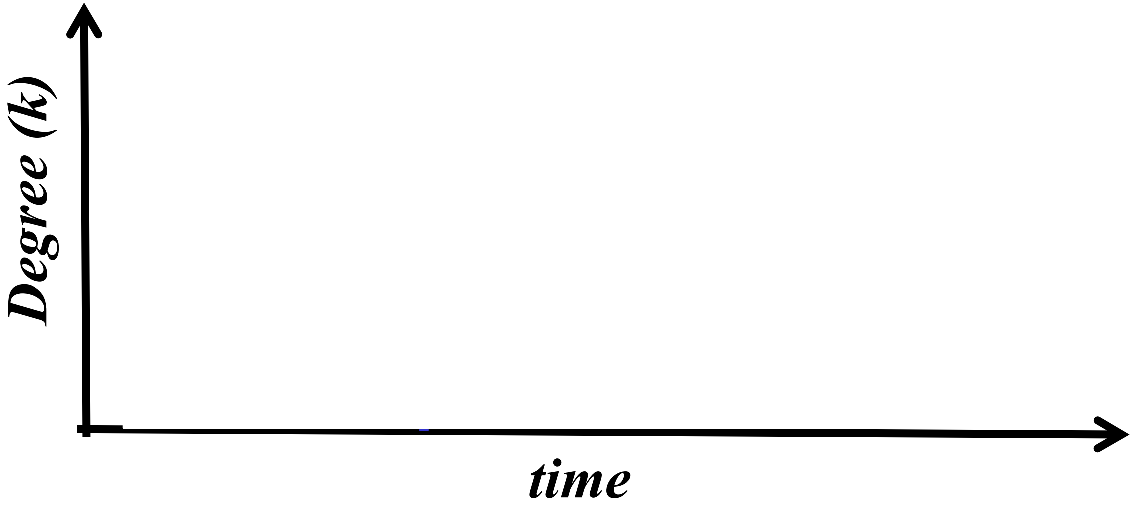
# Section 1

# Can Latecomers Make It?

**SF model:** $k(t) \sim t^{1/2}$ **(first mover advantage)**

**Fitness model:** **fitness** $(\eta)$ $\Pi(k_i) \cong \dfrac{\eta_i k_i}{\sum_j \eta_j k_j}$ $k(\eta,t) \sim t^{\beta(\eta)}$

$\beta(\eta)$




Bianconi & Barabási, *Physical Review Letters* 2001; *Europhys. Lett.* 2001.

- **Growth**

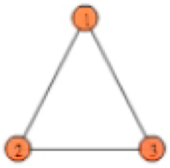
  In each timestep a new node $j$ with $m$ links and fitness $\eta_j$ is added to the network, where $\eta_j$ is a random number chosen from a *fitness distribution* $\rho(\eta)$. Once assigned, a node's fitness does not change.

- **Preferential Attachment**

  The probability that a link of a new node connects to node $i$ is proportional to the product of node $i$'s degree $k_i$ and its fitness $\eta_i$,

$$\Pi_i = \frac{\eta_i k_i}{\sum_j \eta_j k_j}. \qquad (6.1)$$

## Section 2 Fitness Model



$$\frac{\partial k_i}{\partial t} = m \frac{\eta_i k_i}{\sum_k \eta_j k_j}$$

$$k_{\eta_i}(t, t_i) = m \left(\frac{t}{t_i}\right)^{\beta(\eta_i)}.$$

$$\left\langle \sum_j \eta_j k_j \right\rangle$$

over all possible realizations of the quenched fitnesses $\eta$. Since each node is born at a different time $t_o$, we can write the sum over $j$ as an integral over $t_o$

$$\left\langle \sum_j \eta_j k_j \right\rangle = \int d\eta \rho(\eta) \eta \int_1^t dt_0 k_\eta(t, t_0). \quad (6.34)$$

By replacing $k_\eta(t, t_o)$ with (6.3) and performing the integral over $t_o$, we obtain

$$\left\langle \sum_j \eta_j k_j \right\rangle = \int d\eta \rho(\eta) \eta m \frac{t - t^{\beta(\eta)}}{1 - \beta(\eta)}. \quad (6.35)$$

The dynamic exponent $\beta(\eta)$ is bounded, i.e. $0<\beta(\eta)<1$, because a node can only increase its degree with time ($\beta(\eta)>0$) and $k_i(t)$ cannot increase faster than $t$ ($\beta(\eta)<1$). Therefore in the limit $t\to\infty$ in (6.35) the term $t^{\beta(\eta)}$ can be neglected compared to $t$, obtaining

$$\left\langle \sum_j \eta_j k_j \right\rangle \overset{t\to\infty}{=} Cmt(1 - O(t^{-\varepsilon})), \quad (6.36)$$

where $\varepsilon = (1 - \max_\eta \beta(\eta)) > 0$ and

$$C = \int d\eta \rho(\eta) \frac{\eta}{1 - \beta(\eta)}. \quad (6.37)$$

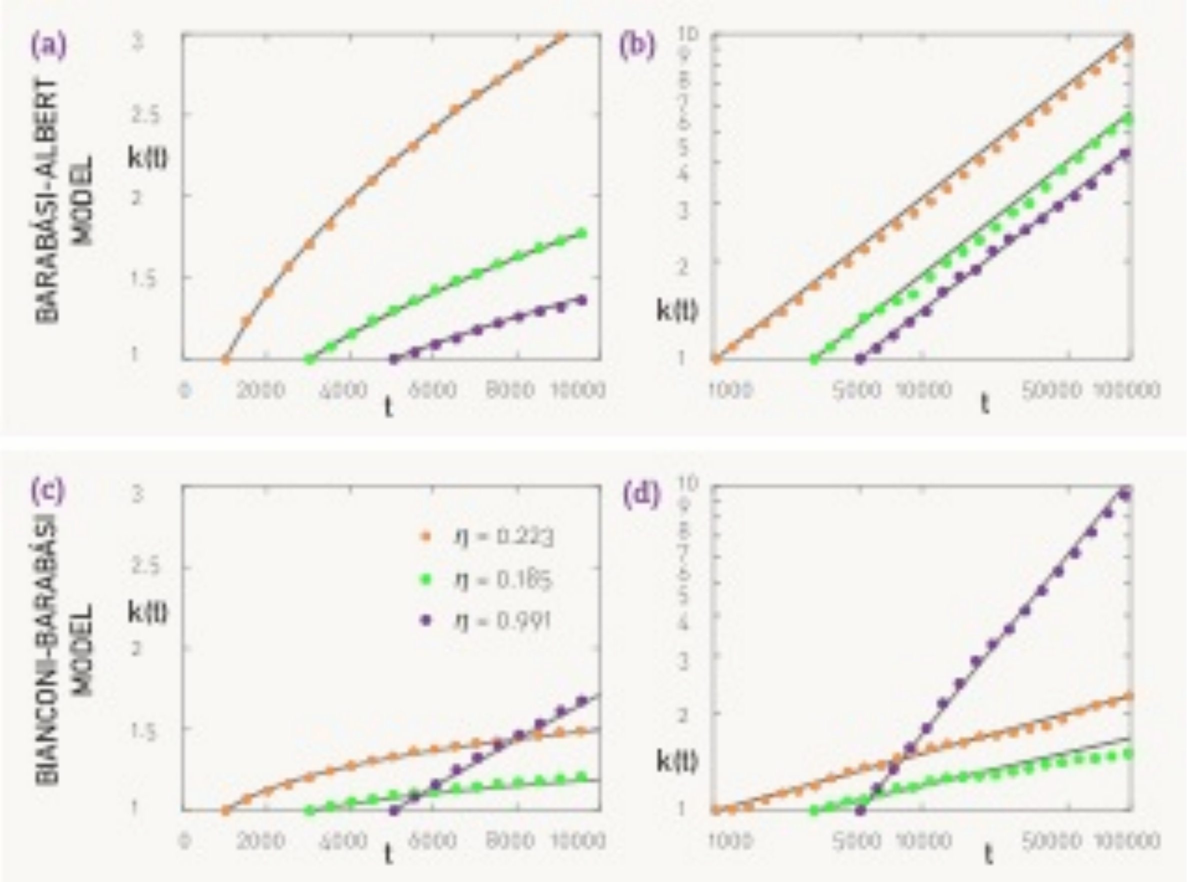
**BA model**: $k(t) \sim t^{1/2}$

**(first mover advantage)**

**BB model**: $k(\eta,t) \sim t^{\beta(\eta)}$

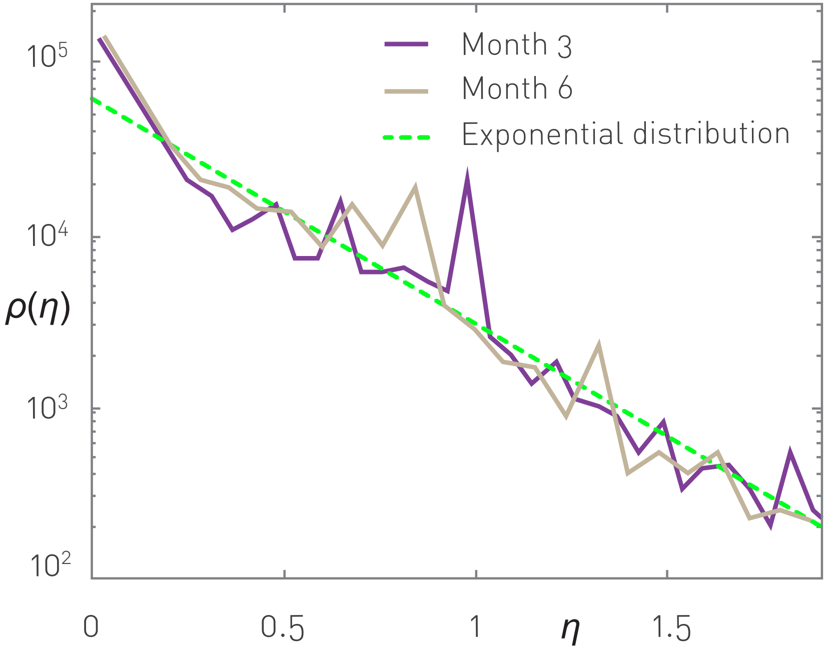
**(fit-gets-richer)**

$\beta(\eta) = \eta / C$



$$k_{\eta_i}(t,t_i) = m\left(\frac{t}{t_i}\right)^{\beta(\eta_i)}.$$

$$\log k_{\eta_i}(t,t_i) = \beta(\eta_i)\log t + B_i,$$



**The First Law:**

Performance is about you, success is about us.

# The Second Law:

Performance drives success.

# The Third Law:

Performance is Bounded

**The Fourth Law:**

Success or recognition is unbounded.

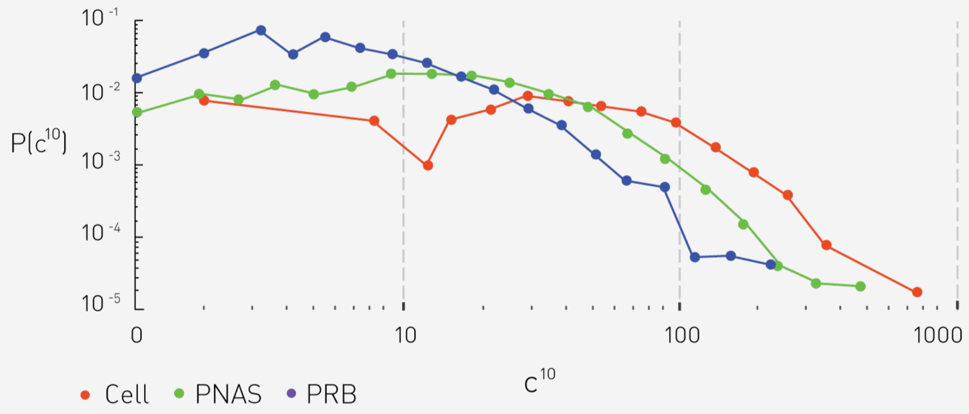
**The Fifth Law:**

Success breeds success.

# The Sixth Law:

Quality times previous success determines future success.

$$\Pi(k_i) \cong \frac{\eta_i \, k_i}{\sum_j \eta_j \; k_j}$$




- IMPACT FACTOR

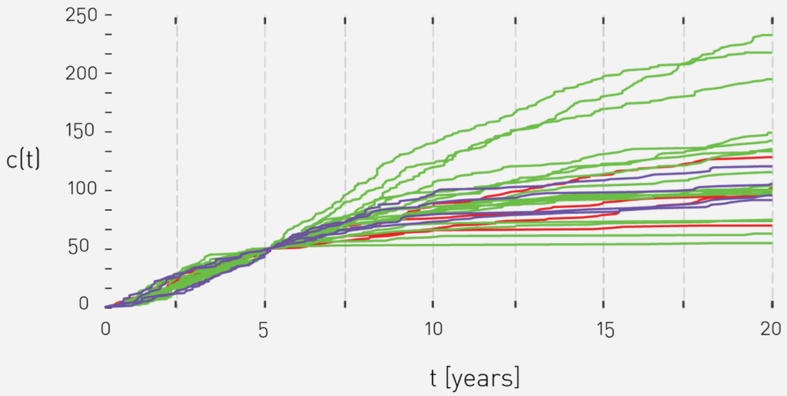
| | |
|---|---|
| 1.67 | Physica A |
| 2.31 | Physical Review E |
| 7.94 | Physical Review Letters |
| 19.35 | Nature Physics |
| 31.03 | Science |
| 38.6 | Nature |
| 44.98 | Reviews of Modern Physics |

✓ **IF does not predict future impact.**

- CITATION COUNT

Total citations c(t), H-index, most cited paper c*

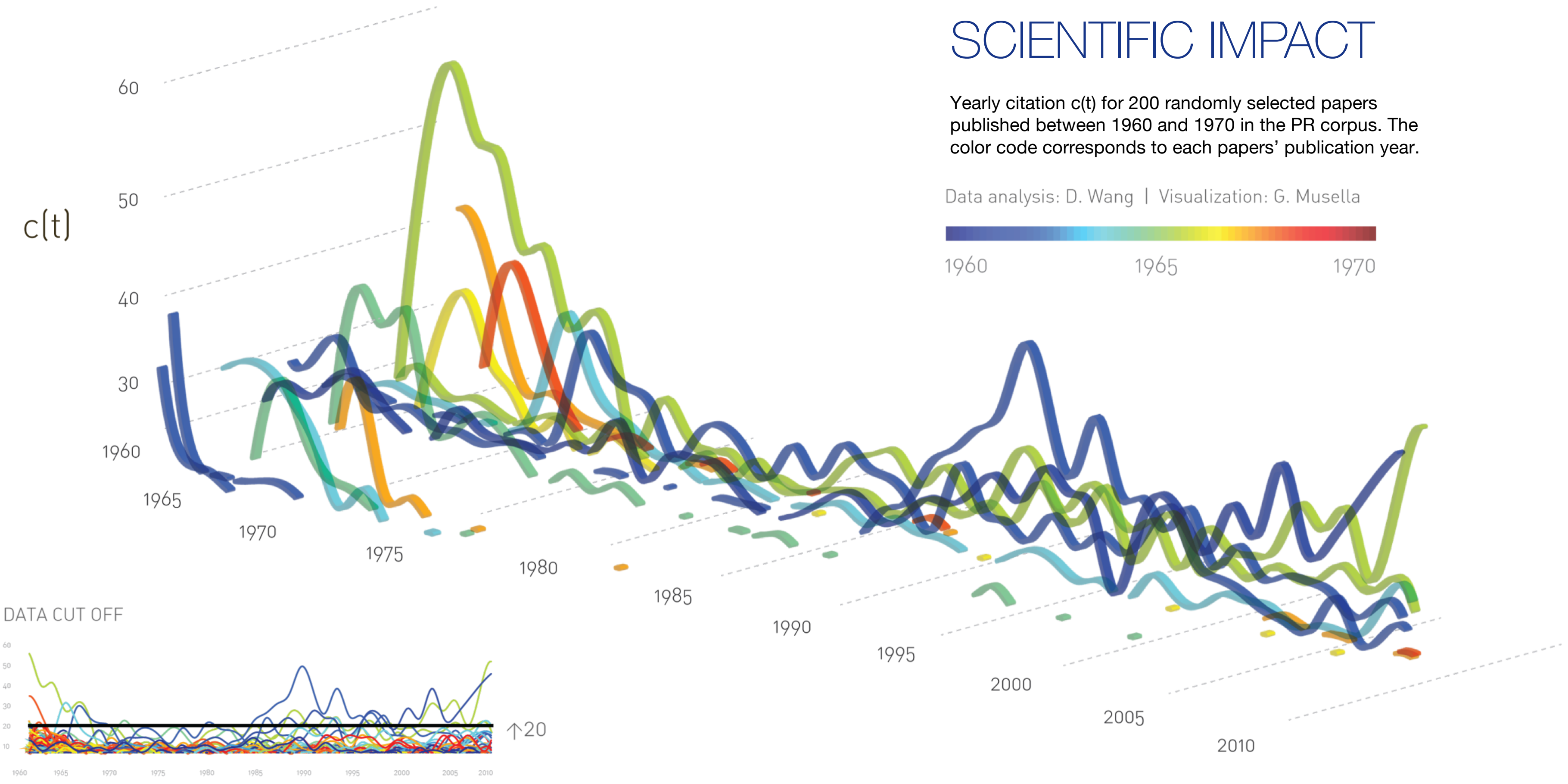
✓ **Favors established researchers**
✓ **Lacks long-term predictive power.**



# QUANTIFYING LONG-TERM SCIENTIFIC IMPACT

Yearly citation c(t) for 200 randomly selected papers published between 1960 and 1970 in the PR corpus. The color code corresponds to each papers' publication year.

Data analysis: D. Wang | Visualization: G. Musella



# MODELING CITATION DYNAMICS

The probability that your paper *i* is cited: $$\Pi_i \sim \eta_i c_i^t P_i(t)$$

- Fitness: Intrinsic Novelty................ $\eta_i$
- Preferential Attachment ............... $c_i^t$
- Aging........................................... $P_i(t) = \frac{1}{\sqrt{2\pi}\sigma_i t} \exp\left(-\frac{(\ln t - \mu_i)^2}{2\sigma_i^2}\right)$

$$\frac{\mathrm{d}c_i^t}{\mathrm{d}N} = \frac{\Pi_i}{\sum_{i=1}^N \Pi_i}$$

$$c_i^t = m\left(e^{\frac{\beta\eta_i}{A}\Phi\left(\frac{\ln t - \mu_i}{\sigma_i}\right)} - 1\right)$$

$$\Phi(x) \equiv (2\pi)^{-1/2}\int_{-\infty}^{x} e^{-y^2/2}\mathrm{d}y$$

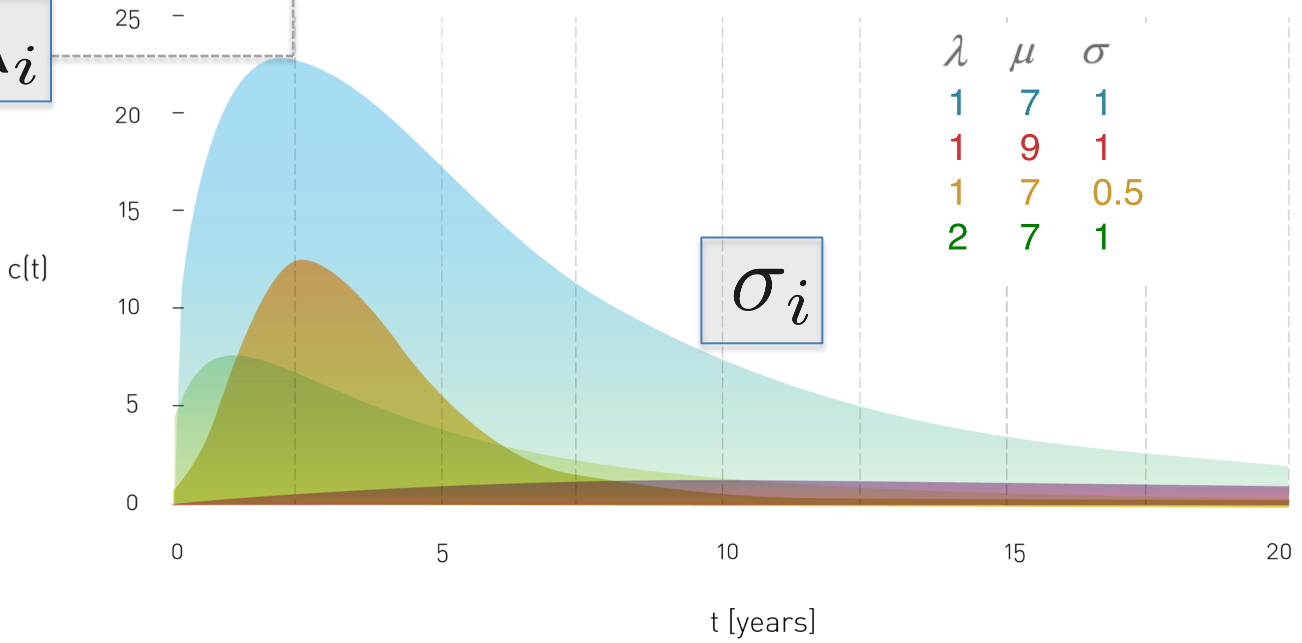
Wang, Song & Barabási. *Science*, 2013

# MODELING CITATION DYNAMICS

$$c_i^t = m\left(e^{\lambda_i \Phi\left(\frac{\ln t - \mu_i}{\sigma_i}\right)} - 1\right)$$

$$T^* \equiv \exp(\mu)$$

$\lambda_i$



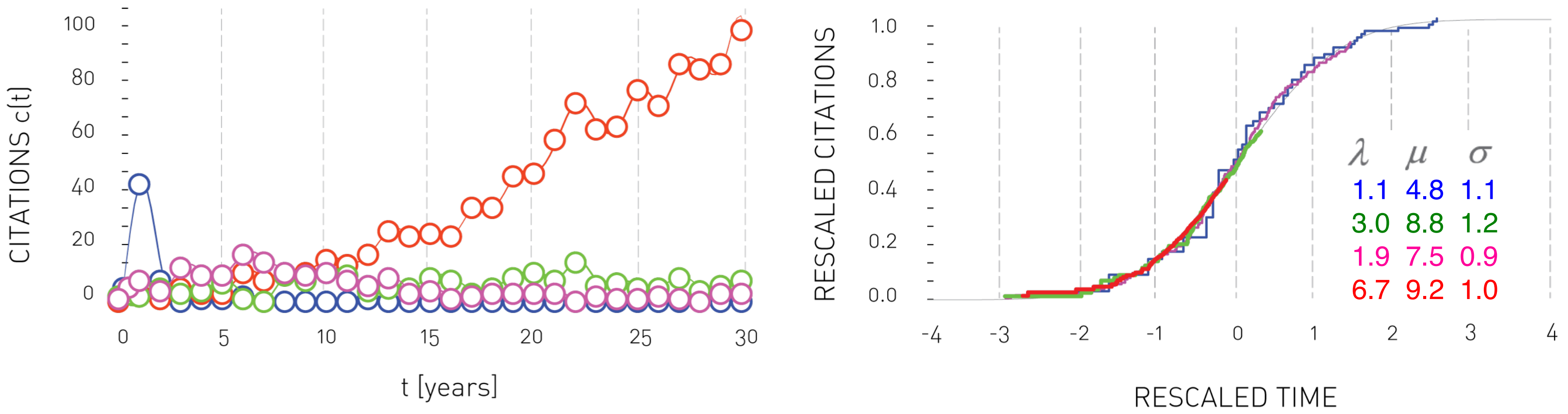

Fitness……. $\lambda_i$

Immediacy… $\mu_i$

Longevity…. $\sigma_i$

Wang, Song & Barabási. *Science*, 2013

# MODELING CITATION DYNAMICS




$$\tilde{t} \equiv (\ln t - \mu_i)/\sigma_i$$

$$\tilde{c} \equiv \ln(1 + c_i^t/m)/\lambda_i$$

$$\longrightarrow \quad \tilde{c} = \Phi\left(\tilde{t}\right)$$

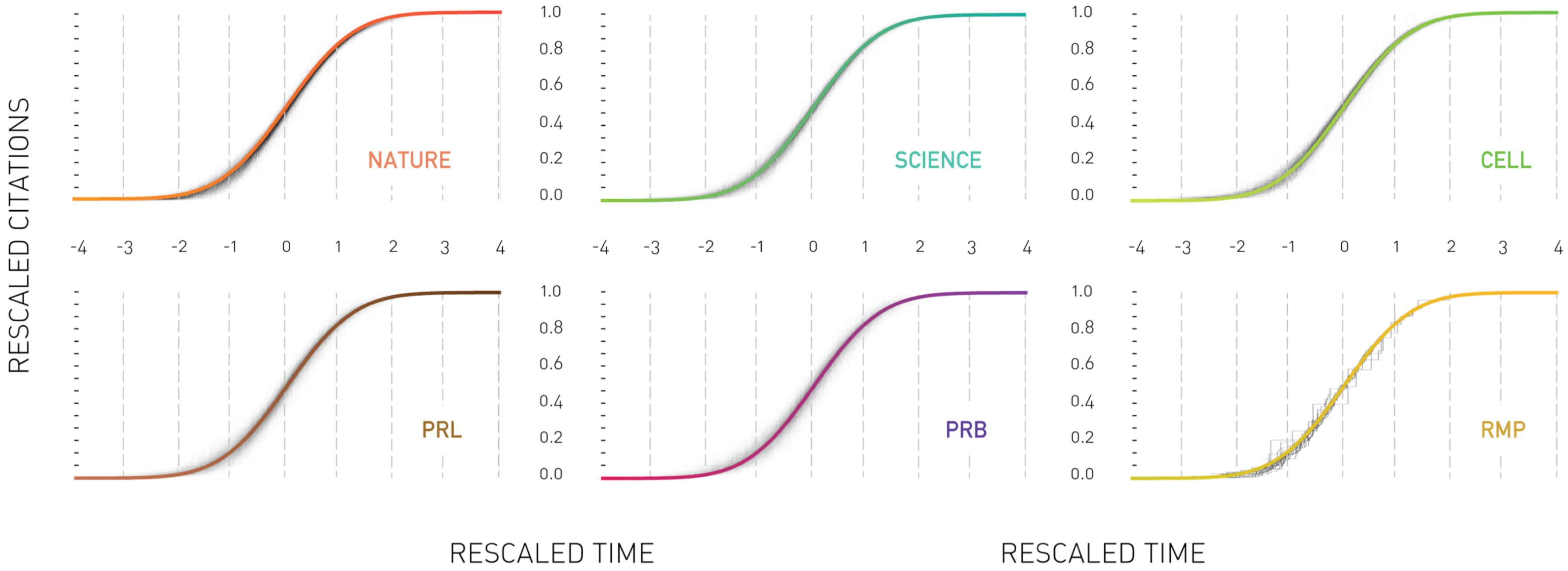
Bonner & Fisher, *Linear magnetic chains with anisotropic coupling,* Physical Review (1964)

Hohenberg & Kohn, *Inhomogeneous electron gas,* Physical Review (1964)

Bardakci et al. *Intrinsically Broken U(6) ⊗ U(6) Symmetry for Strong Interactions,* Physical Review Letters (1964)

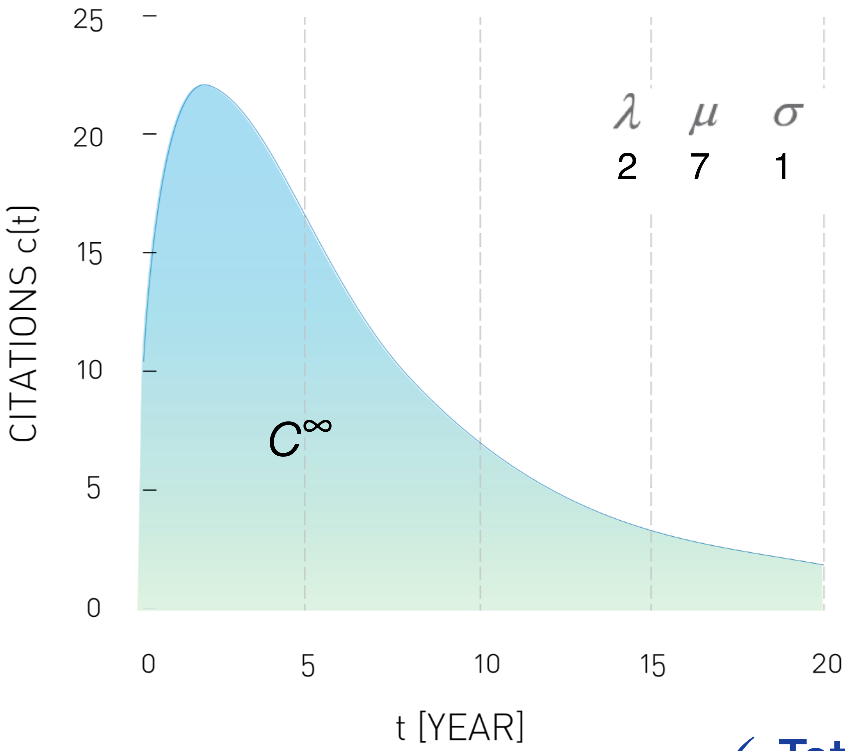
Berglund & W.E. Spicer, *Photoemission studies of copper and silver: Theory,* Physical Review (1964)

# MODELING CITATION DYNAMICS




Wang, Song & Barabási. *Science*, 2013

# MODELING CITATION DYNAMICS




- Total Impact, $c^\infty$

The total number of citations a paper will ever acquire.

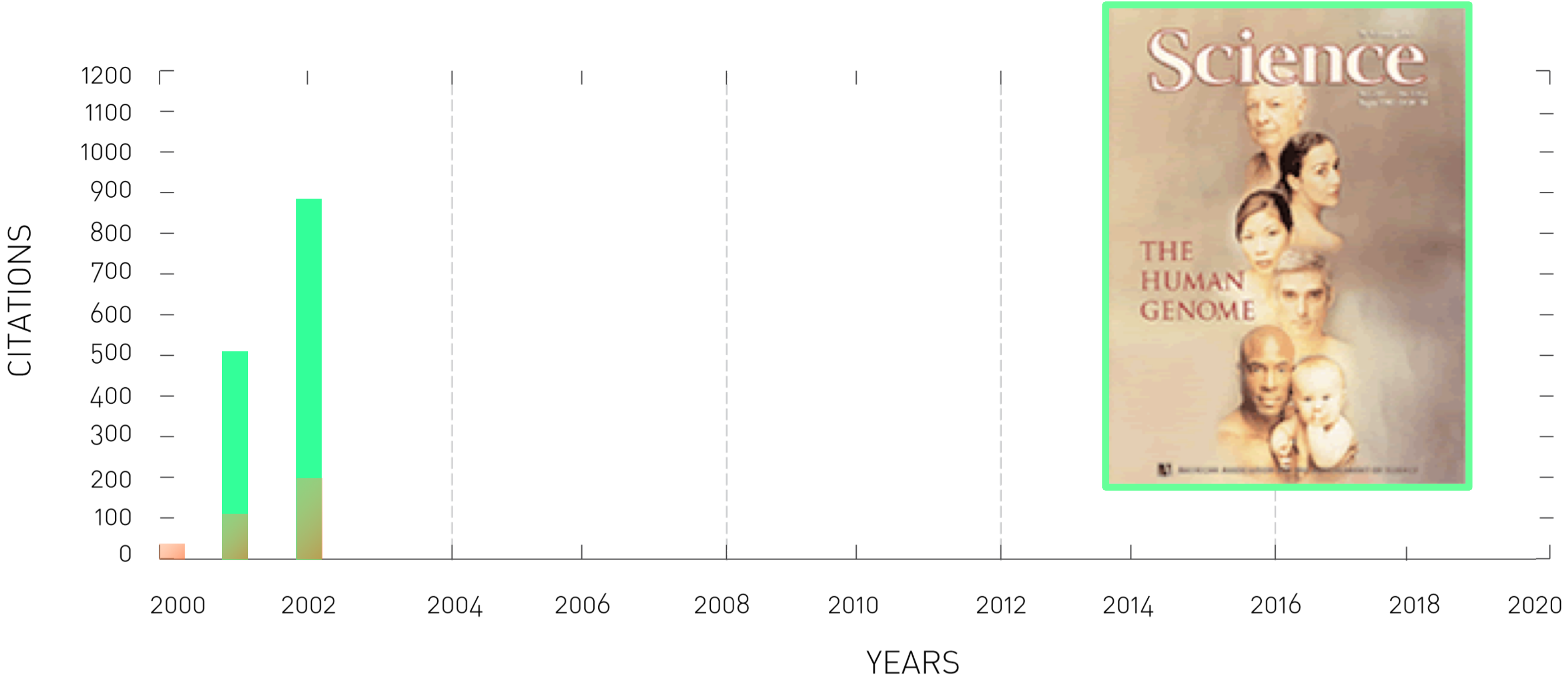
$$c_i^t = m\left(e^{\lambda_i \Phi\left(\frac{\ln t - \mu_i}{\sigma_i} - 1\right)}\right)$$

$$c_i^\infty = m\left(e^{\lambda_i - 1}\right)$$

✓ **Total Impact depends only on a paper's fitness.**

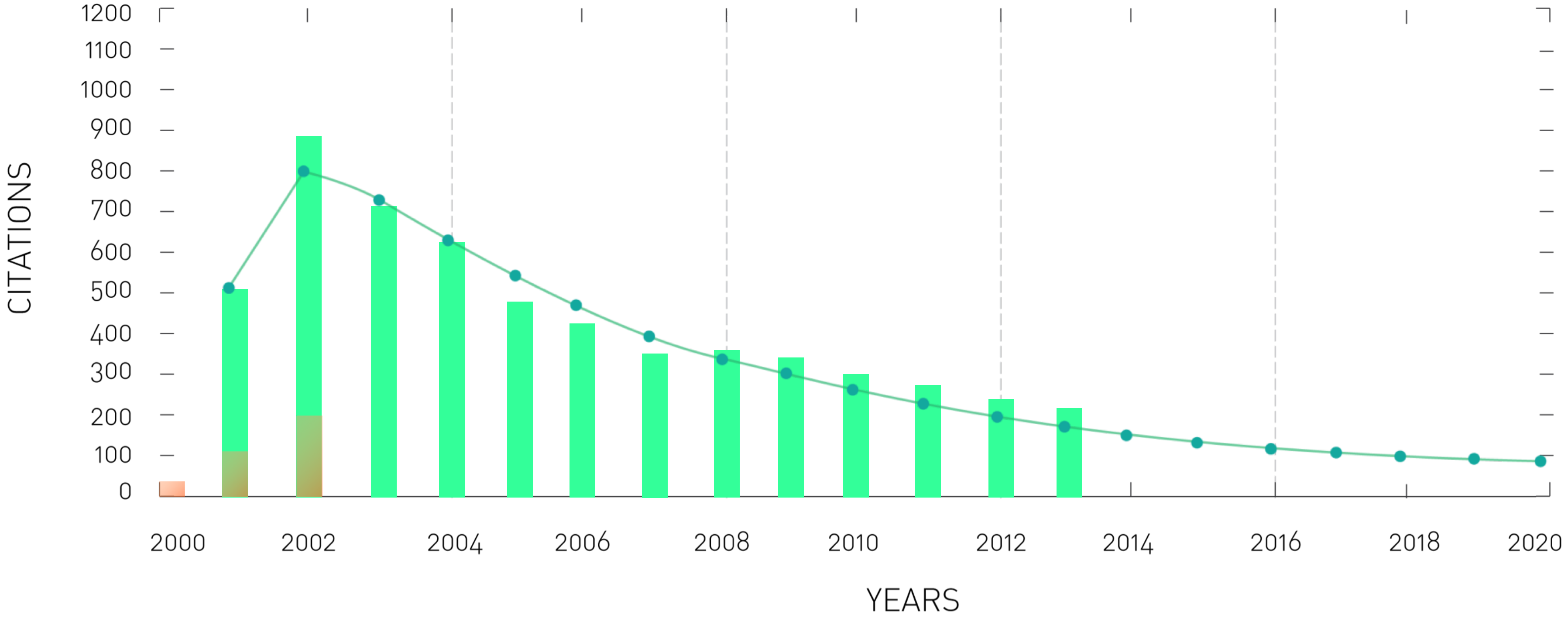
Wang, Song & Barabási. *Science*, 2013

# MODELING CITATION DYNAMICS




**Venter *et al*.**, *The sequence of the human genome*. Science, 2001

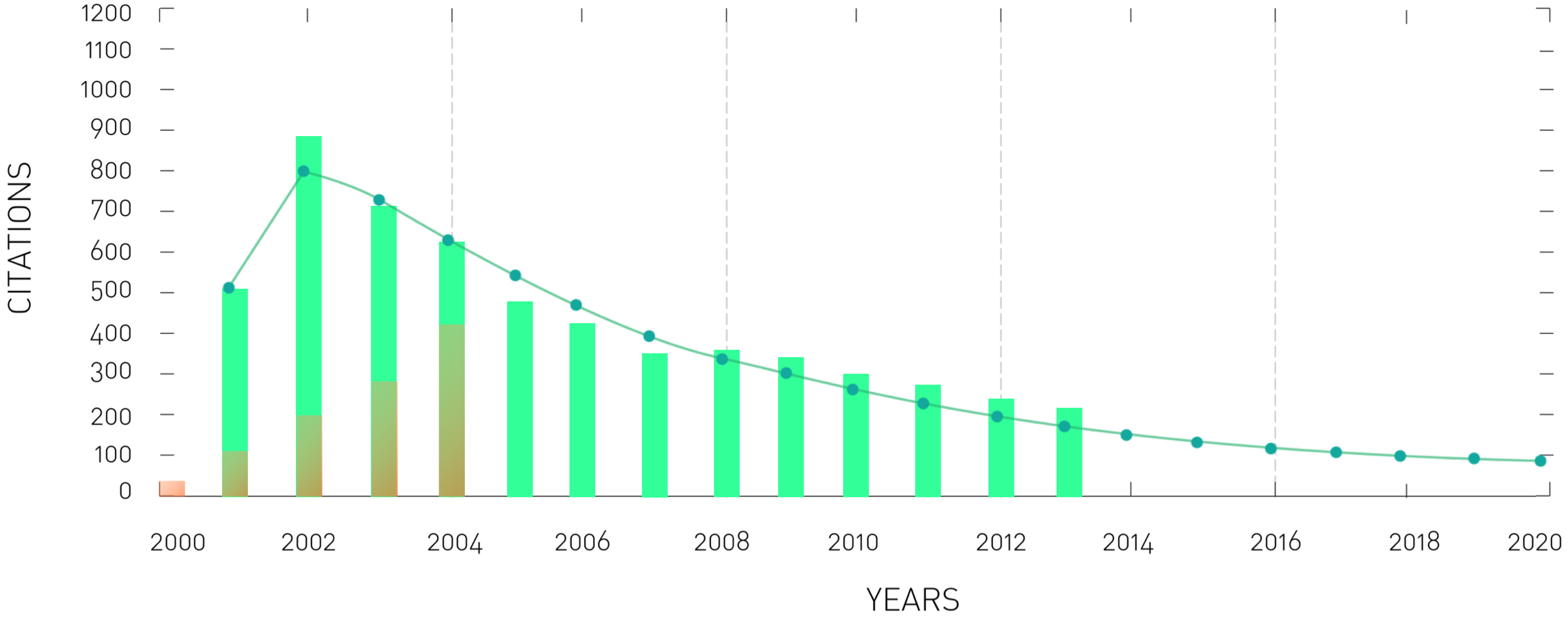
# MODELING CITATION DYNAMICS




**Venter *et al.***, *The sequence of the human genome*. Science, 2001

Cites (2013): ***6,326*** Total impact: **13,105**

# MODELING CITATION DYNAMICS




**Barabási & Albert**, *Emergence of scaling in random networks.* Science, 1999

**Venter *et al.***, *The sequence of the human genome*. Science, 2001

Cites (2013): ***6,326*** Total impact: **13,105**

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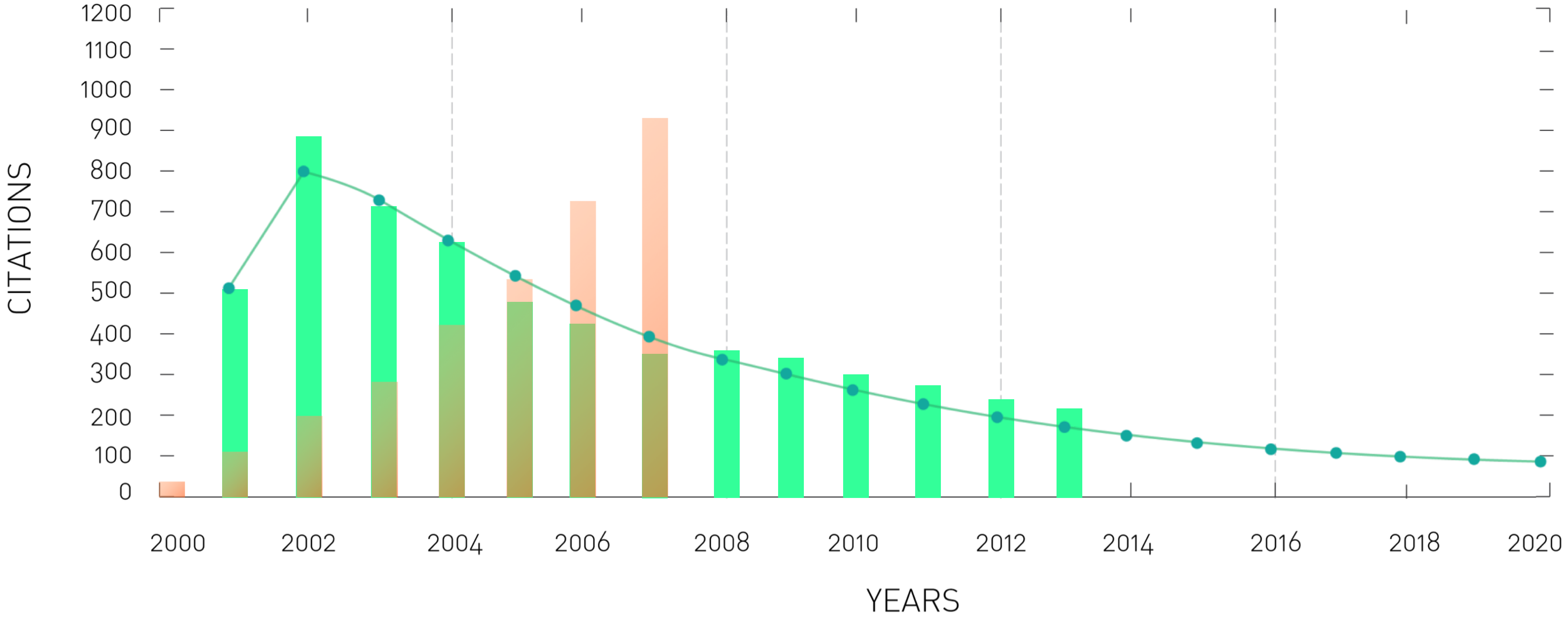


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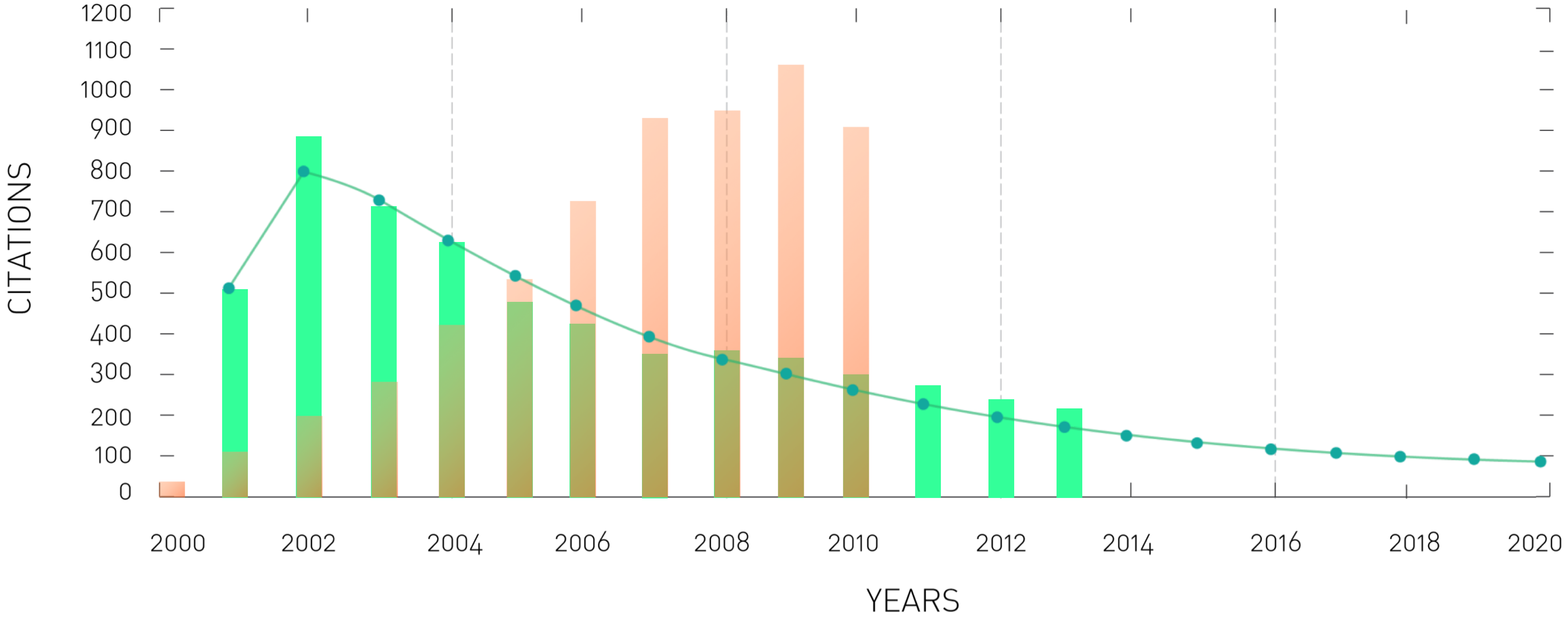


**Barabási & Albert**, *Emergence of scaling in random networks.* Science, 1999

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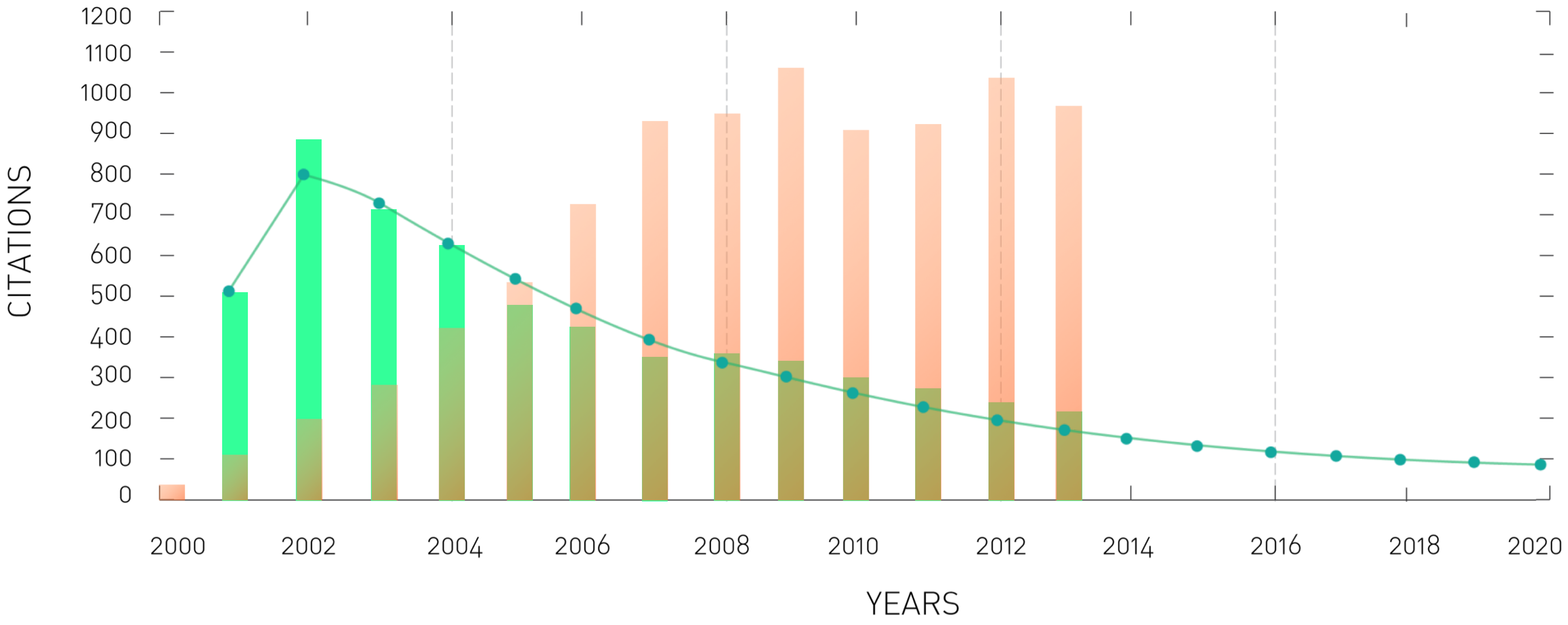


**Barabási & Albert**, *Emergence of scaling in random networks.* Science, 1999

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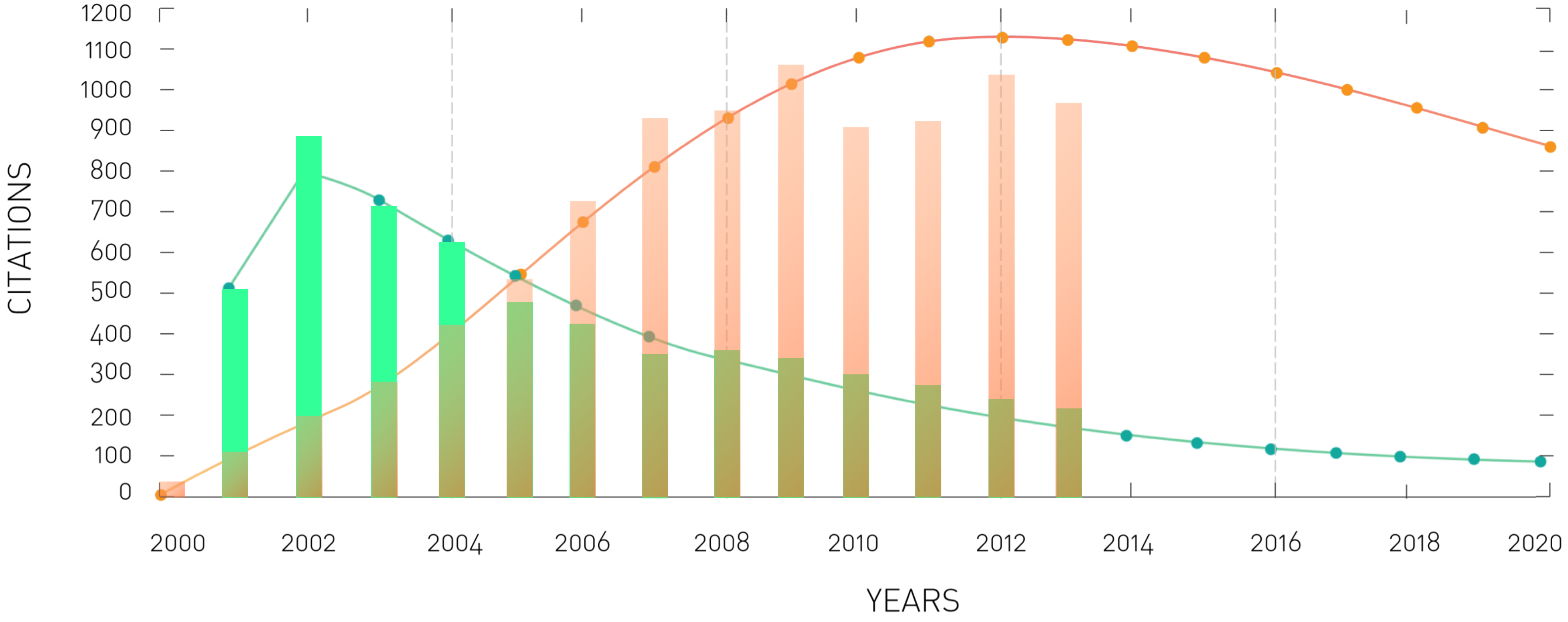
Cites (2013): ***6,326*** Total impact: **13,105**




**Barabási & Albert**, *Emergence of scaling in random networks.* Science, 1999

Cites (2013): ***8,245*** Total impact: **26,183**

**Venter *et al*.**, *The sequence of the human genome*. Science, 2001

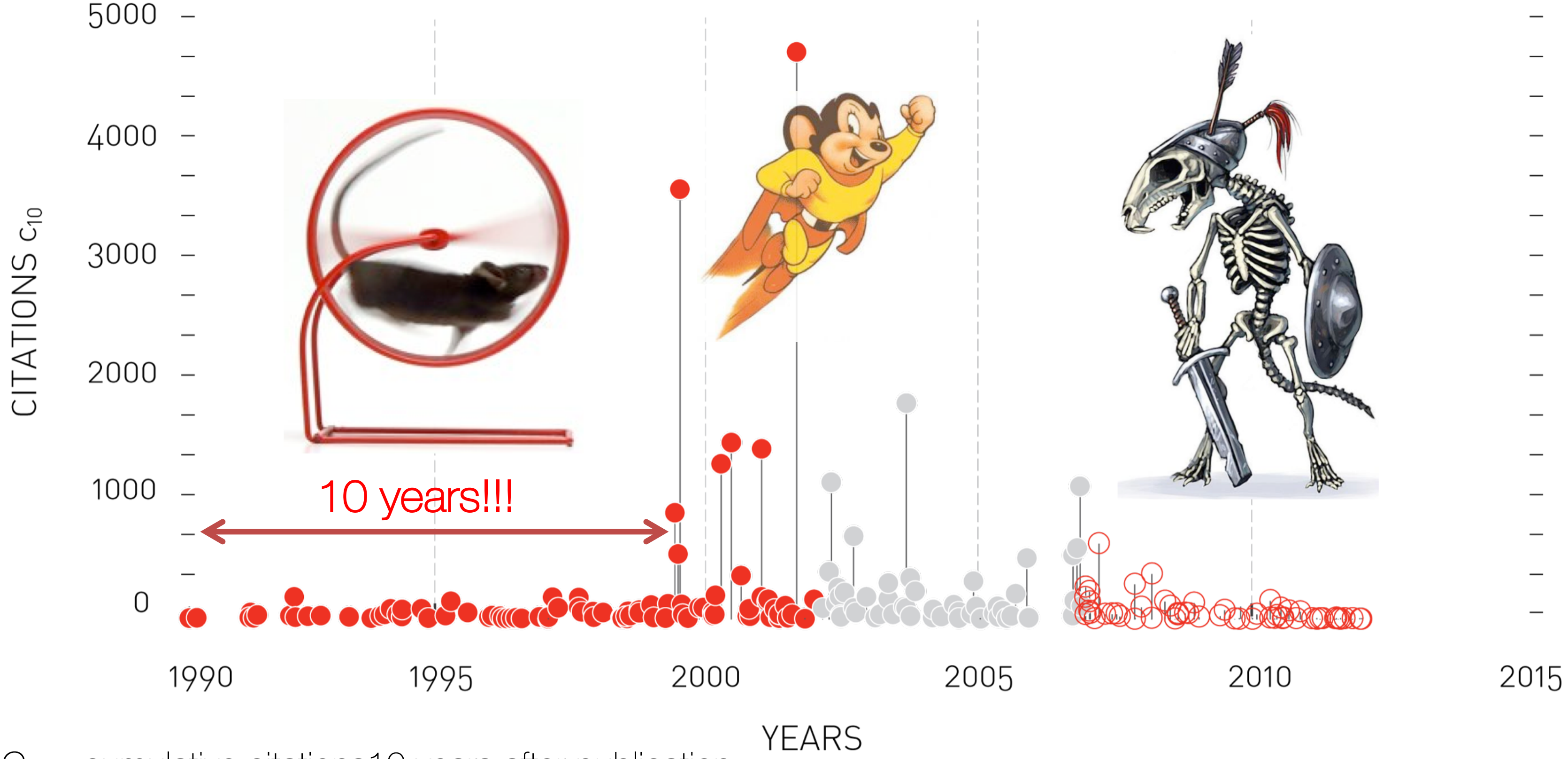
Cites (2013): ***6,326*** Total impact: **13,105**

# **The Sixth Law:**

Quality times previous success determines future success.

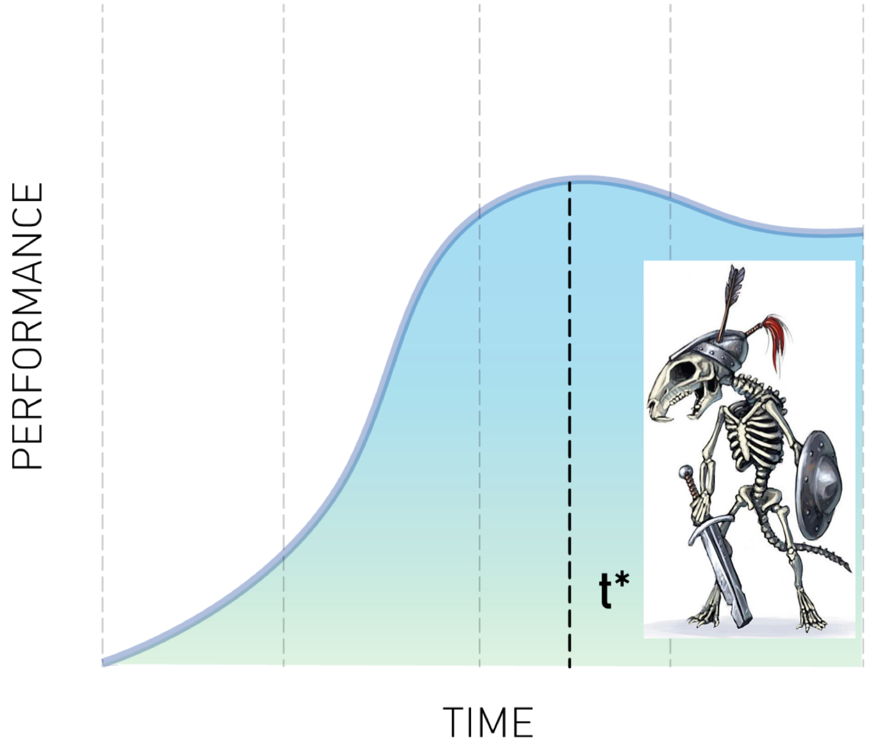
$$\Pi(k_i) \cong \frac{\eta_i k_i}{\sum_j \eta_j k_j}$$

# CAREERS IN SCIENCE



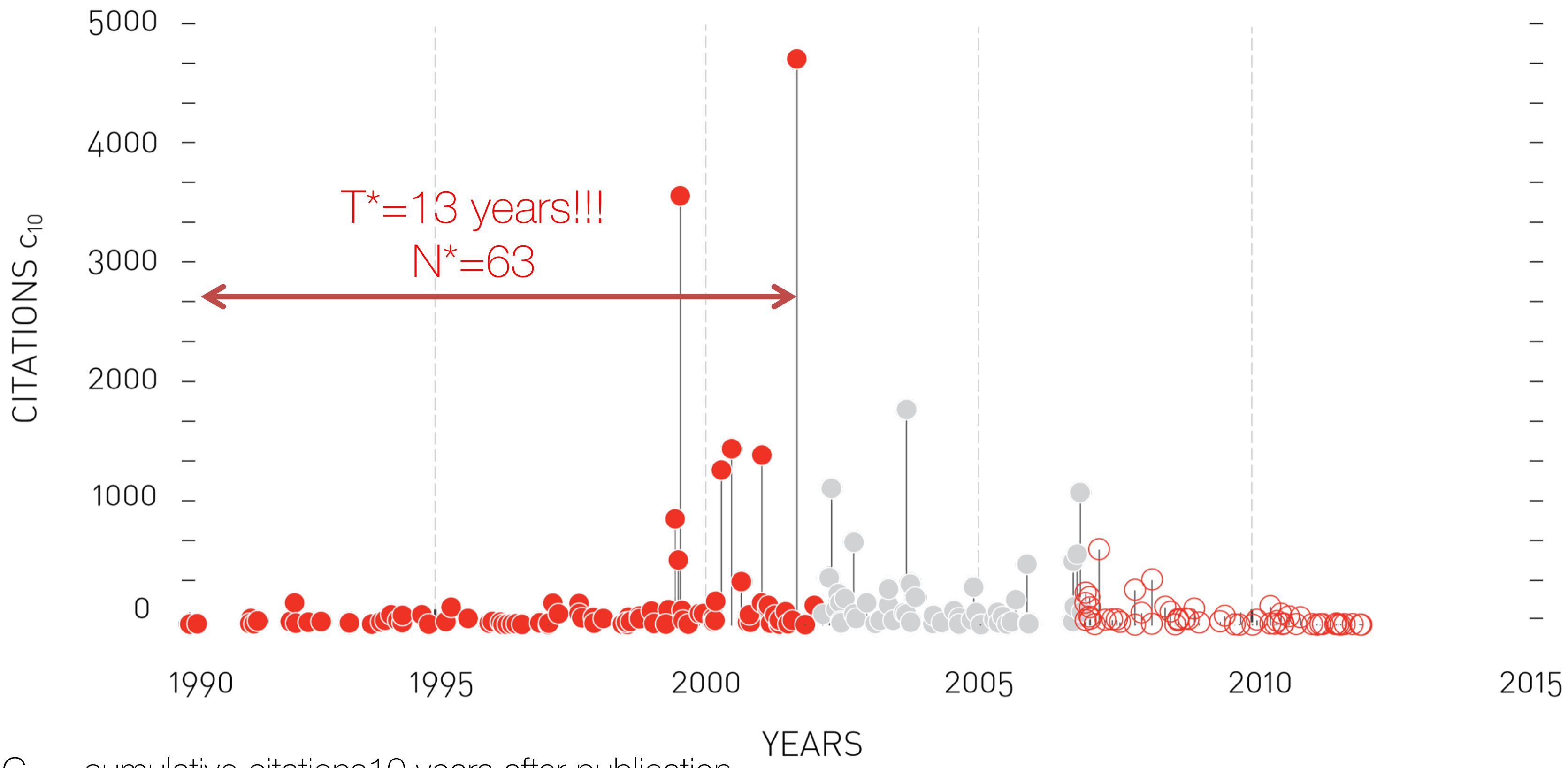

$C_{10}$= cumulative citations10 years after publication

# THE PATH TO SUCCESS: PSYCHOLOGY




Ericsson, Prietula, & Cokely, The making of an expert. Harvard Business Review 85, 114 (2007).
Simonton. Creative productivity. Psychological Review 104, 66 (1997).

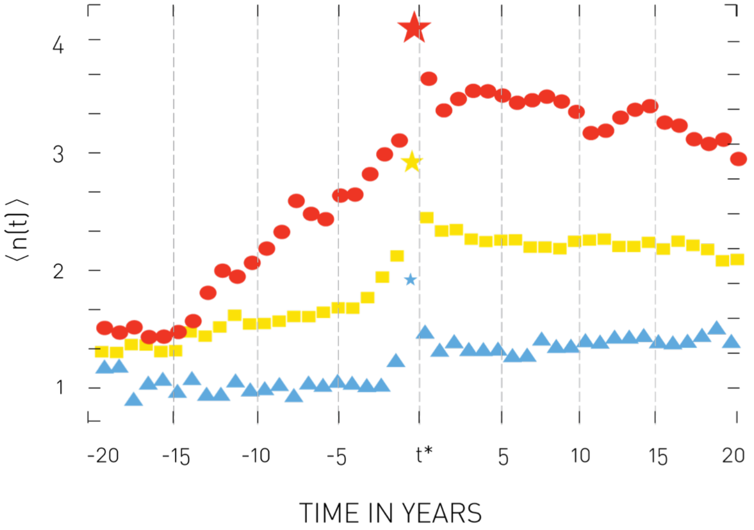
# CAREERS IN SCIENCE




$C_{10}$= cumulative citations10 years after publication

# CAREERS IN SCIENCE

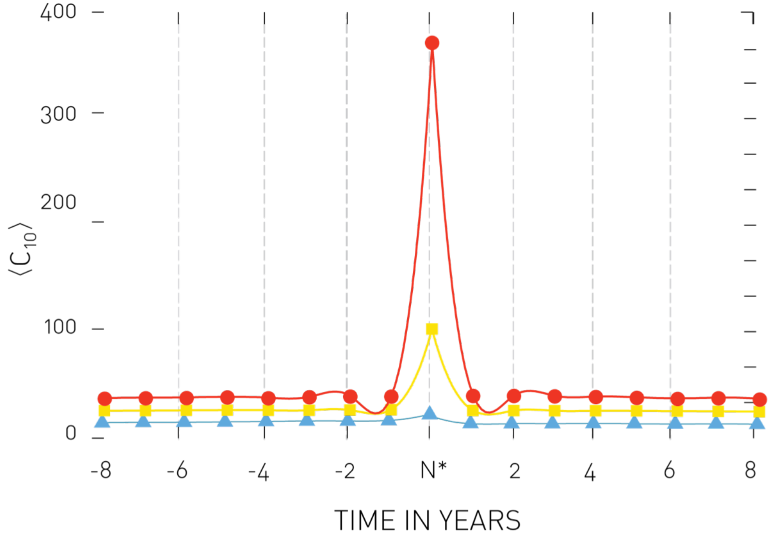
- Performance: Productivity




✓ **Productivity improves until the largest hit**
   ✓ **Higher the hit, stronger the effect**

Sinatra, Wang, Deville, Song & Barabási. 2014

- Impact: Success

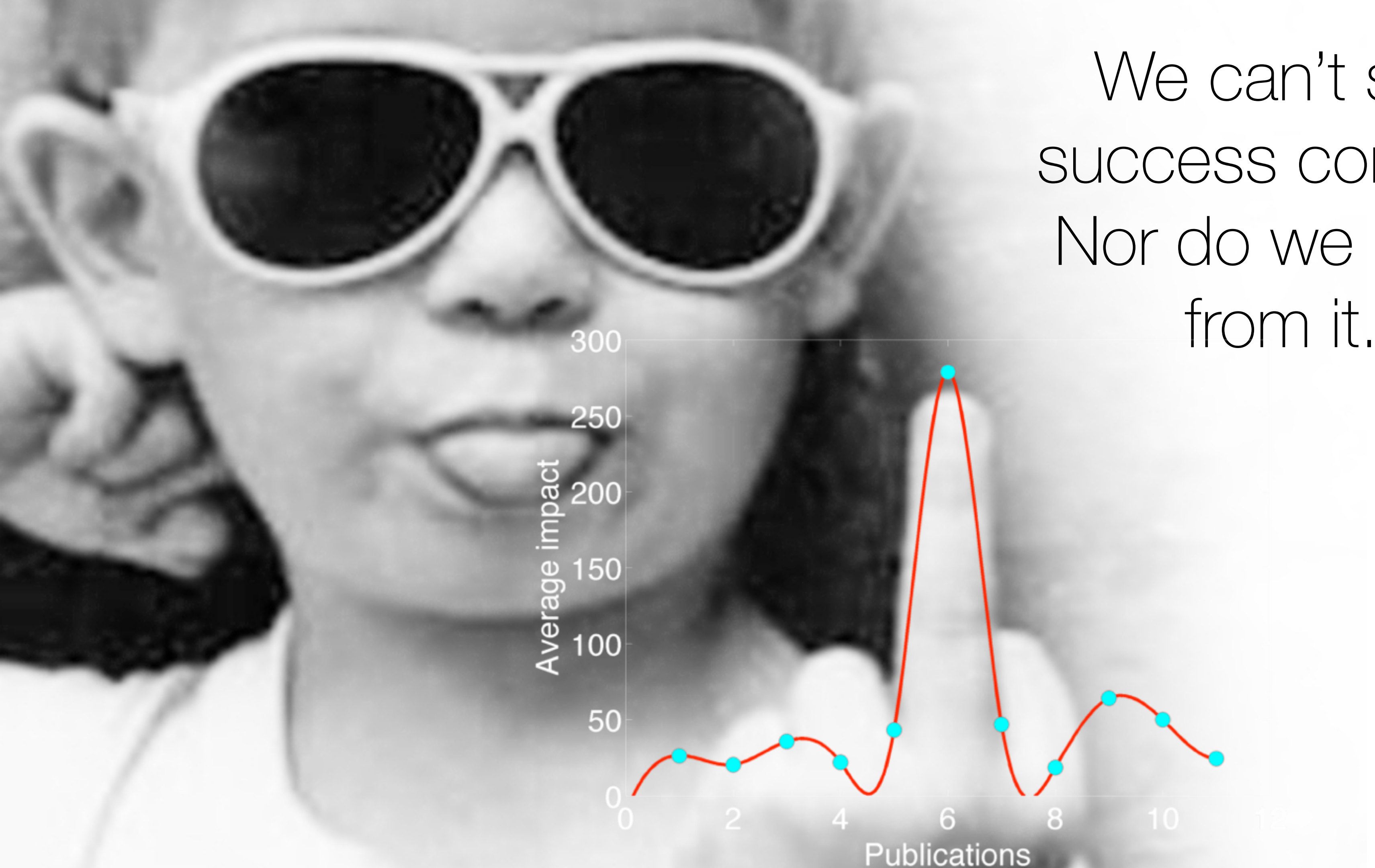



High Impact $(c^*_{10} \geq 200)$

Middle Impact $(20 < c^*_{10} < 200)$

Low Impact $(c^*_{10} \leq 20)$

We can’t see success coming. Nor do we learn from it.



# Age and Discovery

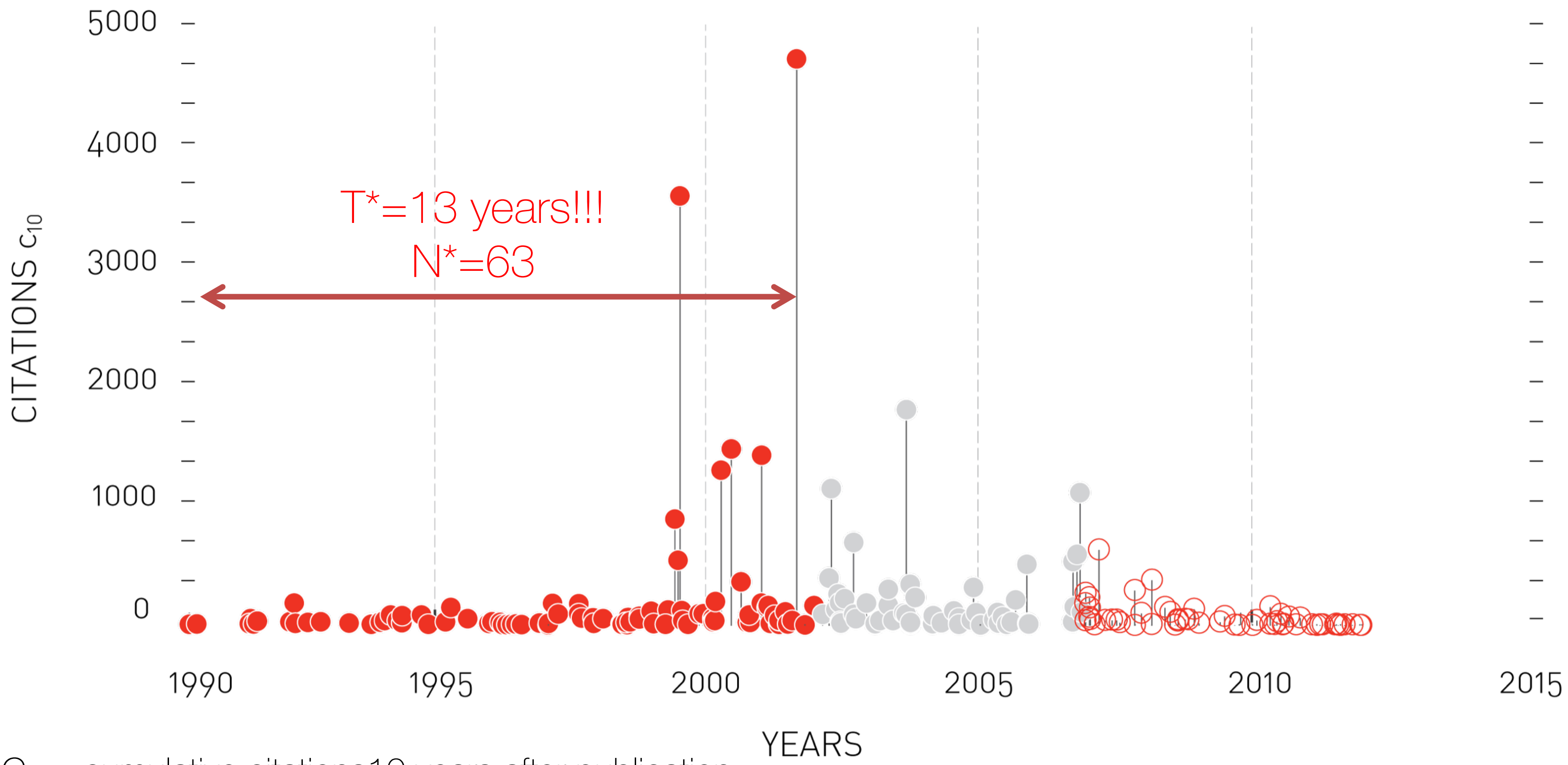
“A person who has not made his great contribution to science before the age of thirty will never do so.”

*-Albert Einstein*

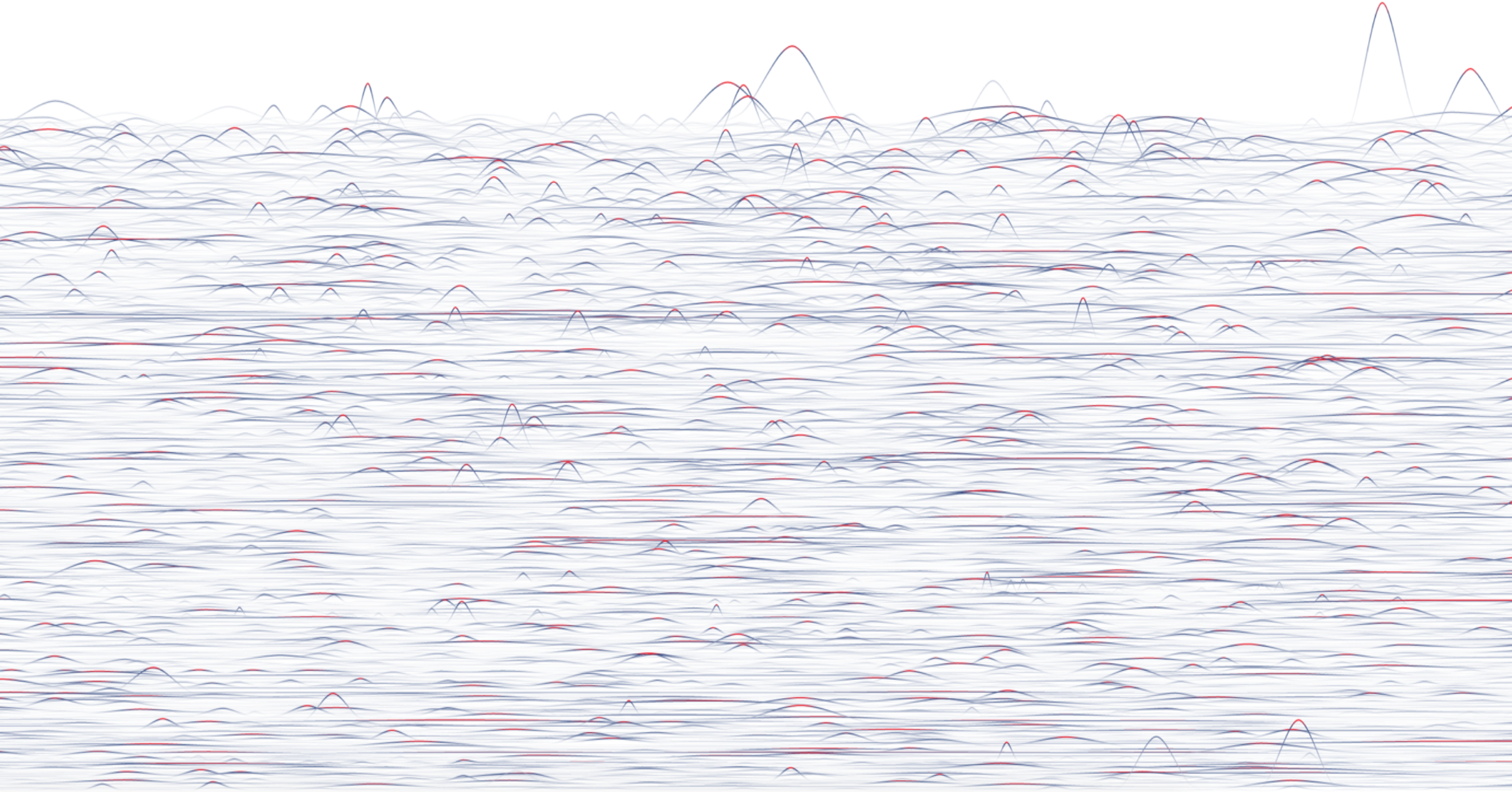
| Physicist | Age |
|---|---|
| Heisenberg | 24 |
| Dirac | 24 |
| Pauli | 25 |
| Fermi | 25 |
| Wigner | 25 |
| Einstein | 26 |
| Rutherford | 28 |
| Bohr | 28 |
| Bose | 30 |
| Compton | 31 |
| De Broglie | 31 |
| Feynman | 31 |
| Maxwell | 34 |
| Schrödinger | 39 |
| Planck | 42 |

http://www.soulphysics.org/2008/05/when-is-prime-age-of-discovery-in/

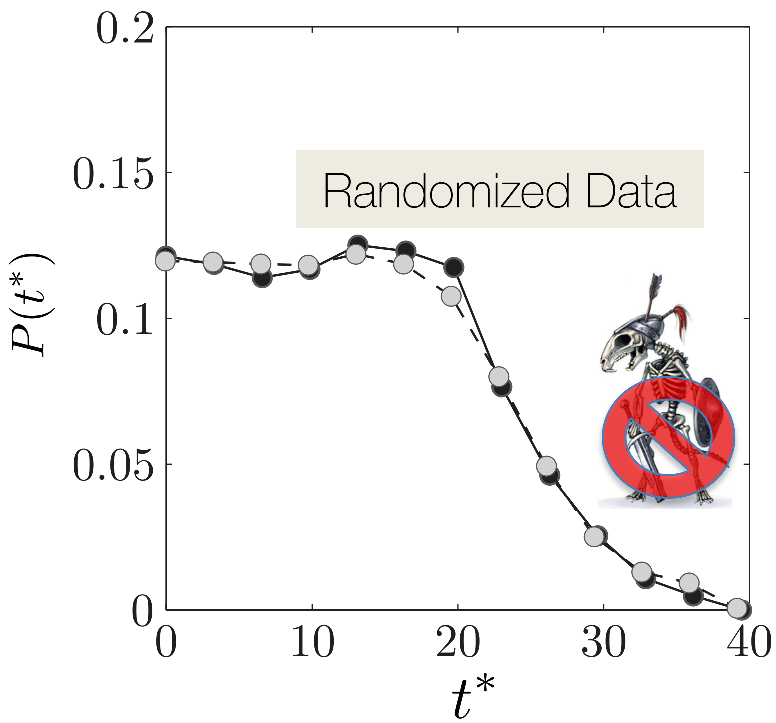
# CAREERS IN SCIENCE

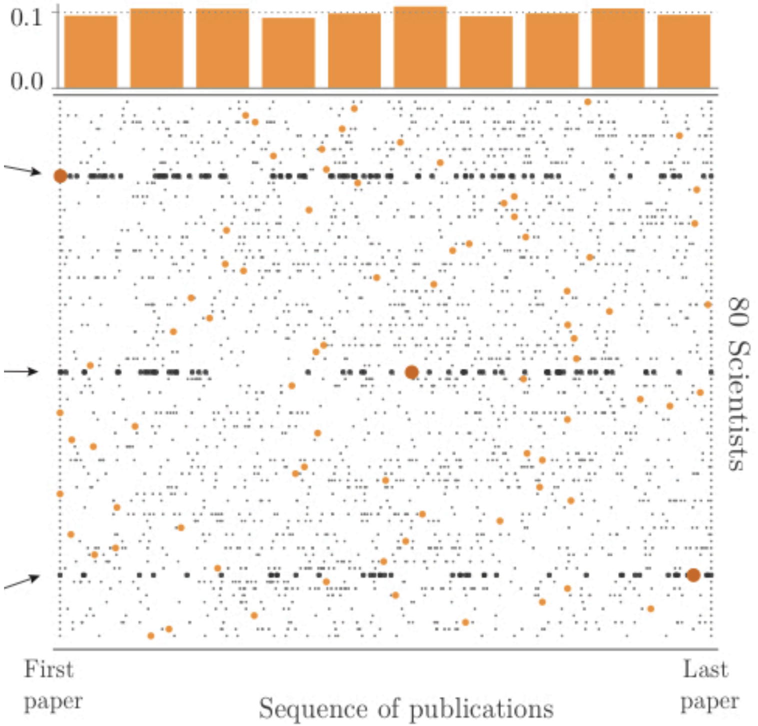



$C_{10}$= cumulative citations10 years after publication



# CAREERS IN SCIENCE: the timing of peak impact is random

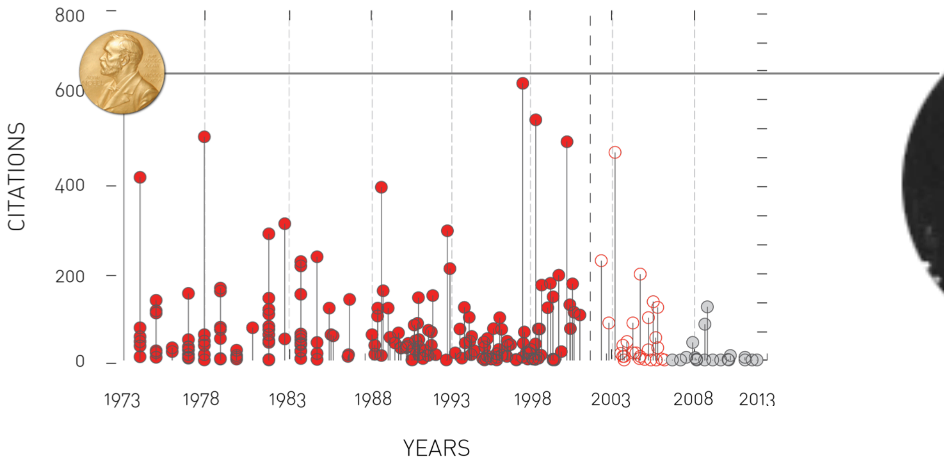


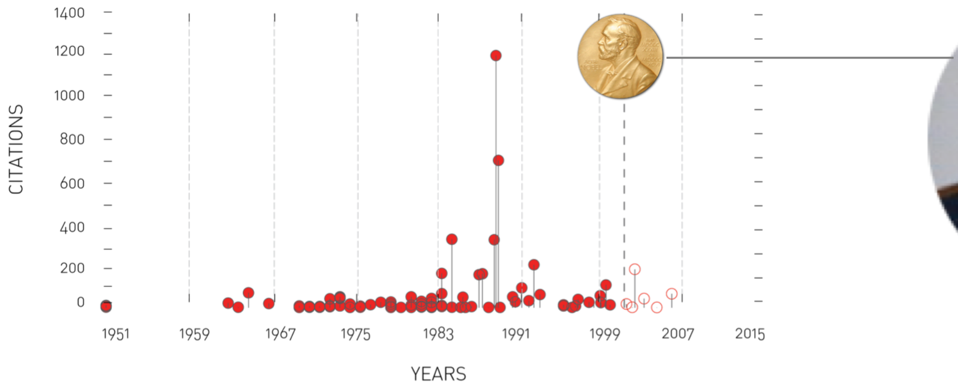

**You never know when your hit comes!**

It could be, with the same probability, the first or the last paper of your career.

# MODELING INDIVIDUAL CAREERS: You never know when the hit comes!



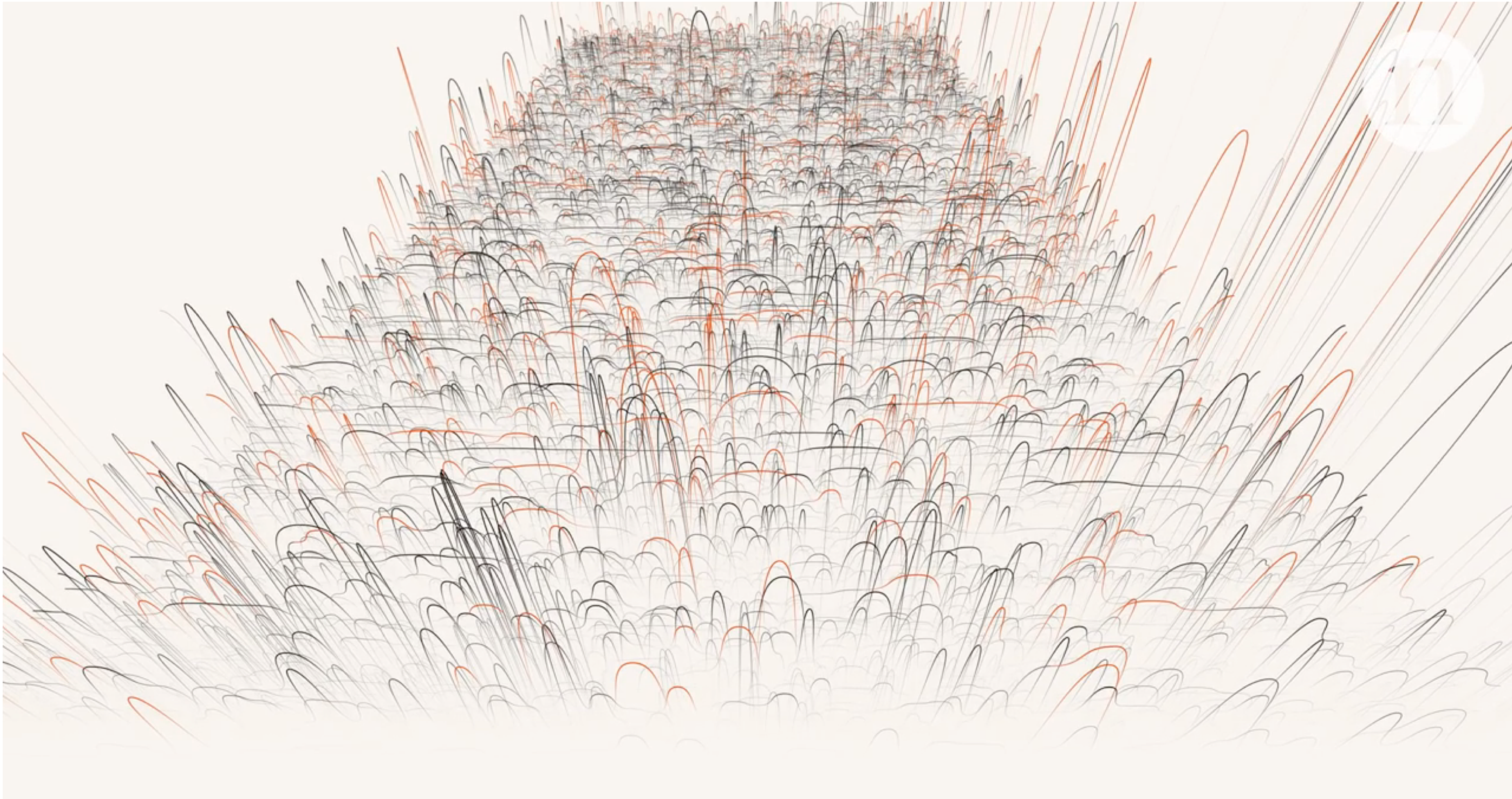

**Frank G. Wilczek**
Physics Nobel, 2004




**John B. Fenn**
Chemistry Nobel, 2002

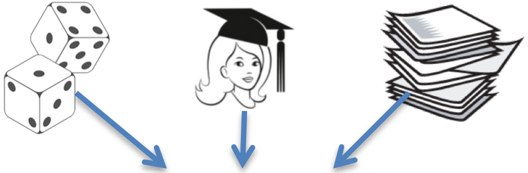

"All I have produced before the age of seventy is not worth taking into account.
At seventy-three I have learned a little about the real structure of nature.
When I am eighty I shall have made still more progress.
At ninety, I shall penetrate the mystery of things.
At one hundred I shall have reached a marvelous stage, and when I am one-hundred-ten,
everything I do, whether it be a dot or a line, will be alive."

Success can come at any time.



# MODELING INDIVIDUAL CAREERS: Q-Model

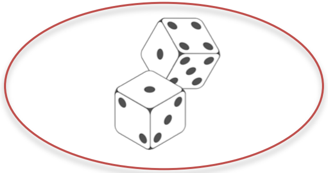
$$c_{10,i\alpha} = Q_i p_\alpha$$



$$P(p, Q, N)$$

$$\Sigma \equiv \begin{pmatrix} \sigma_p^2 & \sigma_{p,Q} & \sigma_{p,N} \\ \sigma_{p,Q} & \sigma_Q^2 & \sigma_{Q,N} \\ \sigma_{p,N} & \sigma_{Q,N} & \sigma_N^2 \end{pmatrix} = \begin{pmatrix} 0.93 & 0.00 & 0.00 \\ 0.00 & 0.21 & 0.09 \\ 0.00 & 0.09 & 0.33 \end{pmatrix}$$

$$P(p)P(Q, N)$$



- P(p) decuples from N and Q:
  - ✓ Everyone has the same initial chance of making a discovery
- N and Q are coupled:
  - ✓ The more you publish, the higher the chance that you will make a major discovery

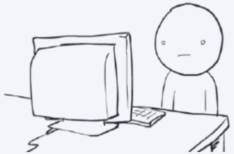
Sinatra, Wang, Deville, Song & Barabási. Science (2016)

# How Does Innovation Happen? Q-Model

Idea


$r$

You



$Q$

Success
Impact


$S$

$$r \times Q = S$$

Sinatra, Wang, Deville, Song & Barabási. Science (2016)

# Steve Jobs & Q-Model

$$S = Q \times r$$

Great Idea, Poor Execution

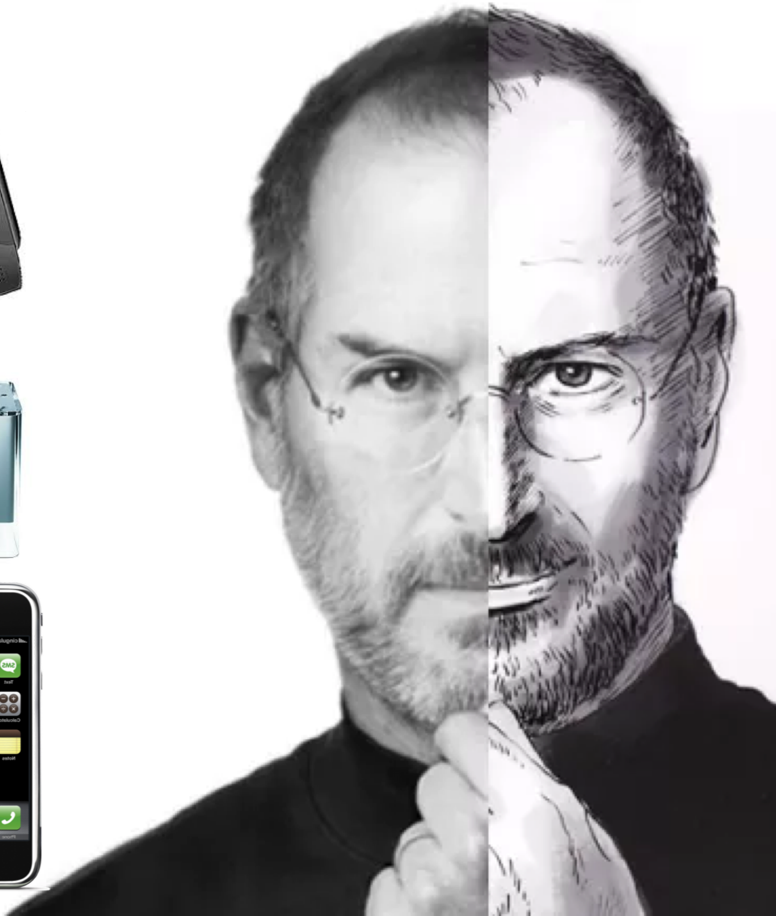
r= 10 Q=0.1 S=1


Poor Idea, Great Execution

r= 0.1 Q=10 S=1

Great Idea, Great Execution

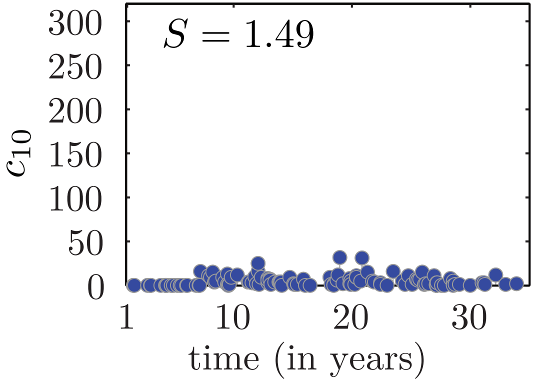
r= 10 Q=10 **S=100**



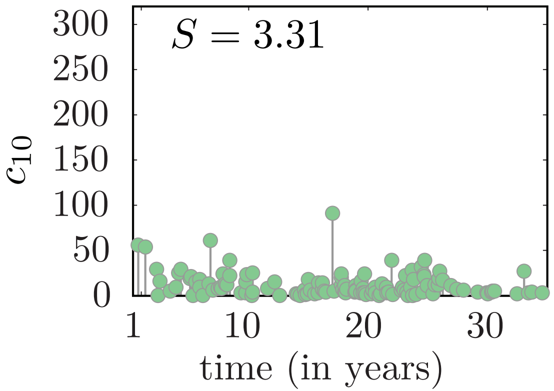
# INDIVIDUAL CAREERS: Careers have different impact

$$Q = e^{\langle \log c_{10} \rangle - \mu_p}$$

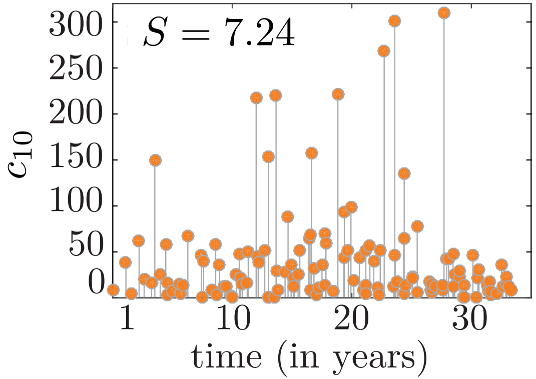
## Low Q




## Medium Q

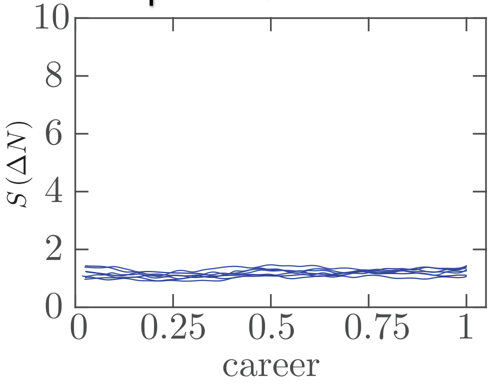


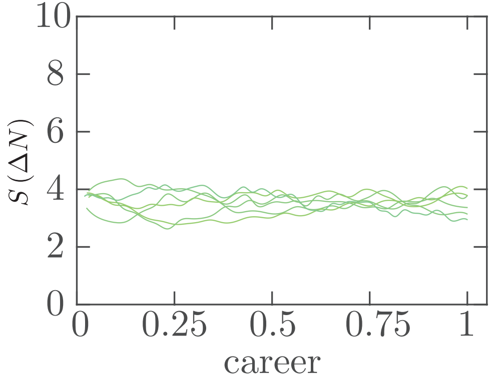

## High Q

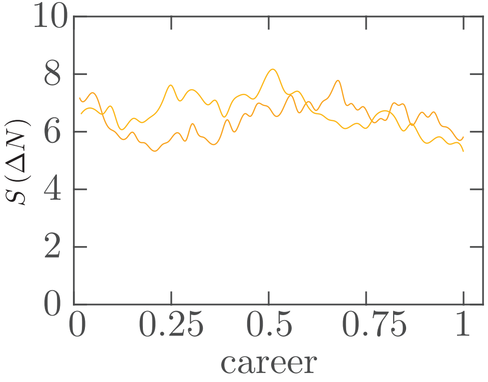



C=p x Q

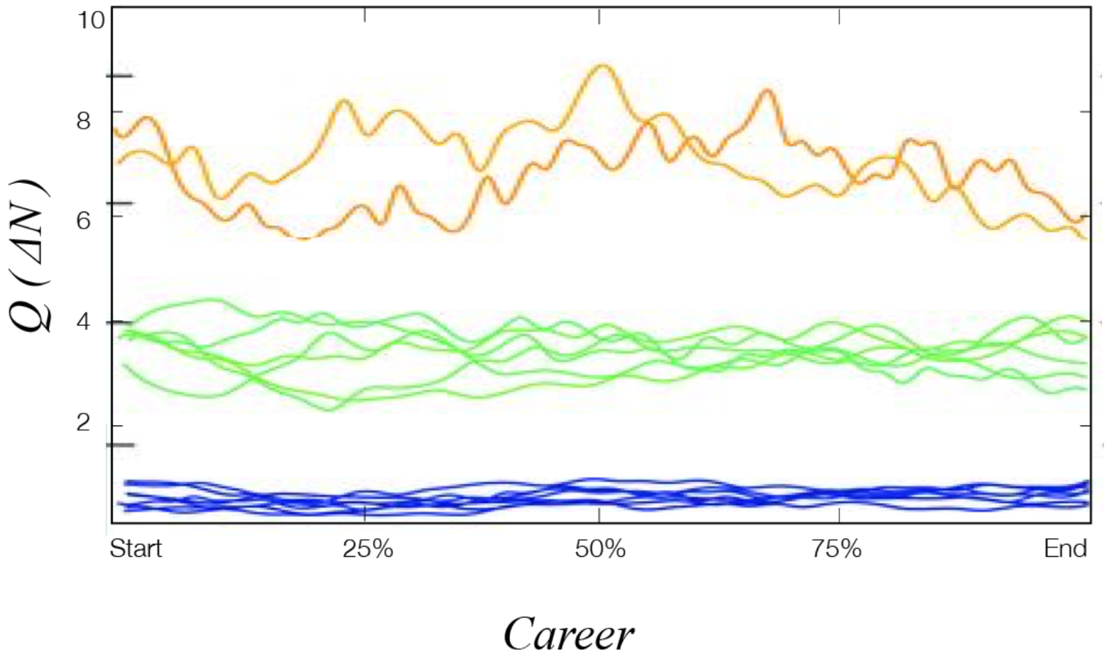
## Q is stable during a career




Sinatra, Wang, Deville, Song & Barabási. Science (2016)




$S = Q \times r$

The Q factor does not change during our career.

Q is the best predictor of a Nobel prize

Citations. H-factor are less predictive.  Productivity is the worst predictor…

# MODELING INDIVIDUAL CAREERS: You never know when the hit comes!

$$C = p \times Q$$

Impact = luck x Quality Factor

- Each scientist randomly selects a project p and improves on it with a factor Q
- *High impact publications:* a high $S_i$ scientist selects by chance a high p project
- any scientist can publish low impact papers by selecting a low p.

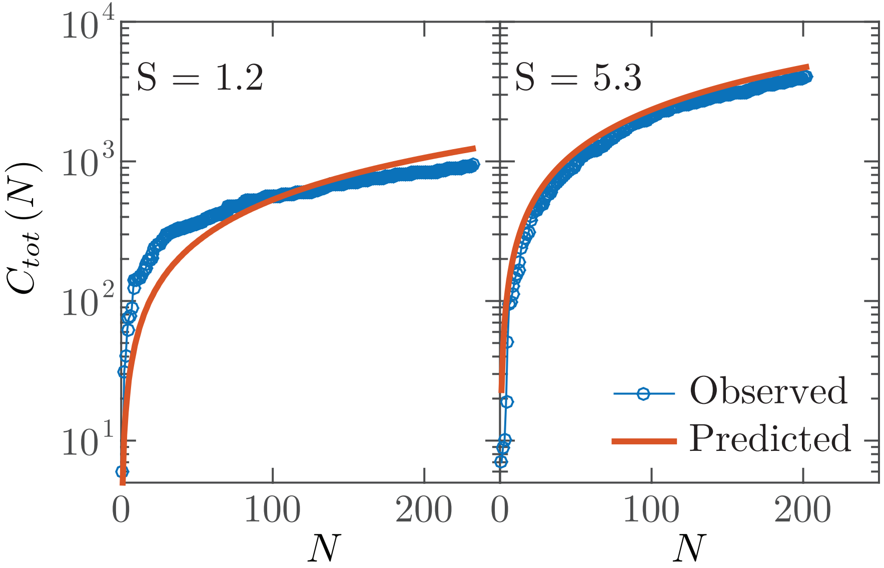
## Q:

- Does not vary during a career
- Predicts citation dynamics
- Predicts the growth of the h-index during a career
- Best predictor of exceptional achievement (like a Nobel)

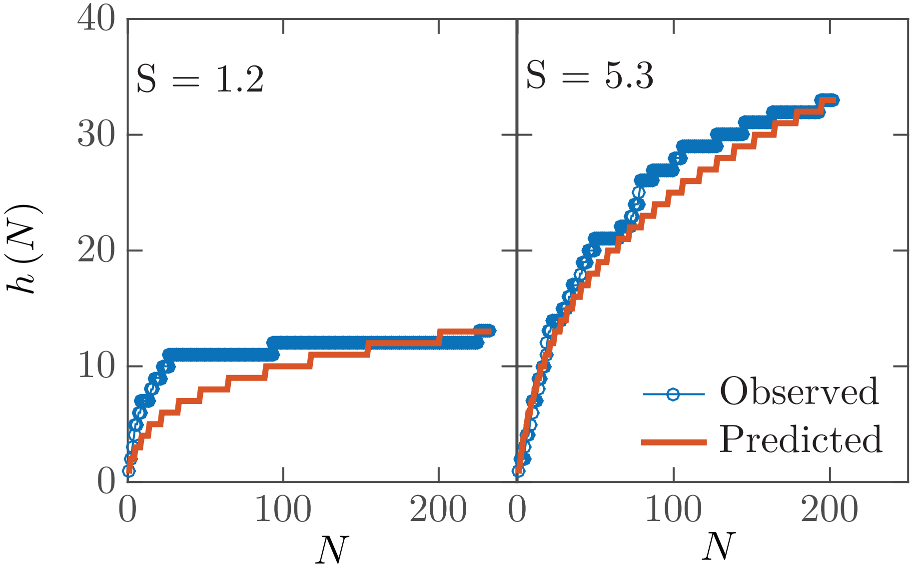
Sinatra, Wang, Deville, Song & Barabási, Science 2016

# MODELING INDIVIDUAL CAREERS: Q predicts the traditional impact indicators!

***Q*** **predicts the dynamics of the total number of citations during a career**




***Q*** **predicts the variation of the *h*-index during a career**

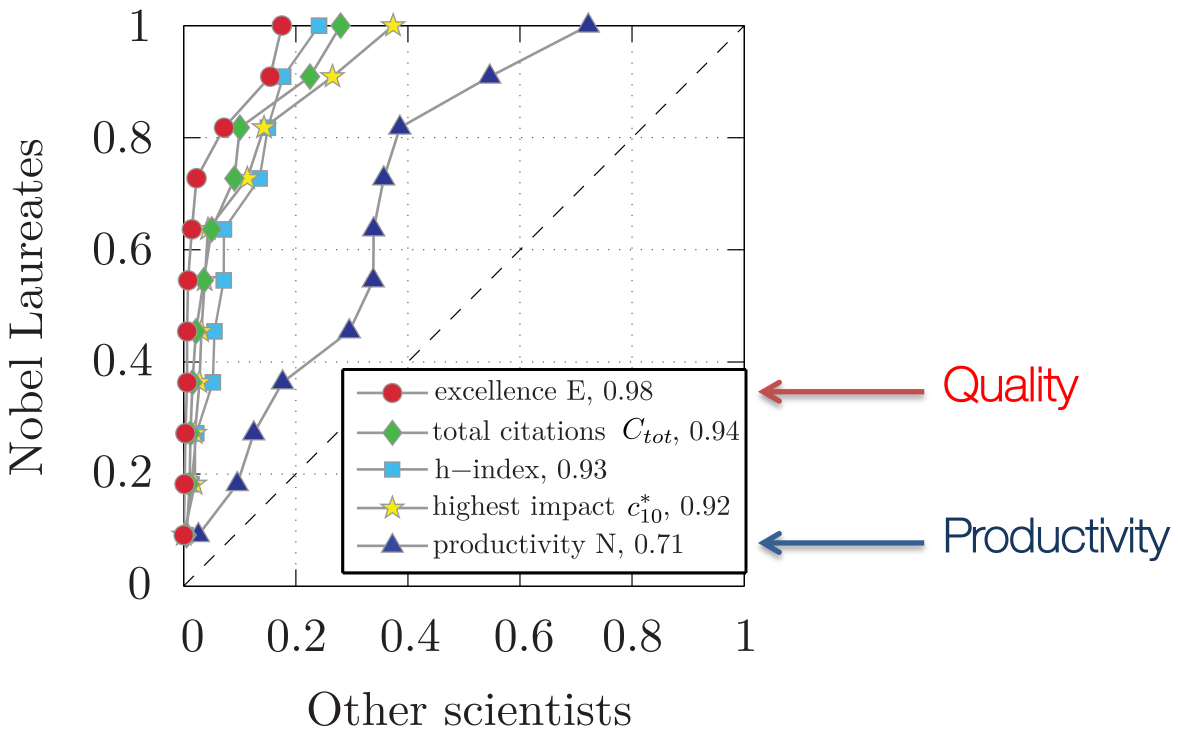



***Citations and h-index grow during a career → Q : time-independent predictor of impact.***

Sinatra, Wang, Deville, Song & Barabási, Science 2016

# MODELING INDIVIDUAL CAREERS: Ranking Nobel Prize Winners

C=p x Q

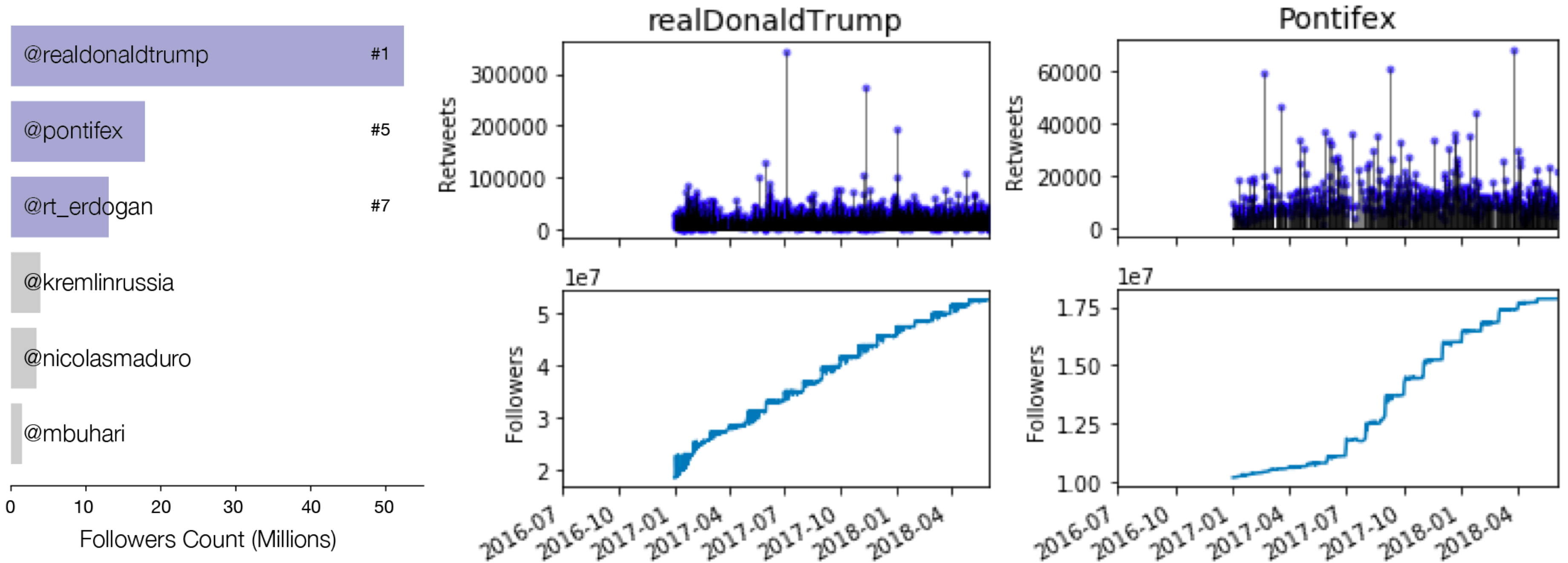



✓ Quality factor, Q is the best predictor of a Nobel prize

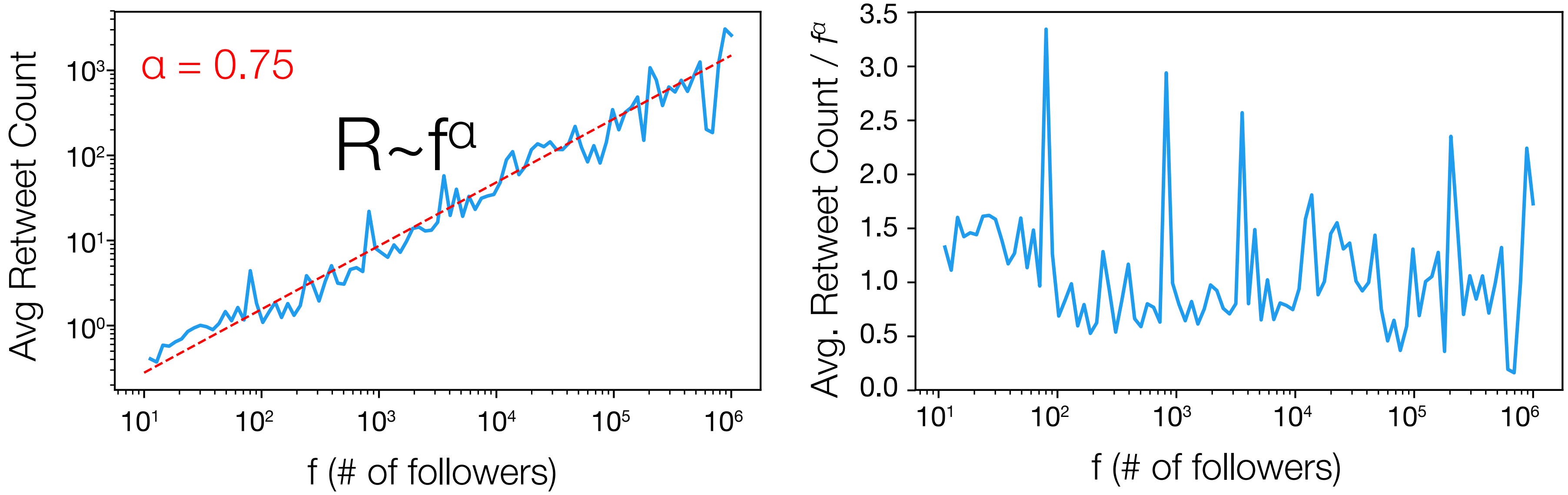
✓ Productivity is the worst.

Sinatra, Wang, Deville, Song & Barabási. 2014

# Q-factor: Twitter Dynamics



# Q-factor: Popularity Drives Retweets... Up to a Point.




Follower Engagement:

$E = R/f^{\alpha}$

# Q-factor


Idea

r

**Q-factor:**
engage with followers.

Q

**Followers**

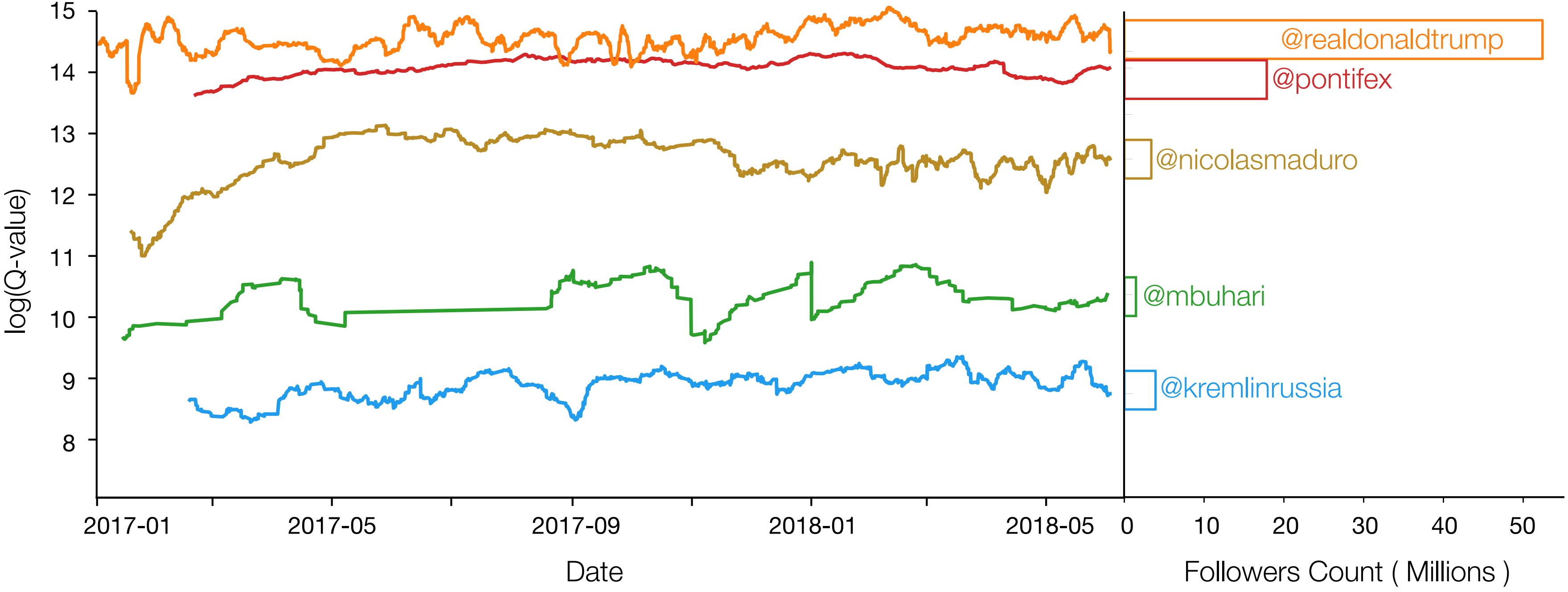
f

**Engagement/Impact of a tweet**:
# retweets
# favorites

R

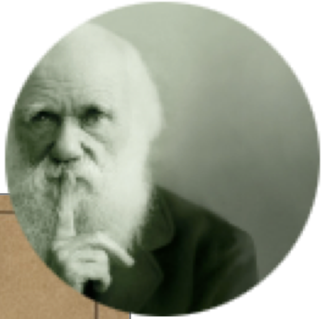
$$r \times Q \times f^{a} = R$$

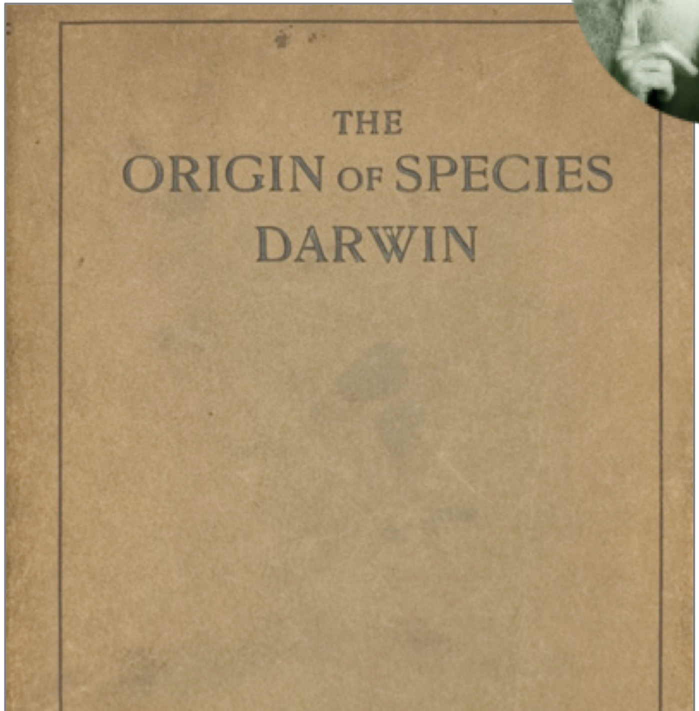
# Twitter Q-factor

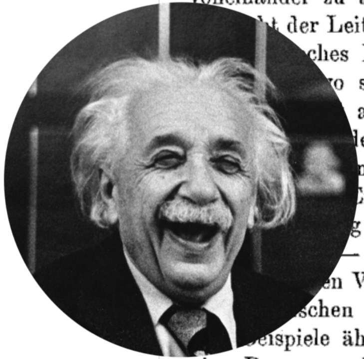



$$r \times Q \times f^{\alpha} = R$$

# HOW DO WE ASSIGN CREDIT FOR SUCCESS?





**3. *Zur Elektrodynamik bewegter Körper;***
***von A. Einstein.***

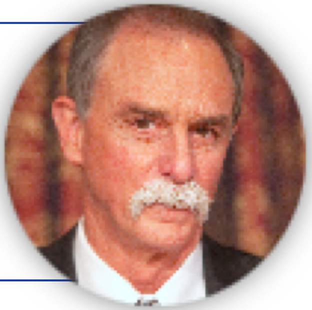
Daß die Elektrodynamik Maxwells — wie dieselbe gegenwärtig aufgefaßt zu werden pflegt — in ihrer Anwendung auf bewegte Körper zu Asymmetrien führt, welche den Phänomenen nicht anzuhaften scheinen, ist bekannt. Man denke z. B. an die elektrodynamische Wechselwirkung zwischen einem Magneten und einem Leiter. Das beobachtbare Phänomen hängt hier nur ab von der Relativbewegung von Leiter und Magnet, während nach der üblichen Auffassung die beiden Fälle, daß der eine oder der andere dieser Körper der bewegte sei, streng voneinander zu trennen sind. Bewegt sich nämlich der Magnet
[illegible] der Leiter, so entsteht in der Umgebung des Magneten
[illegible]ches Feld von gewissem Energiewerte, welches an
[illegible]o sich Teile des Leiters befinden, einen Strom
[illegible] aber der Magnet und bewegt sich der Leiter,
[illegible]der Umgebung des Magneten kein elektrisches
[illegible]m Leiter eine elektromotorische Kraft, welcher
[illegible]Energie entspricht, die aber — Gleichheit der
[illegible]g bei den beiden ins Auge gefaßten Fällen
[illegible] — zu elektrischen Strömen von derselben Größe
[illegible]en Verlaufe Veranlassung gibt, wie im ersten Falle
[illegible]schen Kräfte.

[illegible]eispiele ähnlicher Art, sowie die mißlungenen Versuche, eine Bewegung der Erde relativ zum „Lichtmedium" zu konstatieren, führen zu der Vermutung, daß dem Begriffe der absoluten Ruhe nicht nur in der Mechanik, sondern auch in der Elektrodynamik keine Eigenschaften der Erscheinungen entsprechen, sondern daß vielmehr für alle Koordinatensysteme, für welche die mechanischen Gleichungen gelten, auch die

VOLUME 76, NUMBER 11 PHYSICAL REVIEW LETTERS 11 MARCH 1996

**Generation of Nonclassical Motional States of a Trapped Atom**

D. M. Meekhof, C. Monroe, B. E. King, W. M. Itano, and D. J. Wineland
*Time and Frequency Division, National Institute of Standards and Technology, Boulder, Colorado 80303-3328*



VOLUME 55, NUMBER 1 PHYSICAL REVIEW LETTERS 1 JULY 1985

**Three-Dimensional Viscous Confinement and Cooling of Atoms by Resonance Radiation Pressure**

Steven Chu, L. Hollberg, J. E. Bjorkholm, Alex Cable, and A. Ashkin
*AT&T Bell Laboratories, Holmdel, New Jersey 07733*

VOLUME 61, NUMBER 21 PHYSICAL REVIEW LETTERS 21 NOVEMBER 1988

**Giant Magnetoresistance of (001) Fe/(001) Cr Magnetic Superlattices**

M. N. Baibich,[a] J. M. Broto, A. Fert, F. Nguyen Van Dau, and F. Petroff
*Laboratoire de Physique des Solides, Université Paris-Sud, F-91405 Orsay, France*

P. Eitenne, G. Creuzet, A. Friederich, and J. Chazelas
*Laboratoire Central de Recherches, Thomson CSF, B.P. 10, F-91401 Orsay, France*

# EXPERIMENTAL OBSERVATION OF ISOLATED LARGE TRANSVERSE ENERGY ELECTRONS WITH ASSOCIATED MISSING ENERGY AT $\sqrt{s}$ = 540 GeV

UA1 Collaboration, CERN, Geneva, Switzerland

G. ARNISON [j], A. ASTBURY [j], B. AUBERT [b], C. BACCI [i], G. BAUER [1], A. BÉZAGUET [d], R. BÖCK [d], T.J.V. BOWCOCK [f], M. CALVETTI [d], T. CARROLL [d], P. CATZ [b], P. CENNINI [d], S. CENTRO [d], F. CERADINI [d], S. CITTOLIN [d], D. CLINE [1], C. COCHET [k], J. COLAS [b], M. CORDEN [c], D. DALLMAN [d], M. DeBEER [k], M. DELLA NEGRA [b], M. DEMOULIN [d], D. DENEGRI [k], A. Di CIACCIO [i], D. DiBITONTO [d], L. DOBRZYNSKI [g], J.D. DOWELL [c], M. EDWARDS [c], K. EGGERT [a], E. EISENHANDLER [f], N. ELLIS [d], P. ERHARD [a], H. FAISSNER [a], G. FONTAINE [g], R. FREY [h], R. FRÜHWIRTH [1], J. GARVEY [c], S. GEER [g], C. GHESQUIÈRE [g], P. GHEZ [b], K.L. GIBONI [a], W.R. GIBSON [f], Y. GIRAUD-HÉRAUD [g], A. GIVERNAUD [k], A. GONIDEC [b], G. GRAYER [j], P. GUTIERREZ [h], T. HANSL-KOZANECKA [a], W.J. HAYNES [j], L.O. HERTZBERGER [2], C. HODGES [h], D. HOFFMANN [a], H. HOFFMANN [d], D.J. HOLTHUIZEN [2], R.J. HOMER [c], A. HONMA [f], W. JANK [d], G. JORAT [d], P.I.P. KALMUS [f], V. KARIMÄKI [e], R. KEELER [f], I. KENYON [c], A. KERNAN [h], R. KINNUNEN [e], H. KOWALSKI [d], W. KOZANECKI [h], D. KRYN [d], F. LACAVA [d], J.-P. LAUGIER [k], J.-P. LEES [b], H. LEHMANN [a], K. LEUCHS [a], A. LÉVÊQUE [k], D. LINGLIN [b], E. LOCCI [k], M. LORET [k], J.-J. MALOSSE [k], T. MARKIEWICZ [d], G. MAURIN [d], T. McMAHON [c], J.-P. MENDIBURU [g], M.-N. MINARD [b], M. MORICCA [i], H. MUIRHEAD [d], F. MULLER [d], A.K. NANDI [j], L. NAUMANN [d], A. NORTON [d], A. ORKIN-LECOURTOIS [g], L. PAOLUZI [i], G. PETRUCCI [d], G. PIANO MORTARI [i], M. PIMIÄ [e], A. PLACCI [d], E. RADERMACHER [a], J. RANSDELL [h], H. REITHLER [a], J.-P. REVOL [d], J. RICH [k], M. RIJSSENBEEK [d], C. ROBERTS [j], J. ROHLF [d], P. ROSSI [d], C. RUBBIA [d], B. SADOULET [d], G. SAJOT [g], G. SALVI [f], G. SALVINI [i], J. SASS [k], J. SAUDRAIX [k], A. SAVOY-NAVARRO [k], D. SCHINZEL [f], W. SCOTT [j], T.P. SHAH [j], M. SPIRO [k], J. STRAUSS [1], K. SUMOROK [c], F. SZONCSO [1], D. SMITH [h], C. TAO [d], G. THOMPSON [f], J. TIMMER [d], E. TSCHESLOG [a], J. TUOMINIEMI [e], S. Van der MEER [d], J.-P. VIALLE [d], J. VRANA [g], V. VUILLEMIN [d], H.D. WAHL [1], P. WATKINS [c], J. WILSON [c], Y.G. XIE [d], M. YVERT [b] and E. ZURFLUH [d]

# ASSIGNING CREDIT WHERE ITS DUE

## Case A

**2010 Nobel Prize in Chemistry**

Baba, Negishi, J. Am. Chem. Soc. 98, 6729 (1976)

Negishi, Okukado, King,Van Horn, Spiegel, J. Am. Chem. Soc. (1978)

Negishi, King, Okukado, J. Org. Chem. (1977)

Negishi, Vanhorn, J. Am. Chem. Soc. (1977)

Negishi, Vanhorn, J. Am. Chem. Soc. (1978)

Negishi, Valente. Kobayashi, J. Am. Chem. Soc. (1980)

## Case B

**2010 Nobel Prize in Physics**

Novoselov, Geim, Science, 306, 666 (2004)

Geim, Novoselov, Nature (2007)

Novoselov, Jiang, Schedin, Booth, Khotkevich, Morozov, Geim, PNAS (2005)

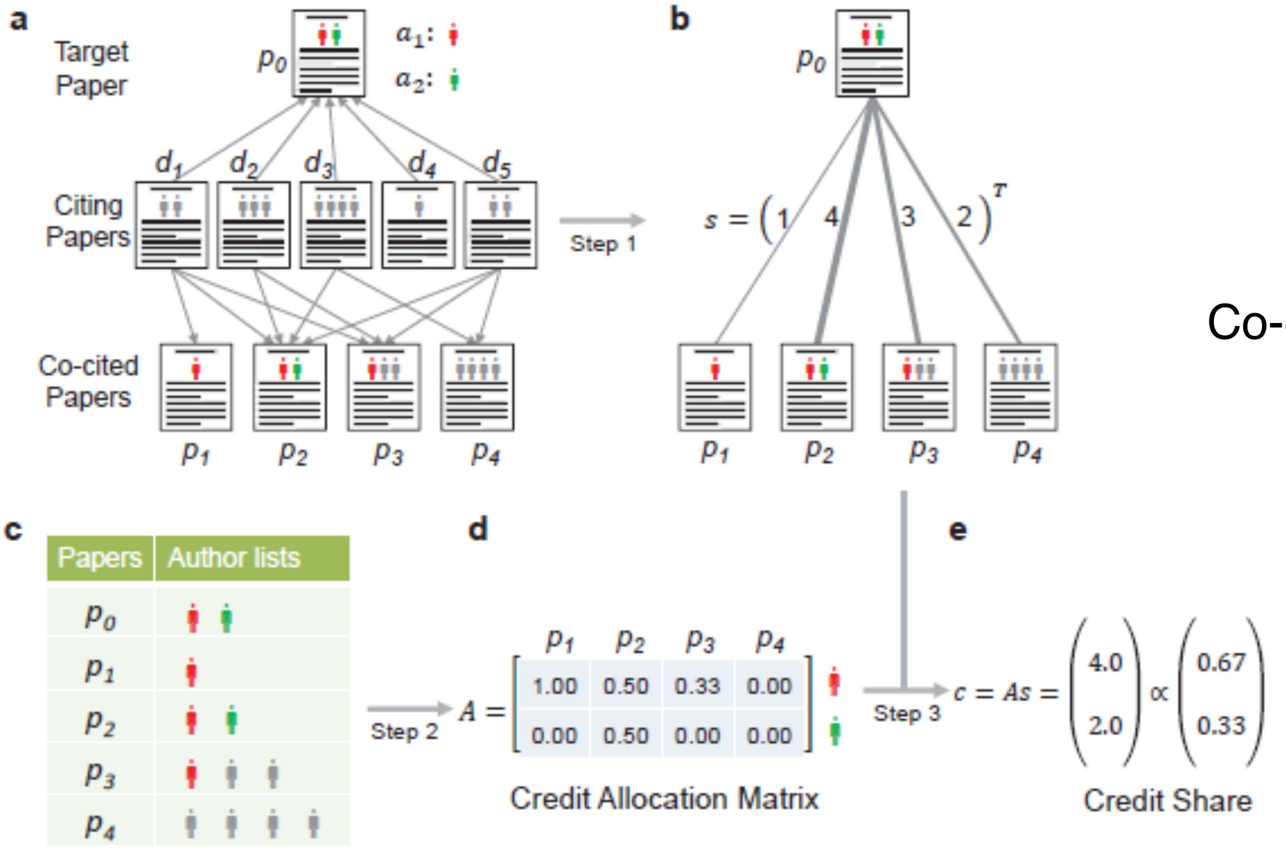
Novoselov, Geim, Morozov, Jiang, Katsnelson, Grigorieva, Dubonos, Firsov, Nature (2005)

Castro Neto, Guinea, Peres, Novoselov, Geim, Rev. Mod. Phys. (2009)

Ferrari, Meyer, Scardaci, Casiraghi, Lazzeri, Mauri,Piscanec. Jiang, Novoselov, Roth, Geim. Phys. Rev. Lett. (2006)

Shen & Barabási. 2014

# ASSIGNING CREDIT WHERE ITS DUE: The Method




Co-cited papers:

Co-citation strength *s*

Credit allocation matrix ***A***

Credit share:

***c=As***

Shen & Barabási. 2014

# CREDIT ASSIGNMENT: How Does it Work?

## Apostolic Exhortation on the Proclamation of the Gospel

Jorge Mario Bergoglio[1] and Albert-László Barabási [2,3,4]
[1]*Apostolic Palace 00120 Vatican City*
[2] *Center for Network Science, Central European University, Budapest 1052, Hungary*
[3] *Institute for Network Science, Northeastern University, Boston, MA 02115, USA*
[4]*Center for Cancer Systems Biology, Dana-Farber Cancer Institute, Boston, MA 02115, USA*

Credit Share: (0.9, 0.1)

## Scale-free Networks in Divine Interventions

Albert-László Barabási [1,2,3] and Jorge Mario Bergoglio[4]
[1] *Center for Network Science, Central European University, Budapest 1052, Hungary*
[2] *Institute for Network Science, Northeastern University, Boston, MA 02115, USA*
[3]*Center for Cancer Systems Biology, Dana-Farber Cancer Institute, Boston, MA 02115, USA*
[4]*Apostolic Palace 00120 Vatican City*

Credit Share: (0.1, 0.9)

Shen & Barabási. 2014

# ASSIGNING CREDIT WHERE ITS DUE

## Case A

### 2010 Nobel Prize in Chemistry

Baba, Negishi, J. Am. Chem. Soc. 98, 6729 (1976)

Negishi, Okukado, King,Van Horn, Spiegel, J. Am. Chem. Soc. (1978)

Negishi, King, Okukado, J. Org. Chem. (1977)

Negishi, Vanhorn, J. Am. Chem. Soc. (1977)

Negishi, Vanhorn, J. Am. Chem. Soc. (1978)

Negishi, Valente. Kobayashi, J. Am. Chem. Soc. (1980)

Credit share: (0.28, 0.72)

## Case B

### 2010 Nobel Prize in Physics

Novoselov, Geim, Science, 306, 666 (2004)

Geim, Novoselov, Nature (2007)

Novoselov, Jiang, Schedin, Booth, Khotkevich, Morozov, Geim, PNAS (2005)

Novoselov, Geim, Morozov, Jiang, Katsnelson, Grigorieva, Dubonos, Firsov, Nature (2005)

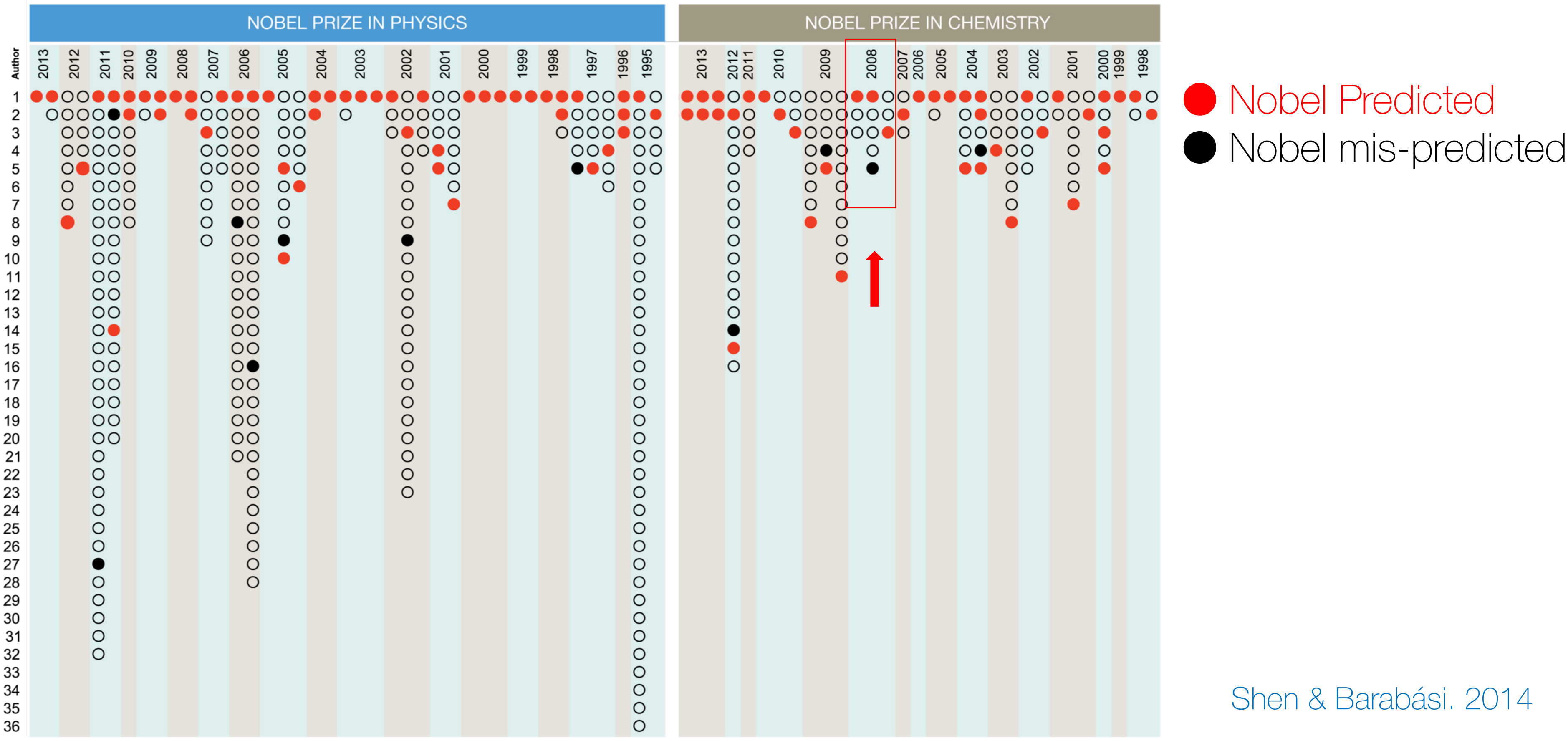
Castro Neto, Guinea, Peres, Novoselov, Geim, Rev. Mod. Phys. (2009)

Ferrari, Meyer, Scardaci, Casiraghi, Lazzeri, Mauri,Piscanec. Jiang, Novoselov, Roth, Geim. Phys. Rev. Lett. (2006)

Credit share: (0.5, 0.5)

Shen & Barabási. 2014

# ASSIGNING CREDIT WHERE ITS DUE: Who Gets the Prize?



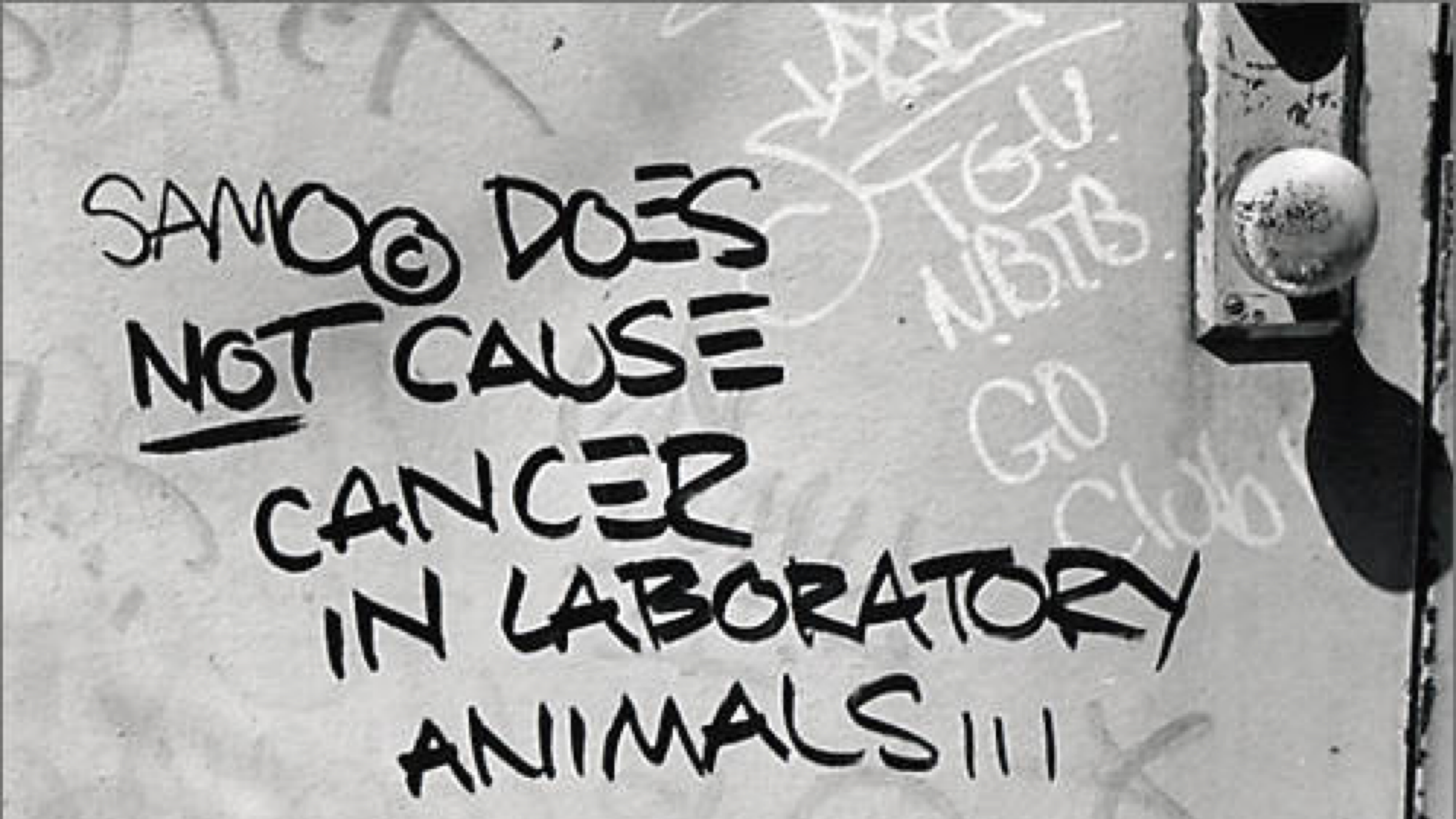

Shen & Barabási. 2014

# The Seventh Law:

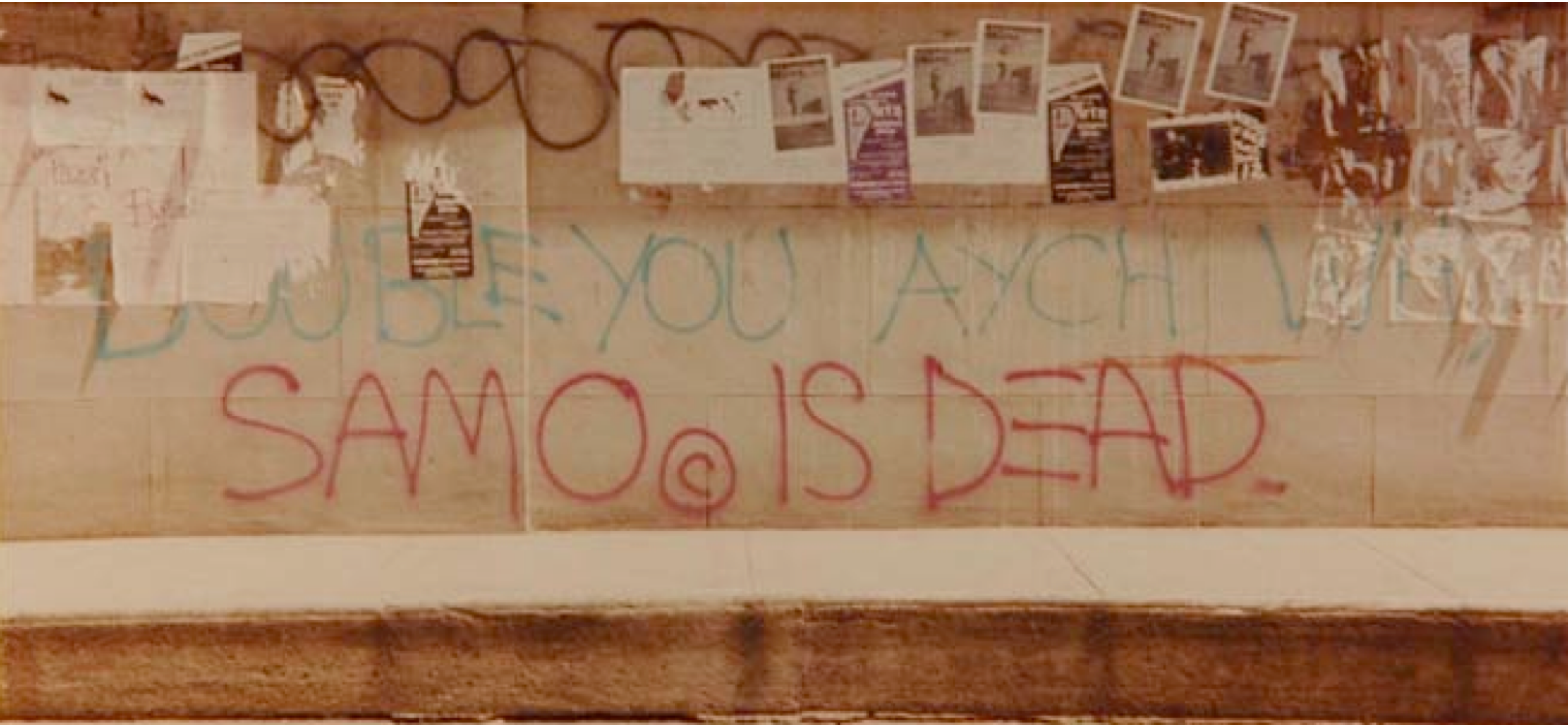
Credit is based on perception not performance.


In art performance is *inherently unmeasurable.*

Recognition, value and success are determined by invisible *influence networks*.


SAMO© DOES
NOT CAUSE
CANCER
IN LABORATORY
ANIMALS!!!


NO
PARKING


DOUBLE YOU AYCH
SAMO© IS DEAD.


CHRISTIE'S
USD 48,000,000
LOT 36B
EUR 42,076,800
GBP 33,288,000
CHF 46,468,800
JPY 5,217,753,600
HKD 370,752,000
RUB 3,157,315,200
CNY 309,638,400
CHRISTIE'S
CHRISTIE'S
CHRISTIE'S

May 19, 2017:

Untitled  (Jean-Michel Basquiat)

$110.5 million

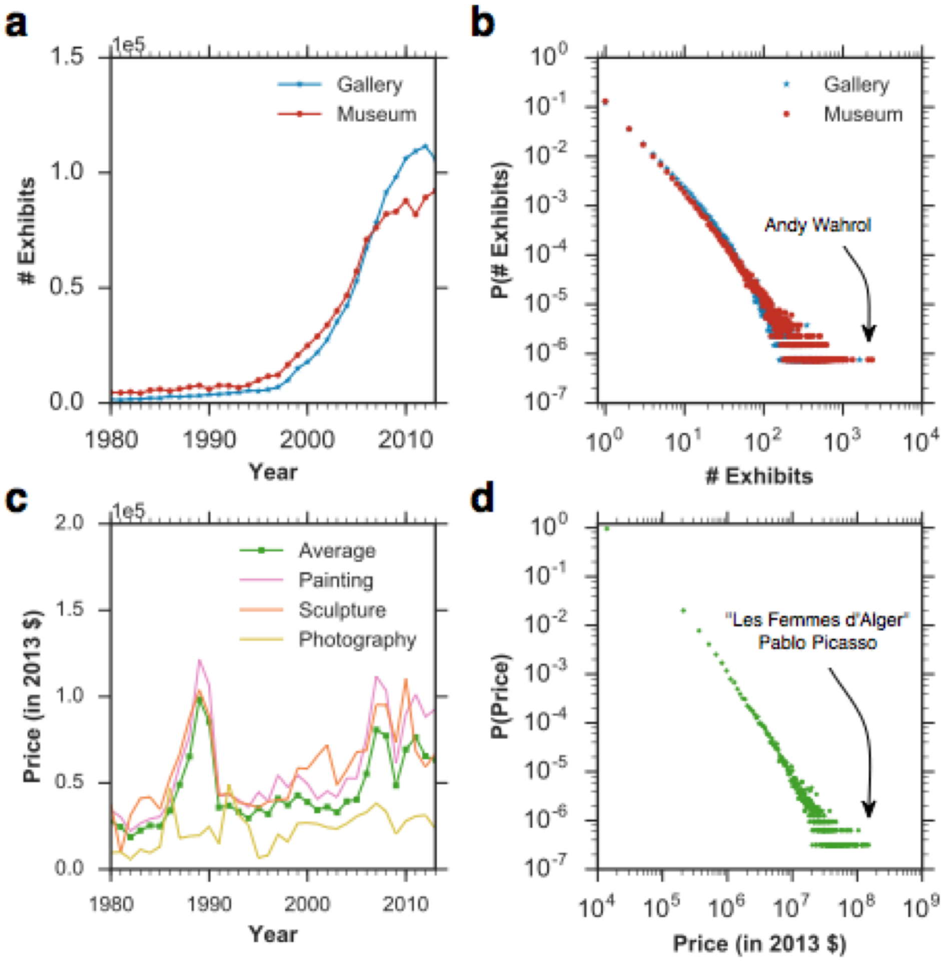

What happens when performance is inherently unmeasurable?

Value, recognition, and success are determined by influence networks.

# The Eight Law:

When quality and performance are hard to measure, networks determine success.

- 1980 to 2016
- 140 Countries
- 463,632 Artists
- 444,495 Exhibits in 14,474 galleries
- 287,807 exhibits in 7,825 museums
- 117,756 auctions



# Mark Grotjahn (1968-)

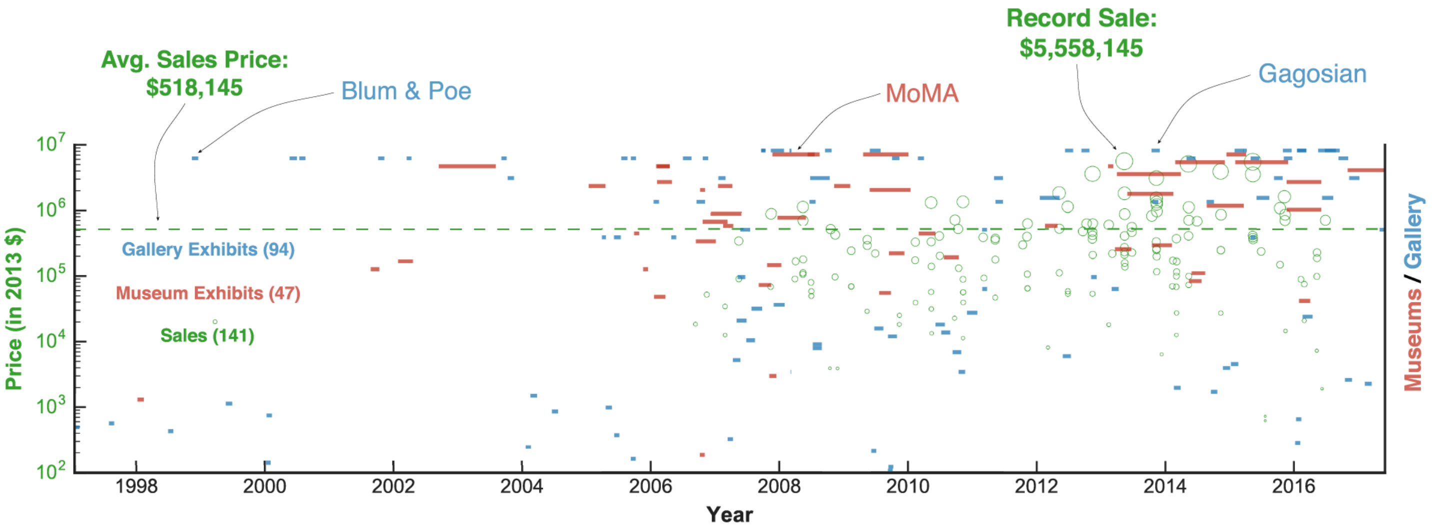
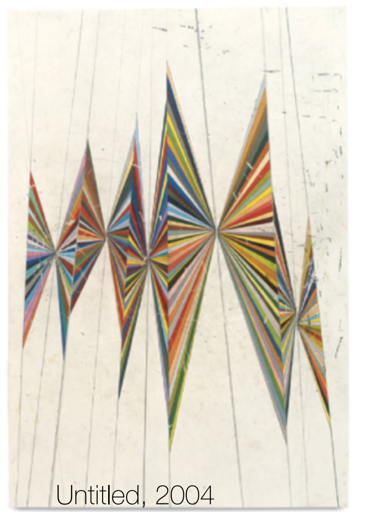
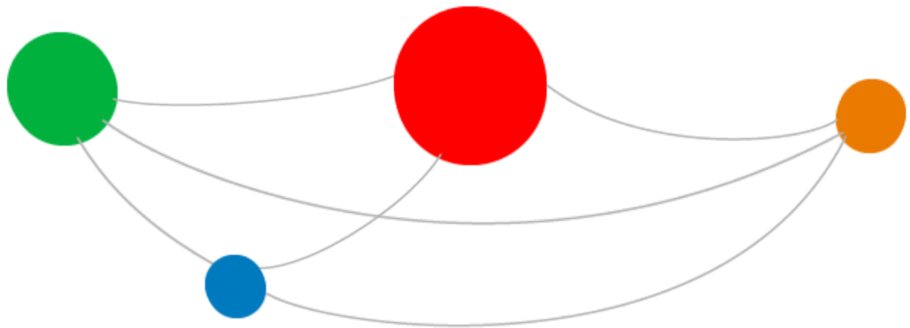


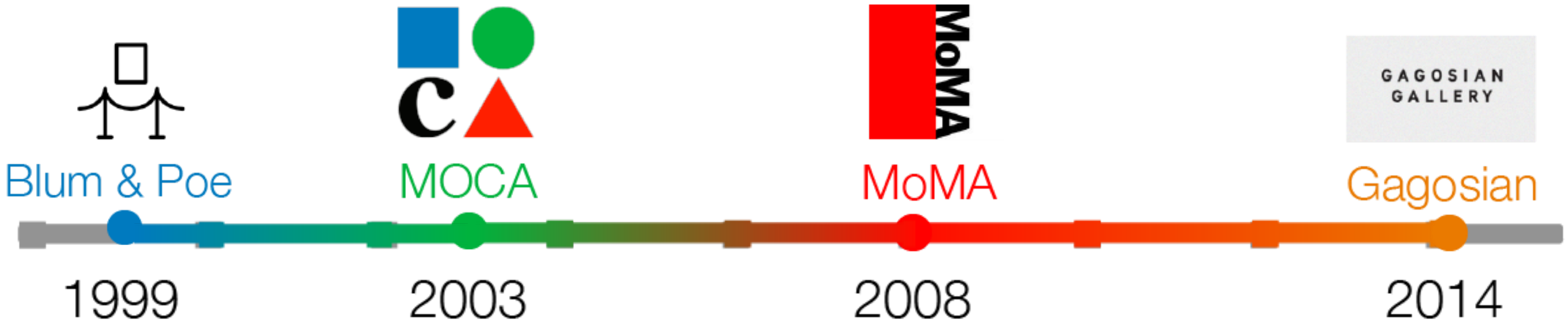

Photo: Monica Almeida, NYT

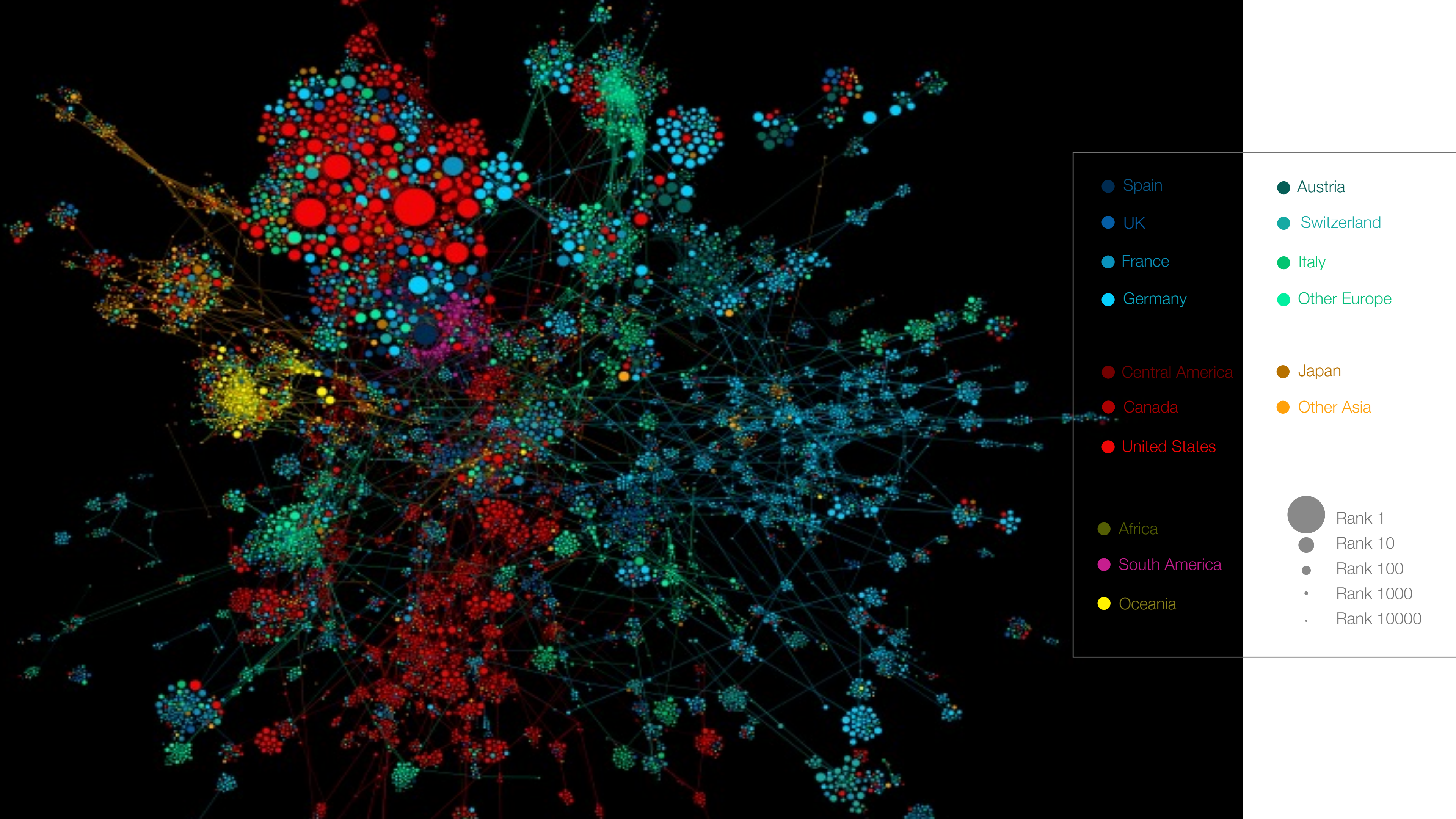
- 1980 to 2016
- 140 Countries
- 463,632 Artists
- 444,495 Exhibits in 14,474 galleries
- 287,807 exhibits in 7,825 museums
- 117,756 auctions



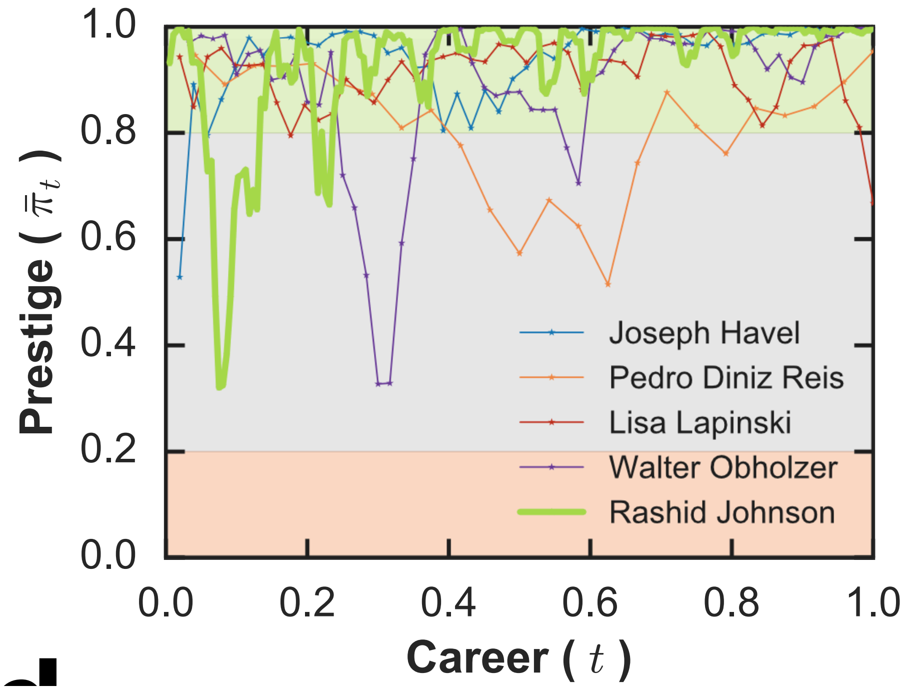
# Art Network



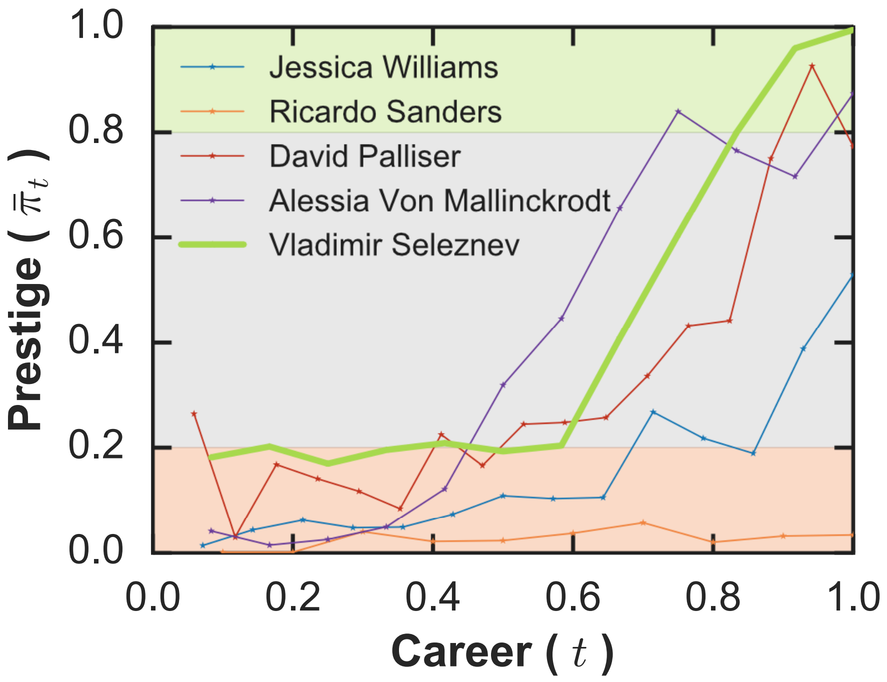

MoMA
GAGOSIAN
GALLERY
Blum & Poe
MOCA
MoMA
Gagosian
1999
2003
2008
2014


Spain
UK
France
Germany
Central America
Canada
United States
Africa
South America
Oceania
Austria
Switzerland
Italy
Other Europe
Japan
Other Asia
Rank 1
Rank 10
Rank 100
Rank 1000
Rank 10000

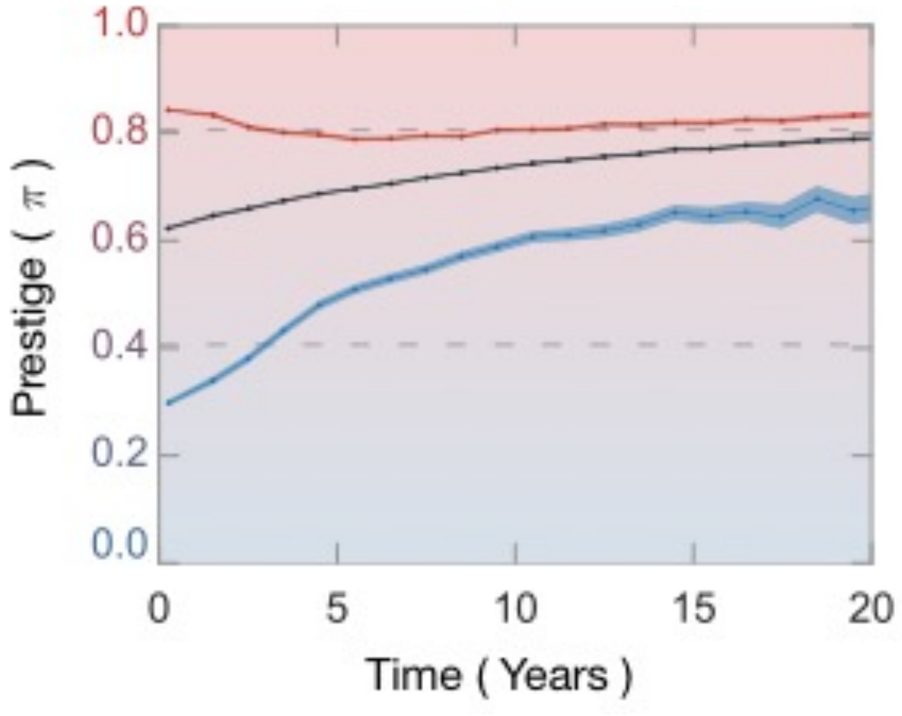
Rich Club (Elite) Artists

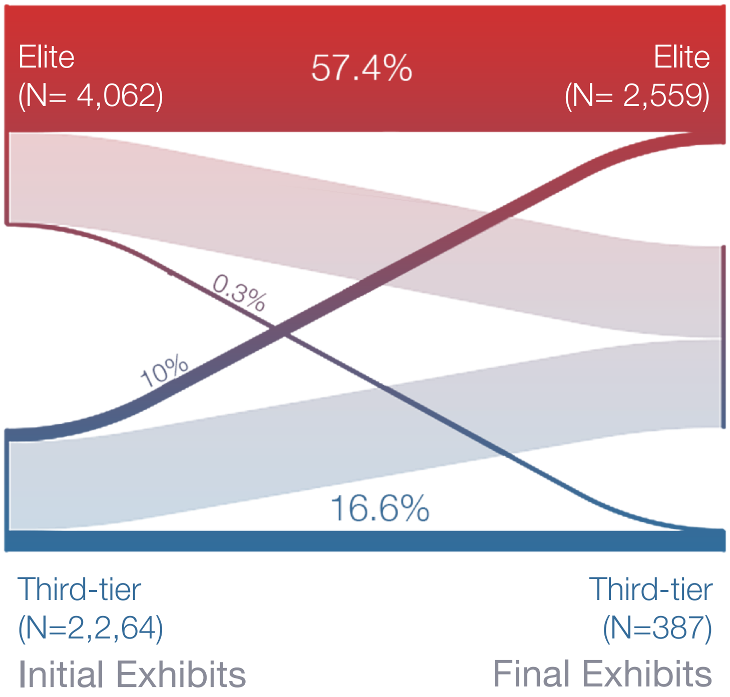



Poor Club Artists



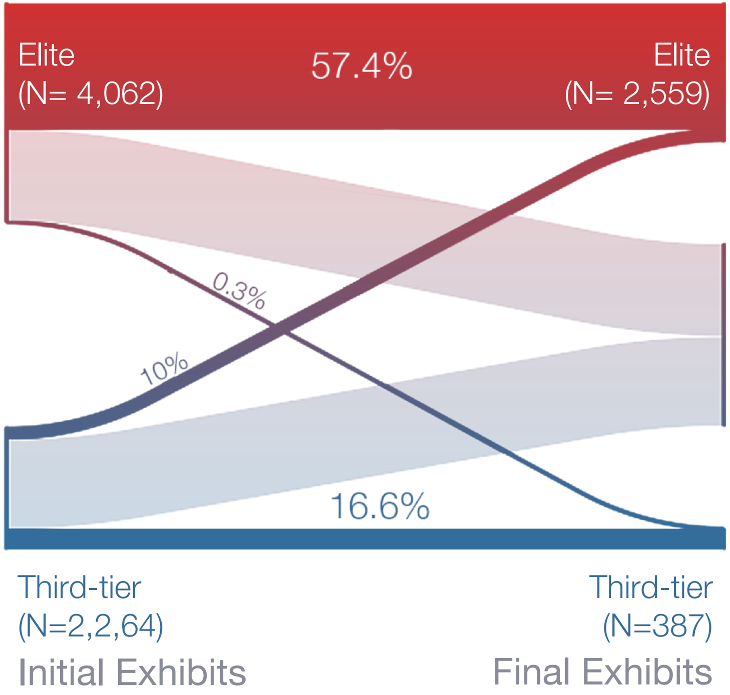

- If you start high, end high. (No downward mobility at the top).
- If you start low, slow upward mobility—with limits.

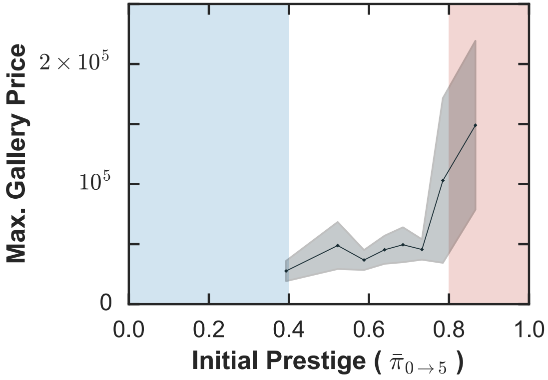


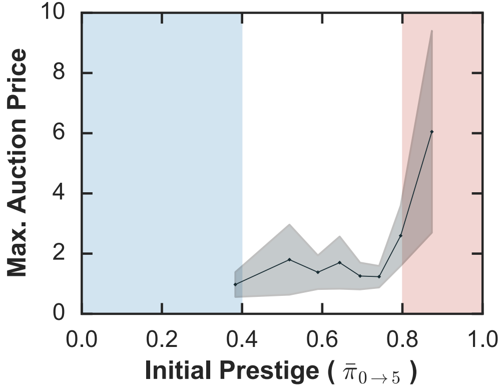




- If you start high, end high. (No downward mobility at the top).
- If you start low, slow upward mobility—with limits.

# Early Prestige and Success



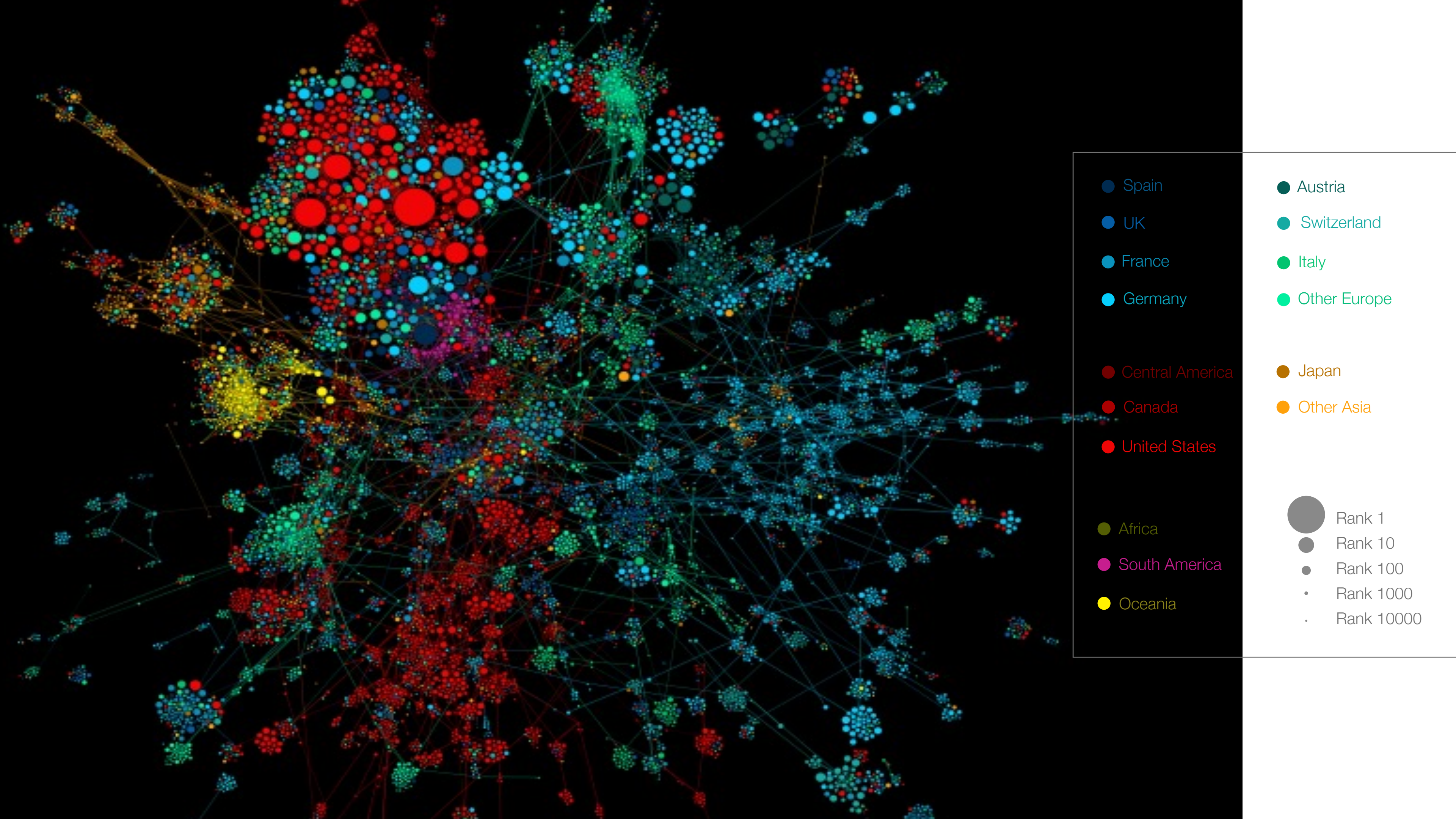



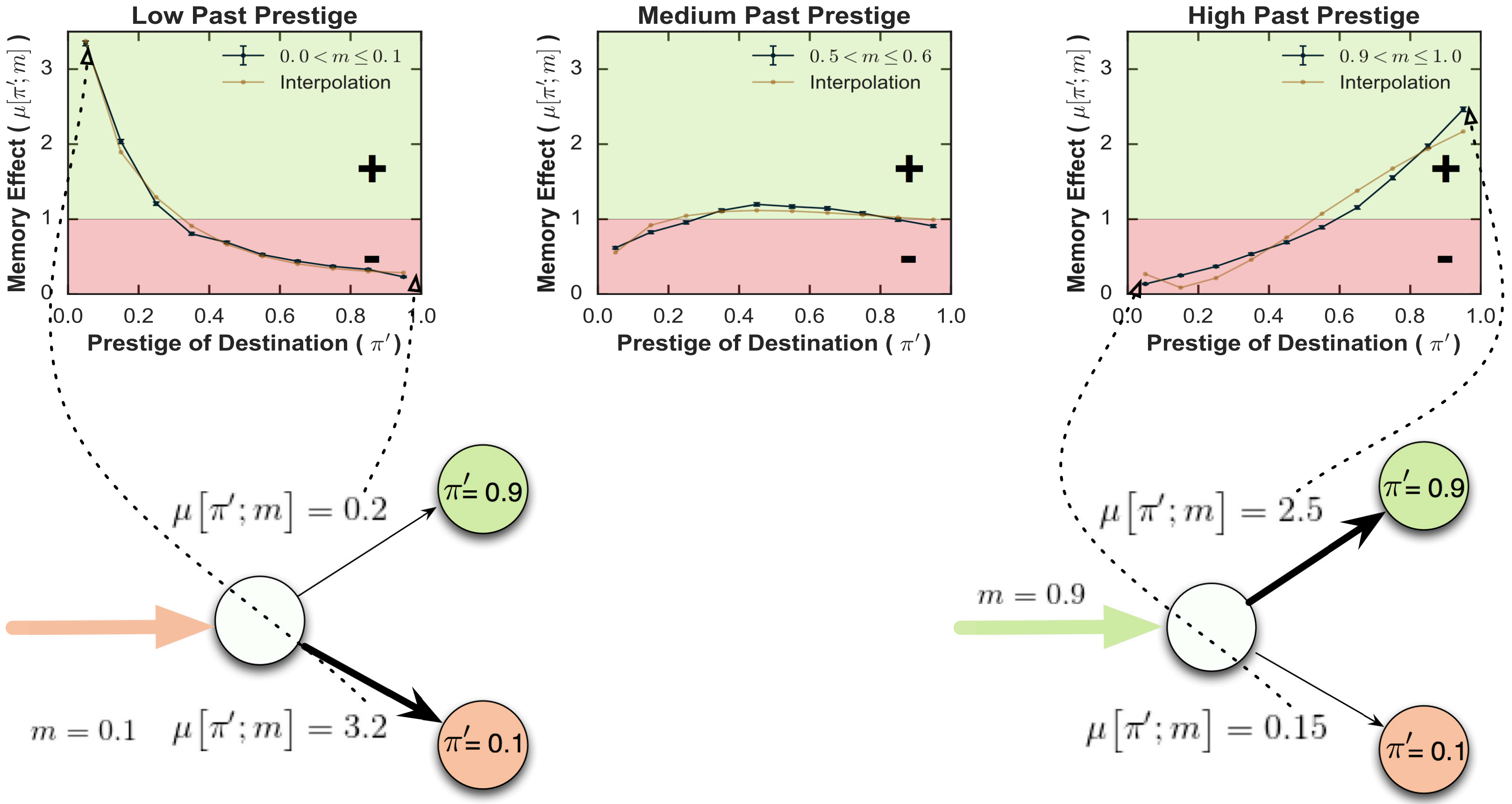

- Little downward mobility for those starting at the top
- Slow upward mobility for those starting at the bottom

Early Prestige Predicts:

- Primary Market Price
- Secondary Market Volume
- Secondary Market Price
- Number of Exhibits
- International Interest


Spain
UK
France
Germany
Central America
Canada
United States
Africa
South America
Oceania
Austria
Switzerland
Italy
Other Europe
Japan
Other Asia
Rank 1
Rank 10
Rank 100
Rank 1000
Rank 10000

# Memory (Reputation) in Career Trajectory




Low Previous Prestige:

16 times more likely you move to a low prestige institution

High Previous Prestige:

16 times more likely you move to an elite institution

# Memory Model: Predicting Artis

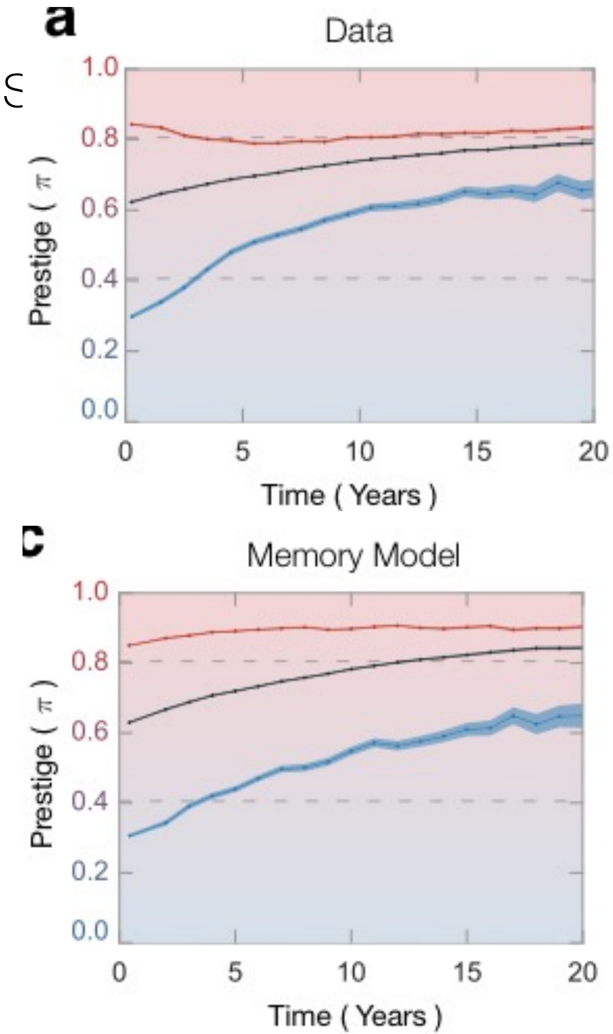
**Memory Effect** **Transition Matrix**

$$p_t\left[i_{\tau+1}|i_\tau,\ldots,i_1\right]=K_t\times\underbrace{\mu\left[\pi_{i_{\tau+1}},m_\tau\right]}_{\text{Memory Effect}}\times\underbrace{p_t\left[i_{\tau+1}|i_\tau\right]}_{\text{Transition Matrix}}$$

$$\mu\left[\pi_{i_{\tau+1}},m_\tau\right]=\frac{p\left[\pi_{i_{\tau+1}}|m_\tau\right]}{p\left[\pi_{i_{\tau+1}}\right]}$$

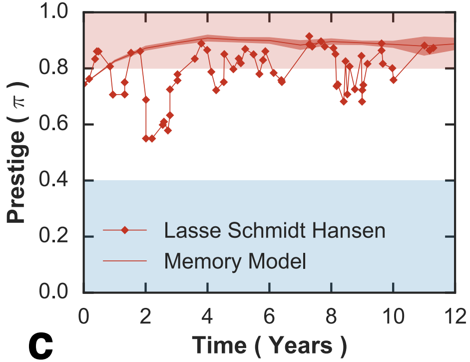
$$m_\tau=\sum_{k=1}^{\tau}\pi_{i_k}$$

**Average Past Prestige**



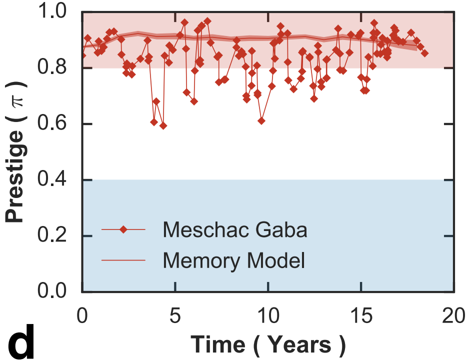
# Predicting Future Careers in Art

**a**



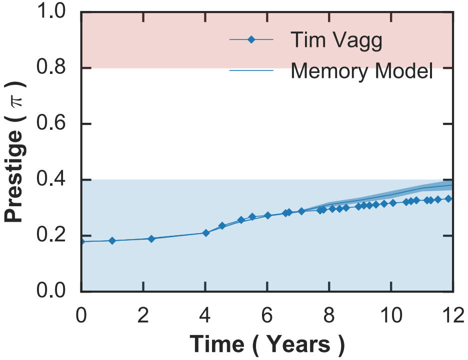

Lasse Schmidt Hansen: *For objects and the Infinite*

**b**



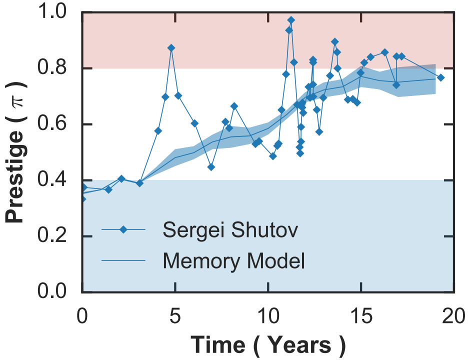

Meshac Gabba: *Ensemble*

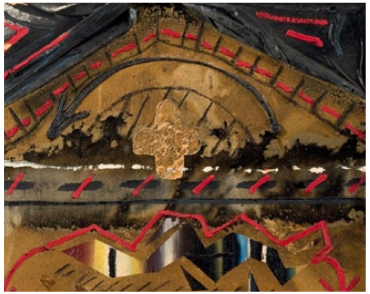
**c**




Tim Vagg: *Postcards from the Holy Land*

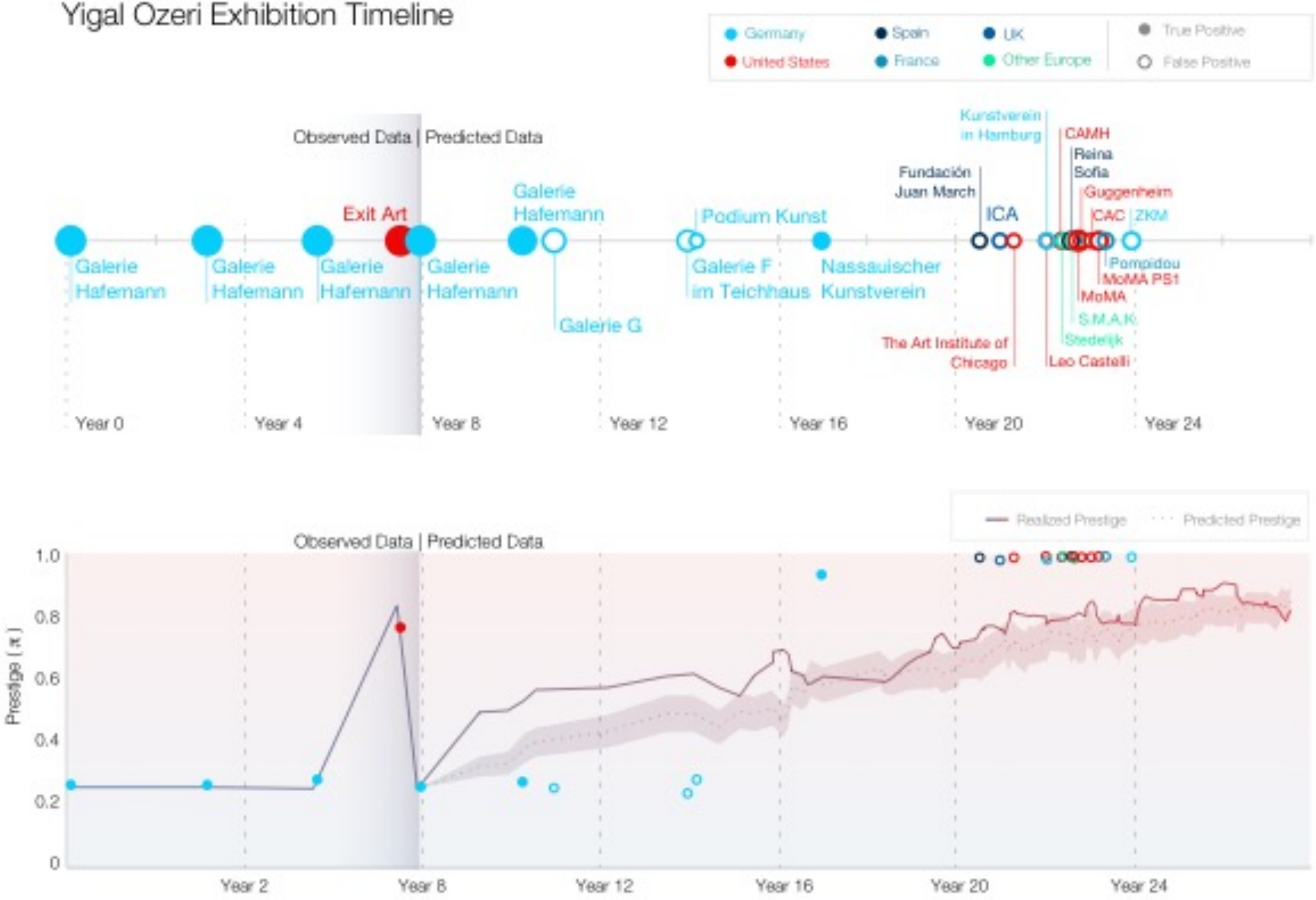
**d**



Sergei Shutov: *Composition*

# Yigal Ozeri Exhibition Timeline



## Veronika Veit Exhibition Timeline


Performance is about *you*,
success is about *us*.

We are looking for
**postdocs** in the lab.
Send me an email if you
are interested!