phenomenon is a  
real phenomenon; until it is  
an *observed* phenomenon.”

— John Archibald Wheeler  
(1911 – 2008, *Physicist*)



# A Lesson from a *Complexity Theorist*



“There is a constant and intimate contact among the things that coexist and coevolve in the universe;

A sharing of bonds and messages that makes reality into a stupendous network of interaction and communication.”

— Ervin Laszlo (1932 - , *Systems Theorist*)

# A Lesson from a *Photographer*



“There is no closed figure in nature  
Every shape participates with another.  
No one thing is independent of another,  
and one thing rhymes with another,  
and light gives them shape.”

— Henri Cartier-Bresson, (1908 – 2004, *Photographer / Artist*)

# A Lesson from *Taoist Master*



“Before I had studied Zen for thirty years,  
I saw mountains as mountains, and waters as waters...

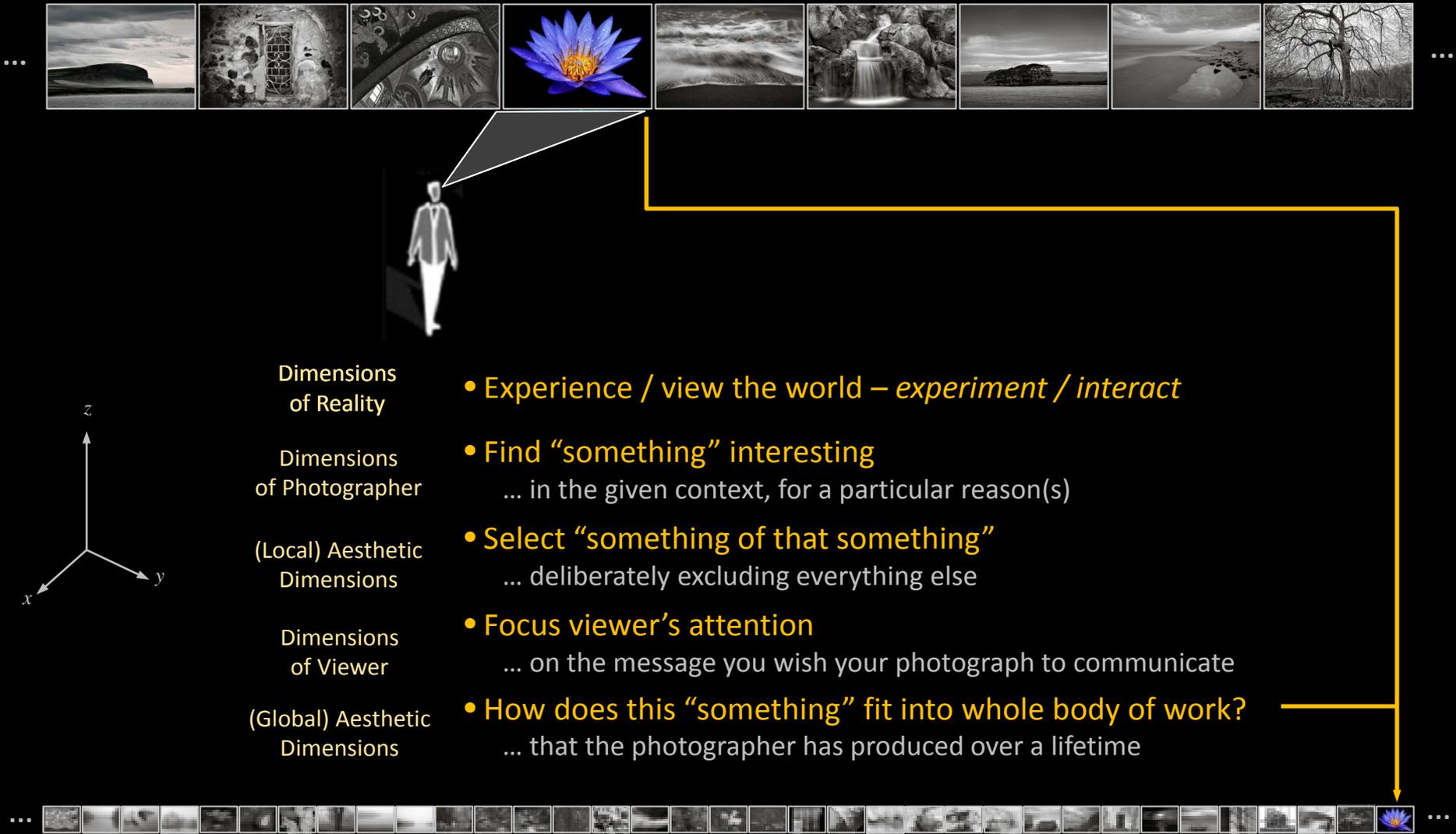
When I arrived at a more intimate knowledge, I came to the point where I saw  
that mountains are not mountains, and waters are not waters.

But now that I have got its very substance I am at rest.  
For it's just that I see mountains once again as mountains,  
and waters once again as waters.”

— Ching-te Ch'uan Teng-lu (“*Transmission of the Lamp*”)

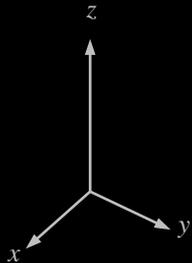
# What Does a *Photographer* Do?

The multidimensional “art” of selection / pattern spaces



# What Does a *Physicist* Do?

The multidimensional “art” of selection / pattern spaces



Dimensions  
of Reality

Dimensions  
of Physicist

(Local) Order  
Dimensions

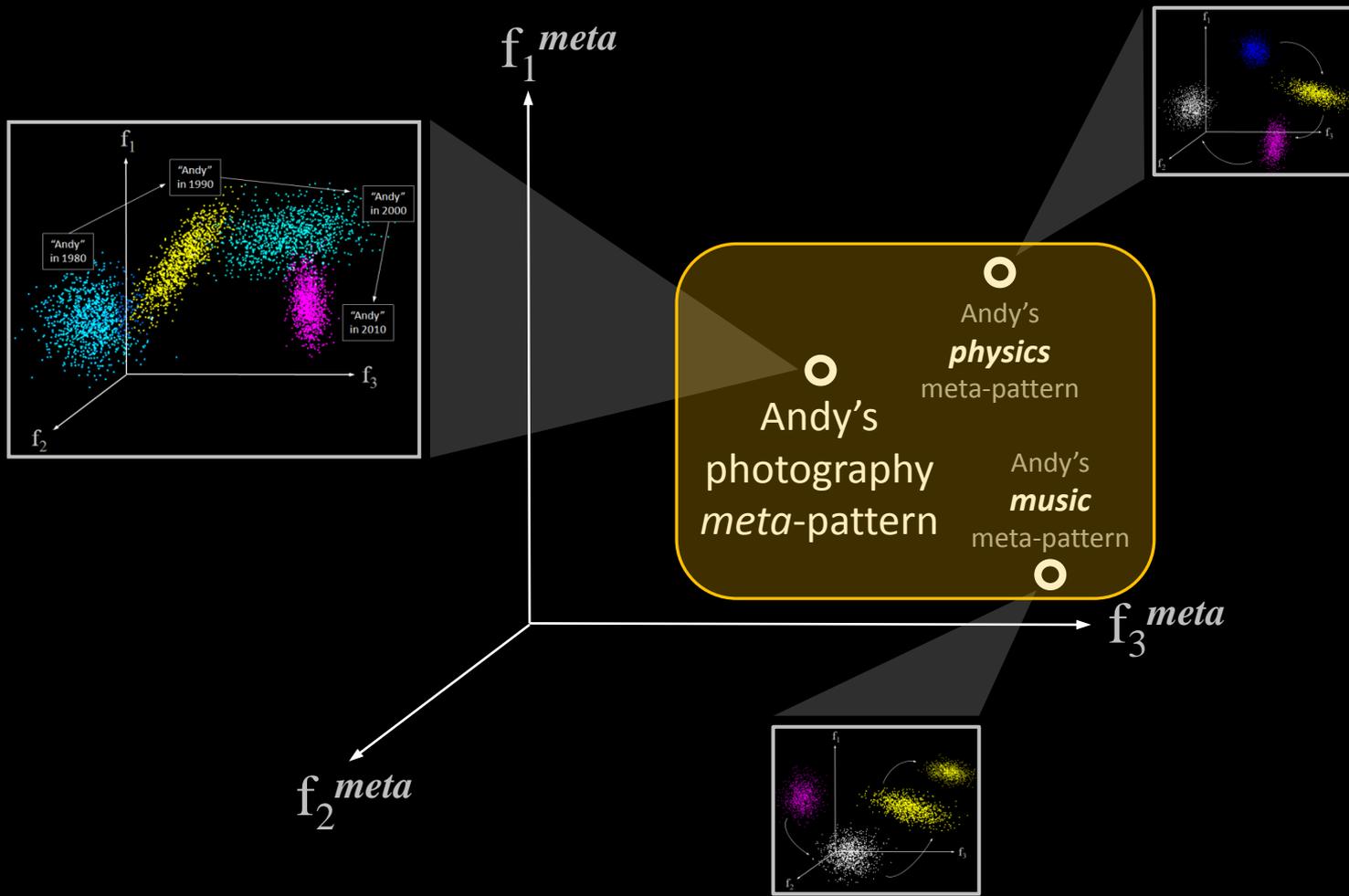
Dimensions  
of Reviewer

(Global) Order  
Dimensions

- Experience / view the world – *experiment / interact*
- Find “something” interesting  
... in the given context, for a particular reason(s)
- Select “something of that something”  
... deliberately excluding everything else
- Focus reviewer’s attention (*peer review*)  
... on the message you wish your physics to communicate
- How does this “something” fit into whole body of work?  
... that the physicist has produced over a lifetime

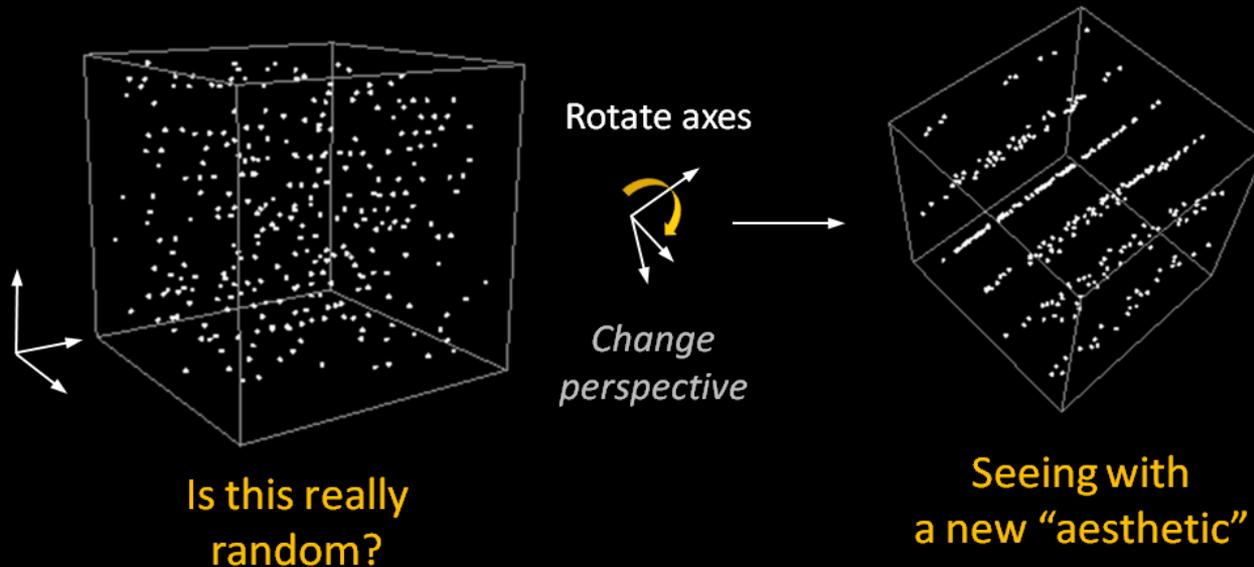


# Evolving Aesthetic Landscapes



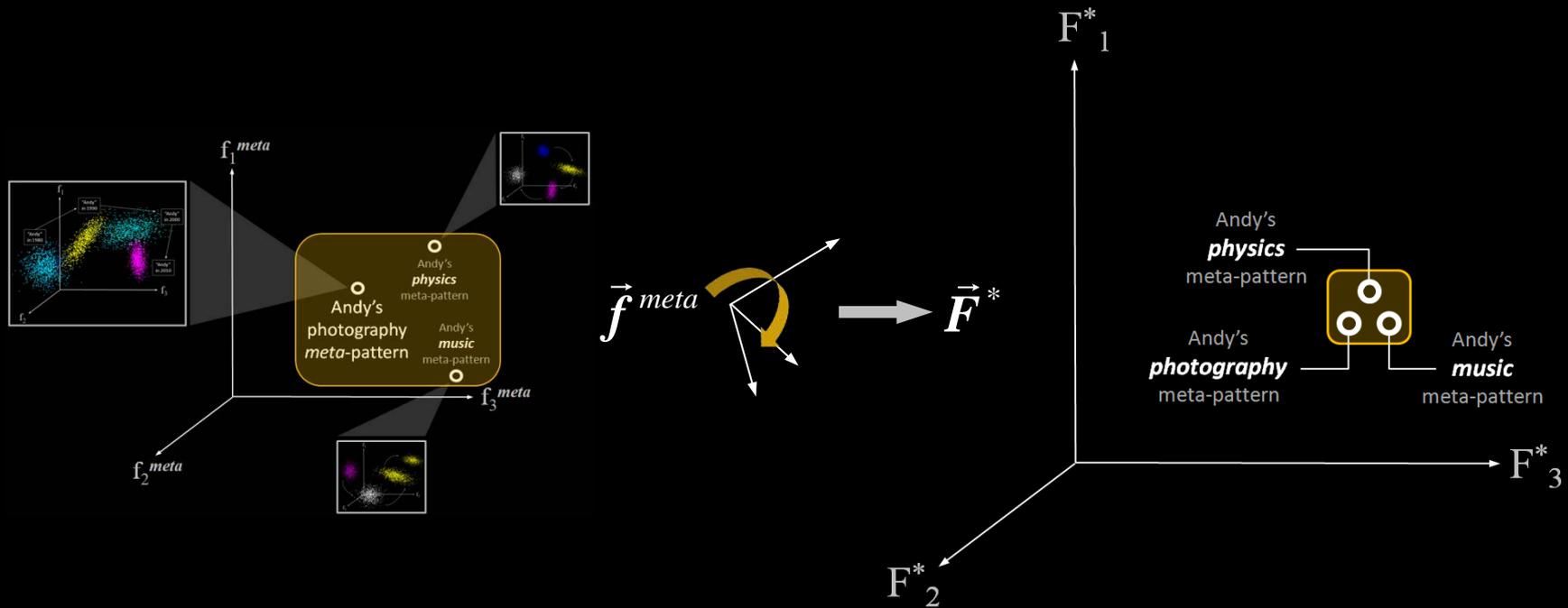
# Evolving Landscapes

Point-of-View is everything!



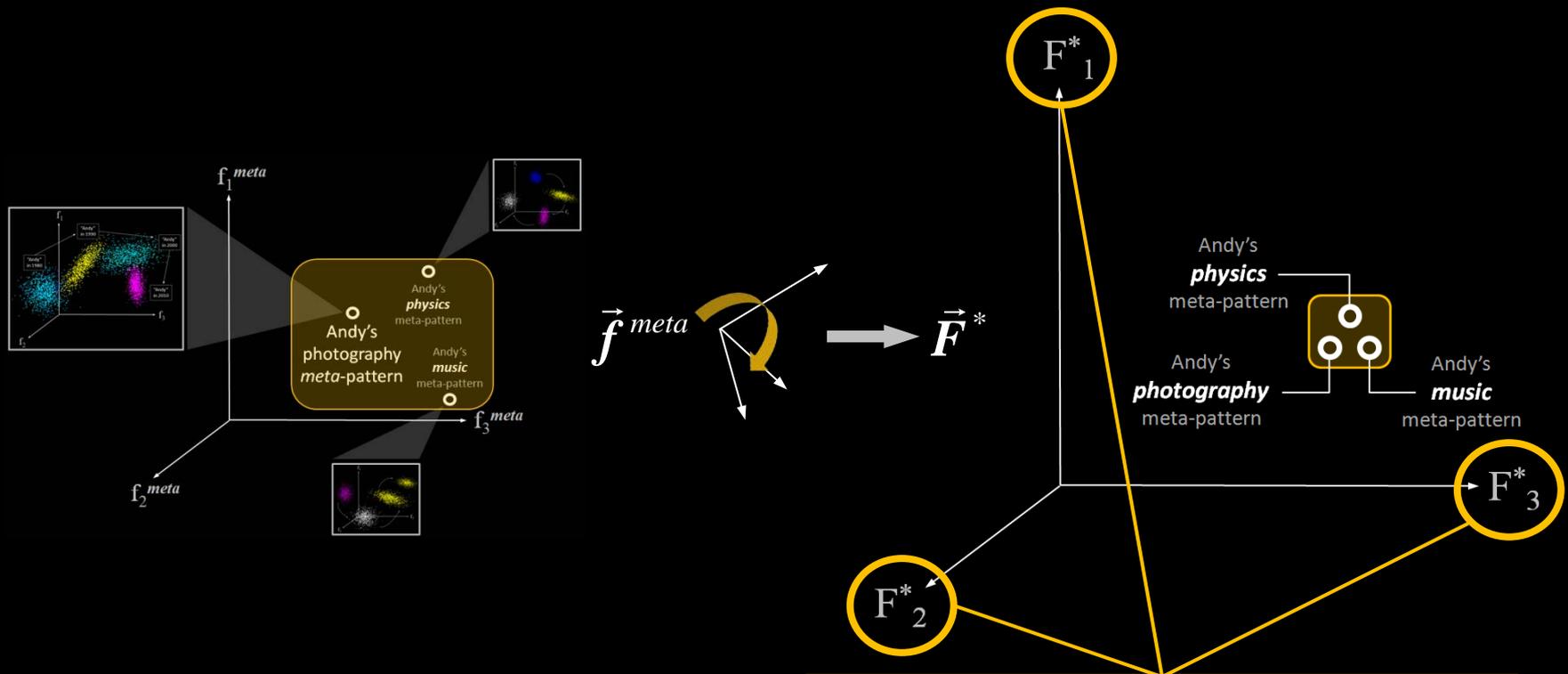
# Evolving Landscapes

Is there a way to “rotate the aesthetic axes” so that ...



# Evolving Landscapes

Is there a way to “rotate the aesthetic axes” so that ...



If so, then these features describe “Andy’s” core meta-pattern – his “I” !

# What do Physics & Complexity have to do with Art & Photography?

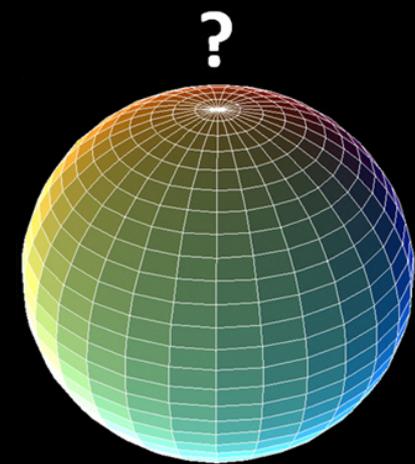
$$\dot{\mathbf{p}} = -\frac{\partial H}{\partial \mathbf{q}} \quad \dot{\mathbf{q}} = \frac{\partial H}{\partial \mathbf{p}} \quad \nabla \cdot \mathbf{E} = 4\pi\rho \quad \nabla \times \mathbf{E} = -\frac{1}{c} \frac{\partial \mathbf{B}}{\partial t}$$

$$\nabla \cdot \mathbf{B} = 0 \quad PV = nRT \quad S = k \ln \Omega \quad \frac{dS}{dt} \geq 0$$

$$\Delta x \Delta p_x \geq \frac{1}{2} \hbar \quad \nabla \times \mathbf{B} = \frac{4\pi}{c} \mathbf{J} + \frac{1}{c} \frac{\partial \mathbf{E}}{\partial t} \quad \Delta E \Delta t \geq \frac{1}{2} \hbar$$

$$dE = dQ - dW \quad G_{\mu\nu} = -8\pi G T_{\mu\nu}$$

$$i\hbar \frac{\partial \Psi}{\partial t} = -\frac{\hbar^2}{2m} \frac{\partial^2 \Psi}{\partial x^2} + V(x) \Psi(x, t) \equiv \hat{H} \Psi(x, t)$$



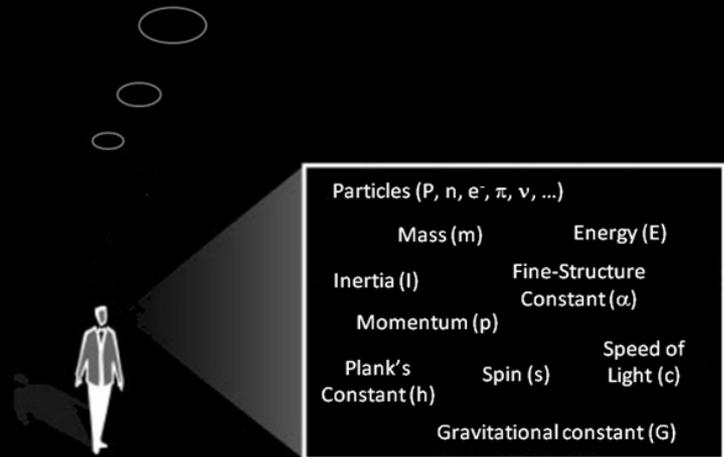
**Reality**

**Parts**  
*(Conceptual Building Blocks)*

**Syntax**

**Grammar**

**Language**



**Traditional Physics**

Graphical elements adapted from [www.idiagram.com](http://www.idiagram.com)

# What do Physics & Complexity have to do with Art & Photography?

**Self-Organized Criticality**



**Complexity**

$$D(s) = s^{-\beta} \quad P(k) \sim k^{-\alpha}$$



log P(k)

log k

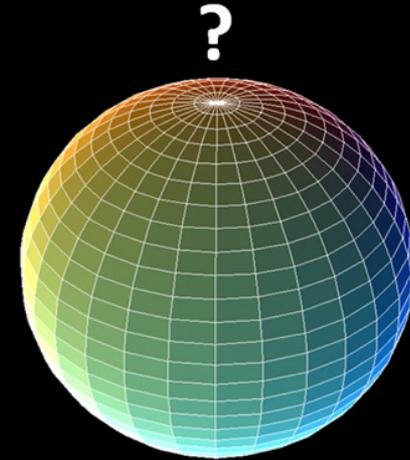
**Metastability      Emergence**

$$\sigma_{i,j}^{(t+1)} = \phi(\sigma_{i,j}^{(t)}, \sigma_{i-1,j}^{(t)}, \sigma_{i+1,j}^{(t)}, \sigma_{i,j-1}^{(t)}, \sigma_{i,j+1}^{(t)})$$

$$S(t) = -\frac{1}{N} \sum_{i=1}^{2^N} p_i^t \log_2 p_i^t$$

**Autopoiesis**





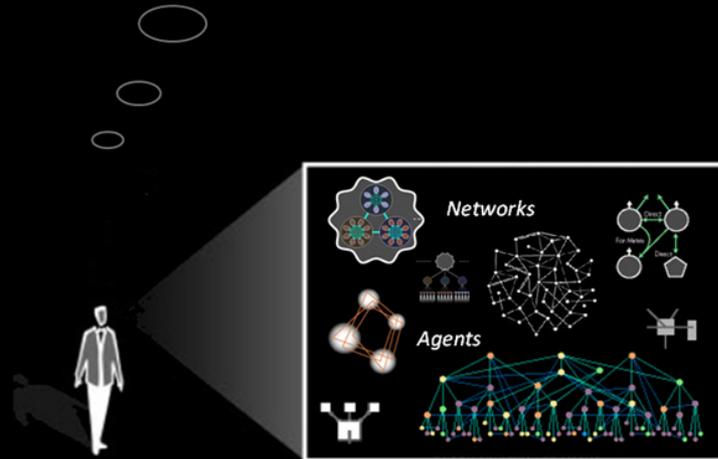
**Reality**

**Parts**  
(Conceptual Building Blocks)

**Syntax**

**Grammar**

**Language**

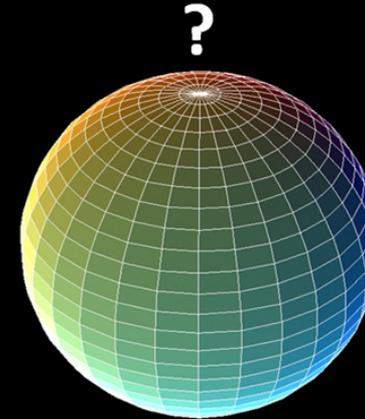


**Complexity Theory**

Graphical elements adapted from [www.idiagram.com](http://www.idiagram.com)

# What do Physics & Complexity have to do with Art & Photography?

1. Levels of Scale
2. Strong Centers
3. Boundaries
4. Alternating Repetition
5. Positive Space
6. Good Shape
7. Local Symmetry
8. Deep Interlock & Ambiguity
9. Contrast
10. Gradients
11. Roughness
12. Echoes
13. The Void
14. Simplicity / Inner-Calm
15. Not-Separateness



Reality

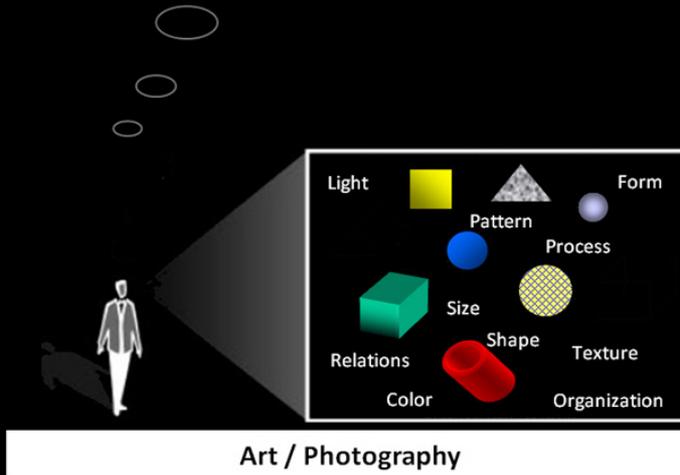
**Parts**  
(Conceptual Building Blocks)

**Syntax**

**Grammar**

**Language**

**Laws of Beauty?**



Graphical elements adapted from [www.idiagram.com](http://www.idiagram.com)

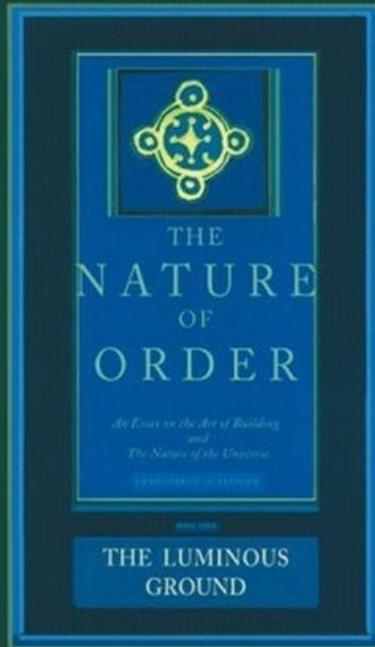
Christopher Alexander, *Nature of Order*  
Center for Environmental Structure, 2003

# Nature of Order

Everything is alive, it is only a matter of degree



Christopher Alexander, *Architect* (1936 - )



“Space itself, matter itself, has life in varying degrees.

There is a consequence of function, geometry, and feeling in space; this space is conceived as a living fabric that - through its structure - encompasses these things.

Space does not merely contain living structure.

Space has life, to a greater or lesser degree.

It is the space itself which resembles self, which functions, which works, which has living structure in it, and which has life.”

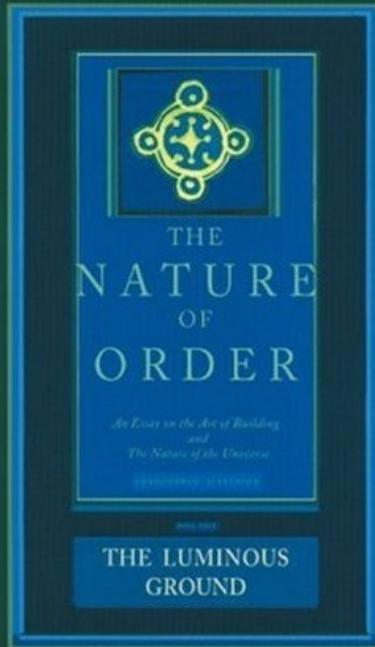
The life which appears is an attribute of space itself.

# Nature of Order

Everything is alive, it is only a matter of degree



Christopher Alexander, *Architect* (1936 - )



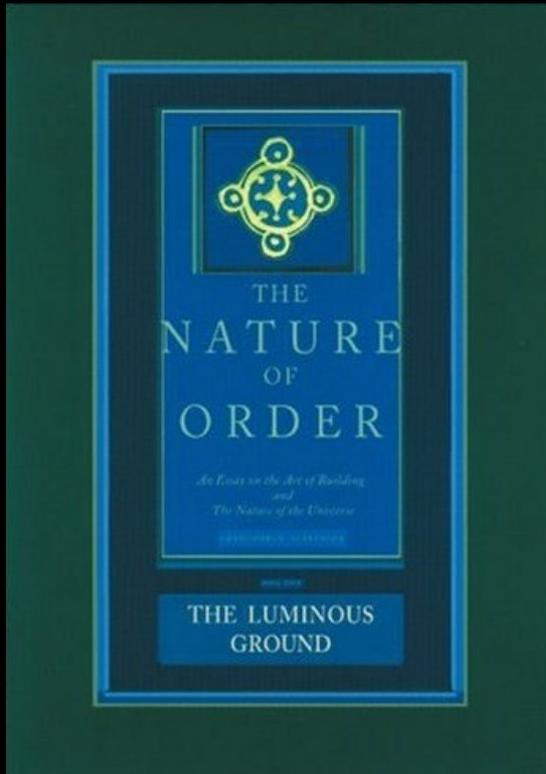
- There is a structure – called *wholeness* - visible in any given part of the world
- The wholeness is an abstract mathematical structure that exists at many levels of scale, and covers the interrelationships of the configurations at different scales
- The primary entities of which the structure is built are centers (which become activated in the space as a result of the configuration as a whole)
- Centers have different levels of strength or coherence, depending on relationships with other centers
- There are fifteen types of relationships among centers which increase or intensify the strength of any given center

# Nature of Order

Everything is alive, it is only a matter of degree



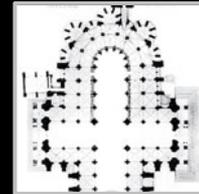
Christopher Alexander, *Architect* (1936 - )



Strong centers



Levels of scale



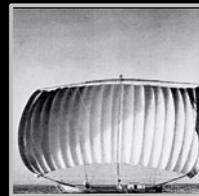
Boundaries



Alternating repetition



Positive space



Good shape



Local symmetries



Deep interlock & ambiguity



Contrast



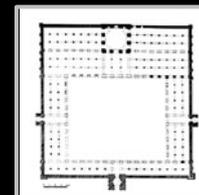
Gradients



Roughness



Echoes



The Void



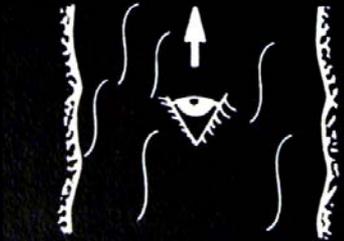
Simplicity & inner calm



Non-seperateness

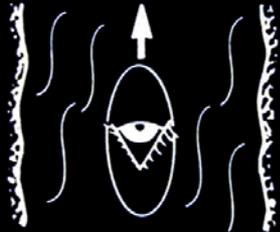
# Physics, Complexity, and Photography: *One Last Take*

“...I see mountains once again as mountains, and waters once again as waters.”



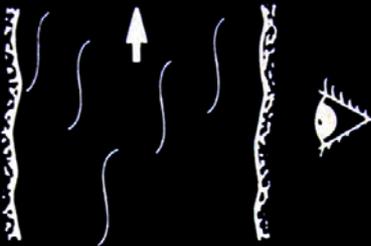
The observer is the stream  
(Complexity theory / Tao)

“...I came to the point where I saw that mountains are not mountains, and waters are not waters...”



The observer attempts to steer a canoe in the stream  
(Quantum physics / Photography)

“Before I had studied Zen for thirty years, I saw mountains as mountains, and waters as waters...”



The observer is outside the stream  
(Newtonian physics)

## Complexity / Tao: no fundamental distinction between “inside” / “outside”

- Forget about *things*...
- Forget about *categories*...
- Forget about *boundaries*...
- *Use camera to find the “I” behind lens!*

## Photography: find meaningful patterns

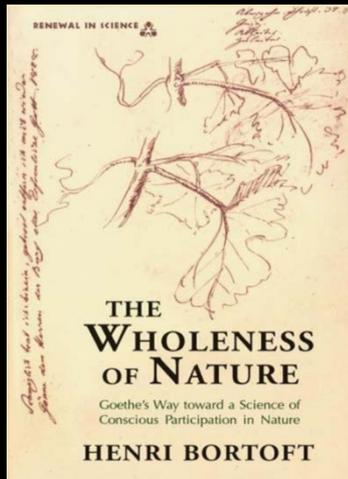
- Use *light, color, form, texture, and pattern* as primitive building blocks out of which to create “mini-worlds” interesting to you
- *You actively roam around the landscape!*

## Physics: let it guide your eye & camera

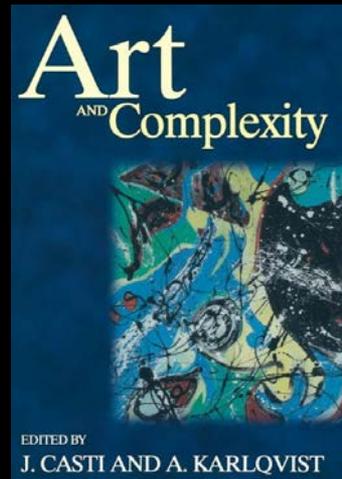
- Search for nature’s forms: *fractals, dynamics, symmetry, order, pattern, ... out there!*

# References

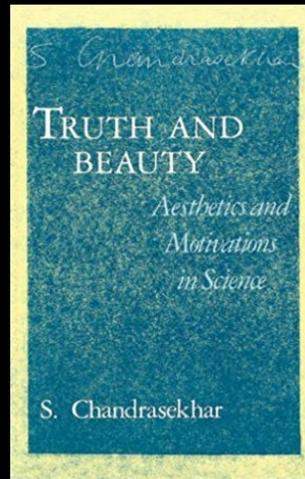
Some books on *physics / complexity / photography / art*



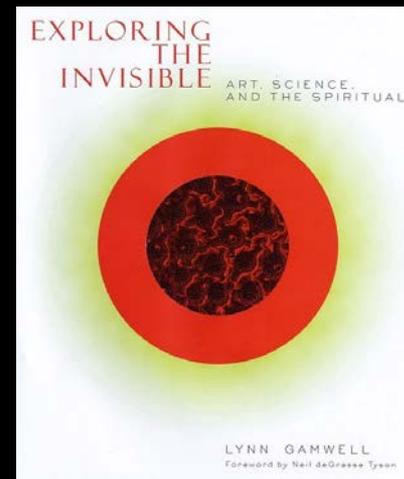
*The Wholeness of Nature*  
Henri Bortoft



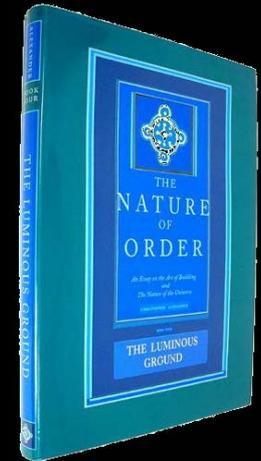
*Art & Complexity*  
J. Casti, A. Karlqvist  
(editors)



*Truth & Beauty*  
S. Chandrasekhar



*Exploring the Invisible*  
Lynn Gamwell



*Nature of Order*  
Christopher  
Alexander