

# More about Correlation

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A classic example

33 years ago...

Jan-28-1986



## Some Remarks

- Space Race
- Cold War
- Many delays
- First civilian as part of the crew
- Reagan's "State of the Union" planned the same day



# A major malfunction

## Challenger's brief flight

### .678 seconds

Following Challenger's liftoff, a puff of black smoke — seen only by automatic launch cameras — indicates a problem with one of the O-ring seals at the joint between segments of the shuttle's right-hand solid rocket booster.

No human eyes see the smoke, and there would have been no way to abort the flight if they had.

### 58 seconds

A small jet of smoke and flame bursts through the side of the booster and quickly grows.

### 73 seconds

The flame burns through the strut attaching the solid rocket booster to the external fuel tank, causing the booster to swivel into the side of the tank. The resulting massive explosion destroys the space shuttle.

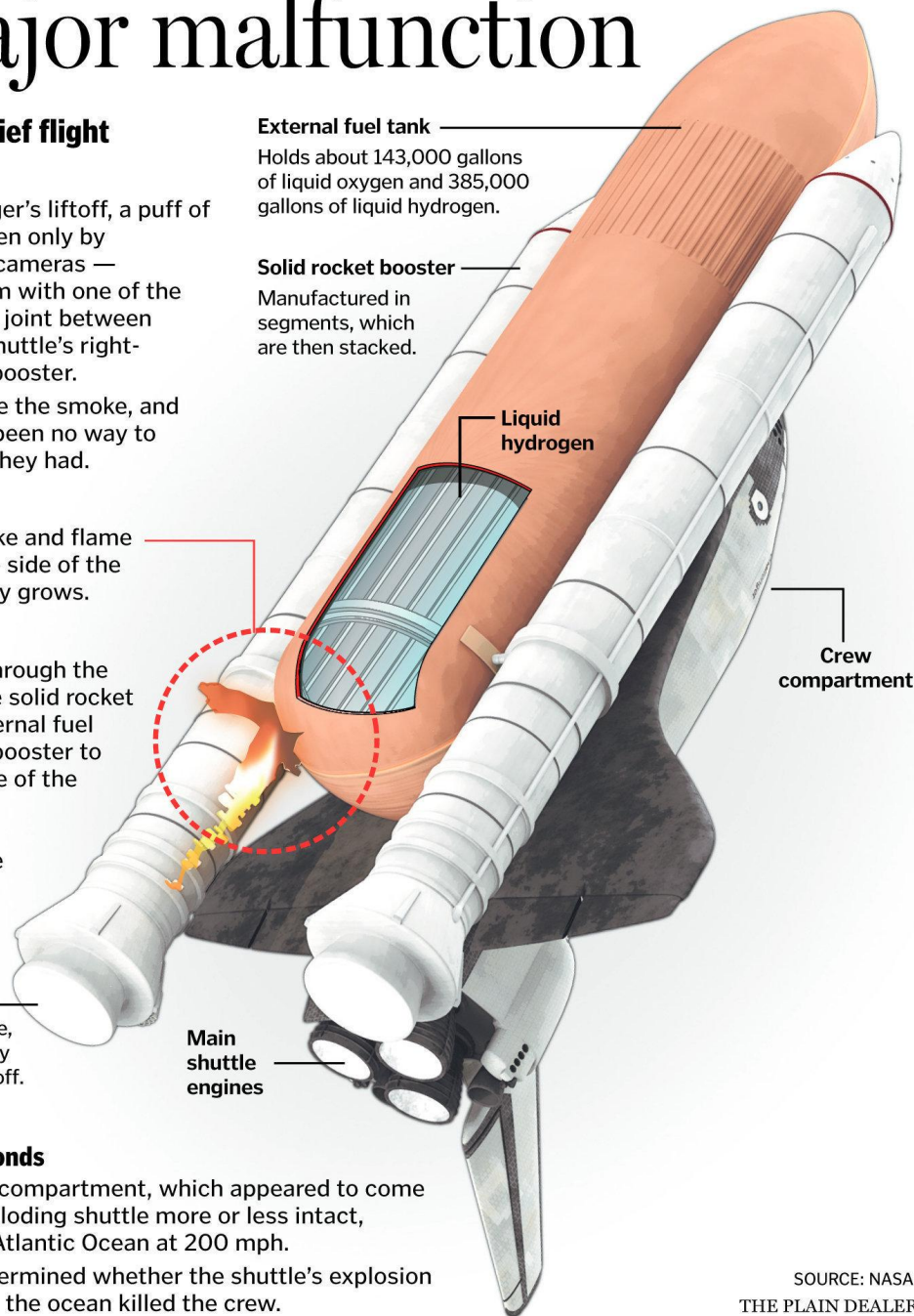
### Full thrust

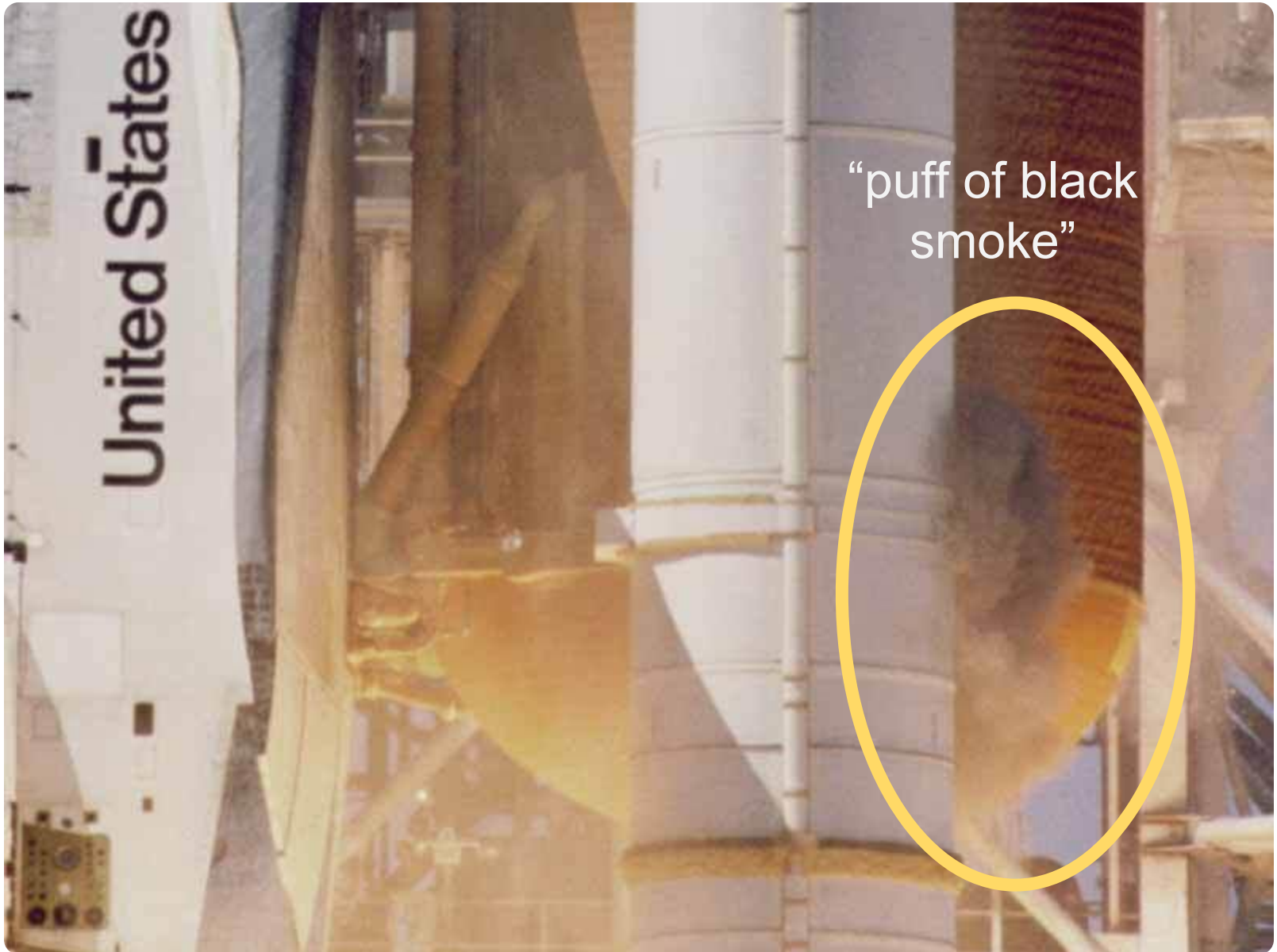
Once the boosters ignite, there is no way to shut them off.

### 3 minutes, 58 seconds

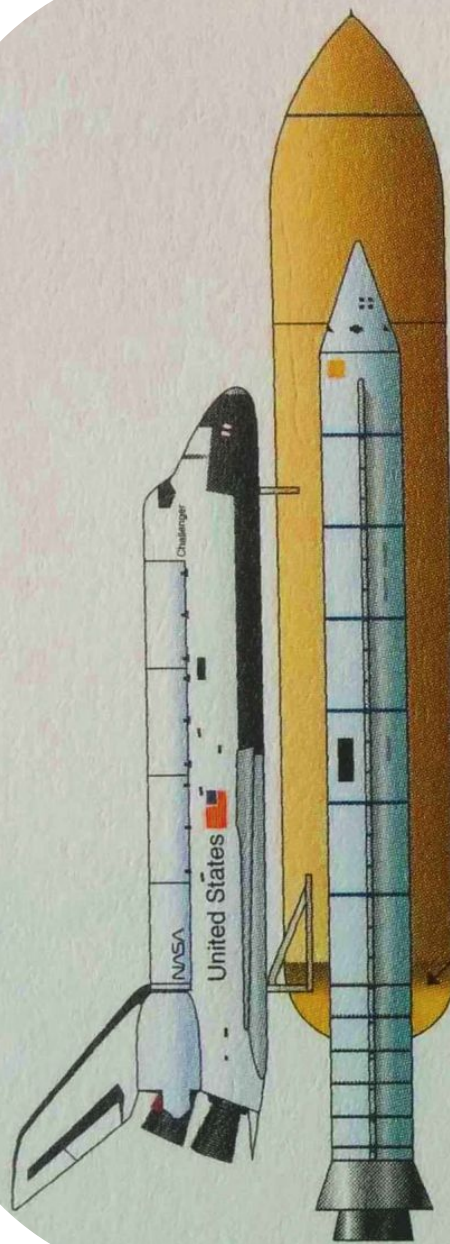
Challenger's crew compartment, which appeared to come away from the exploding shuttle more or less intact, smashes into the Atlantic Ocean at 200 mph.

Officials never determined whether the shuttle's explosion or the impact with the ocean killed the crew.



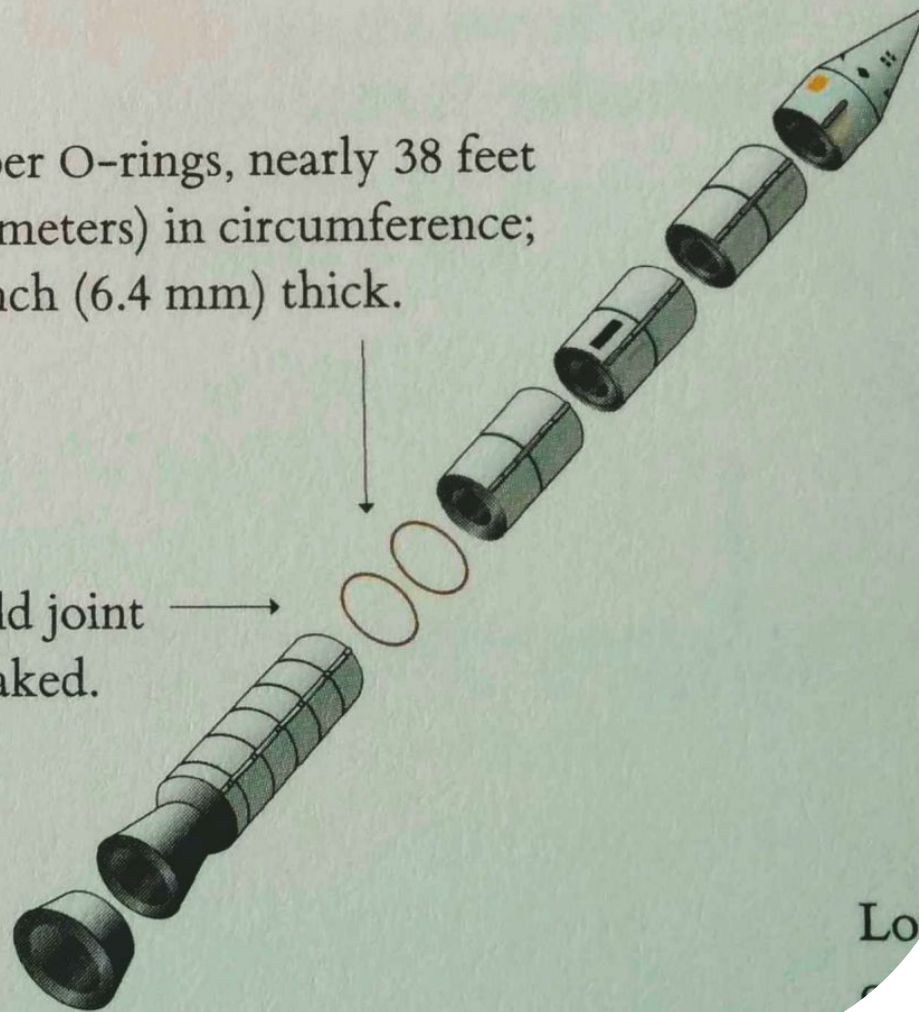






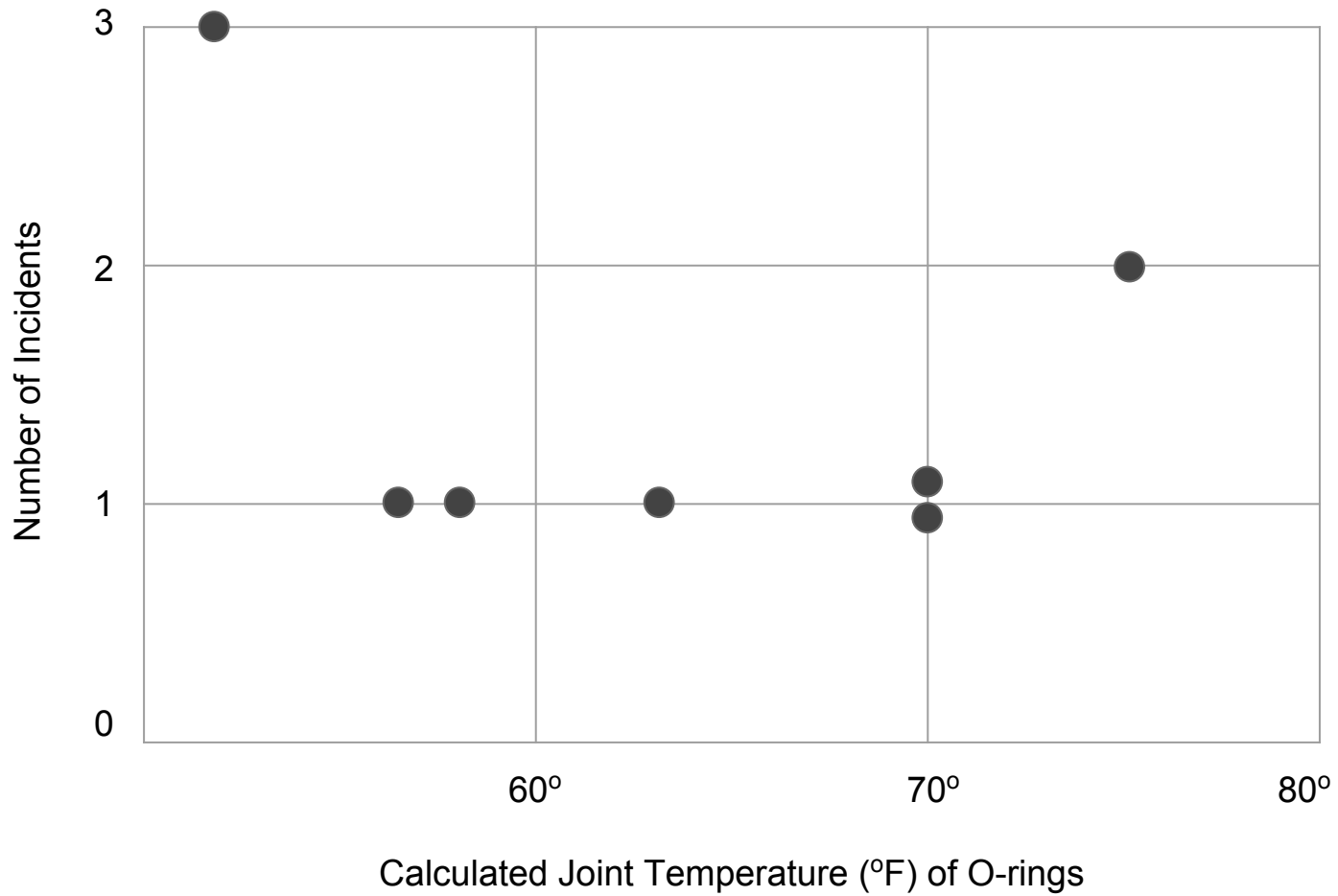
Rubber O-rings, nearly 38 feet  
(11.6 meters) in circumference;  
1/4 inch (6.4 mm) thick.

The field joint  
that leaked.



Low



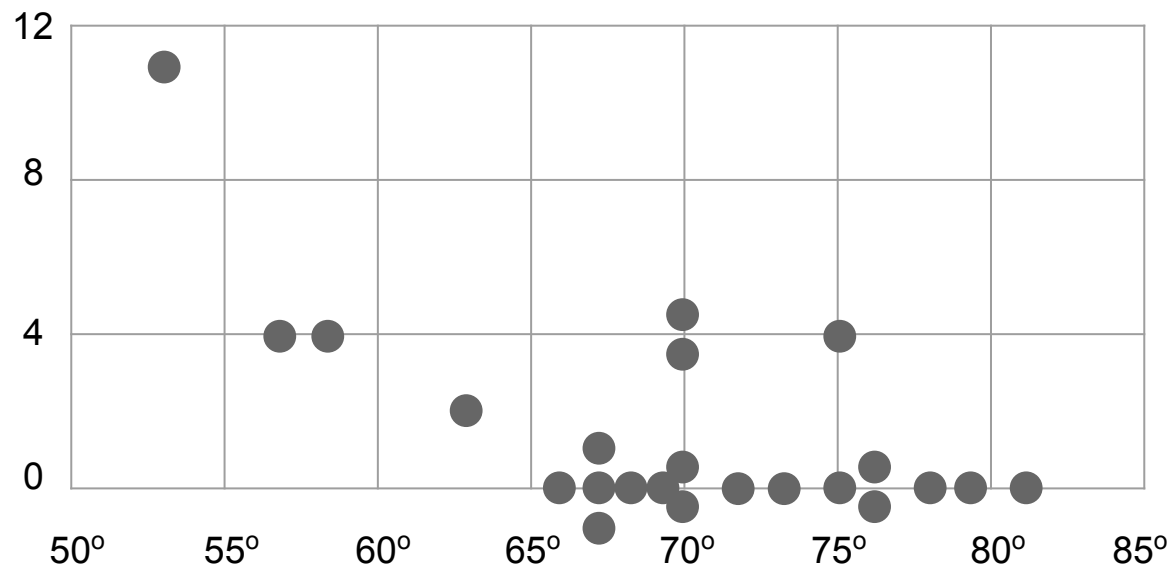


(Published in shuttle commission report; unknown date of creation)

# Relationship between Temperature and O-ring damage

## 24 launches with affected O-rings prior to the Challenger

O-ring damage  
index, each lunch



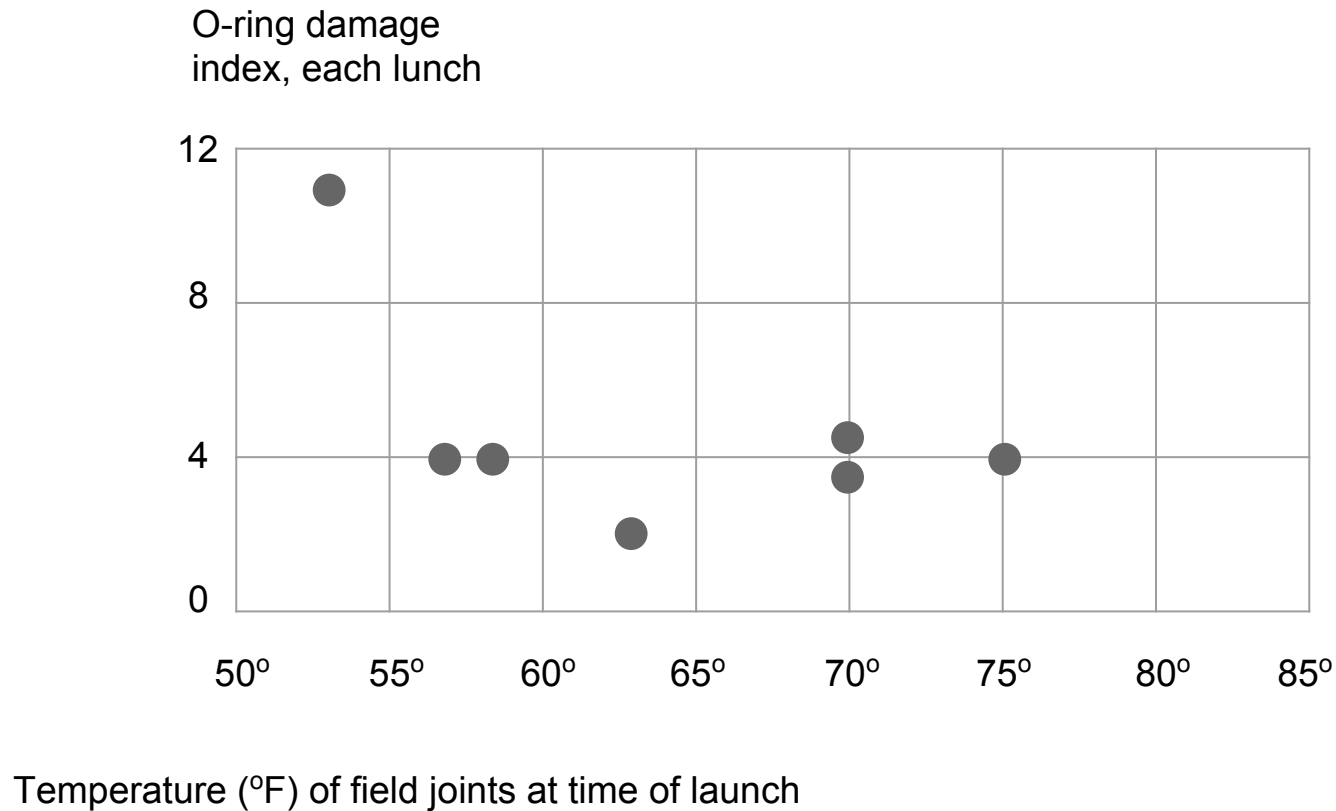
Temperature (°F) of field joints at time of launch

Flight	Date	Temp	Erosion Incidents	Blow-by Incidents	Damage Index	O-ring Damage
51-C	01.24.85	53	3	2	11	yes
41-B	02.03.84	57	1		4	yes
61-C	01.12.86	58	1		4	yes
41-C	04.06.84	63	1		2	yes
1	04.12.81	66			0	no
6	04.04.83	67			0	no
51-A	11.08.84	67			0	no
51-D	04.12.85	67			0	no
5	11.11.82	68			0	no
3	03.22.82	69			0	no
2	11.12.81	70	1		4	unknown
9	11.28.83	70			0	no
41-D	08.30.84	70	1		4	no
51-G	06.17.85	70			0	no
7	06.18.83	72			0	no
8	08.30.83	73			0	no
51-B	04.39.85	75			0	no
61-A	10.30.85	75		2	4	yes
51-I	08.27.85	76			0	no
61-B	11.26.85	76			0	no
41-G	10.05.84	78			0	no
51-J	10.03.85	79			0	no
	06.27.82	80			?	unknown
51-F	07.29.85	81			0	no

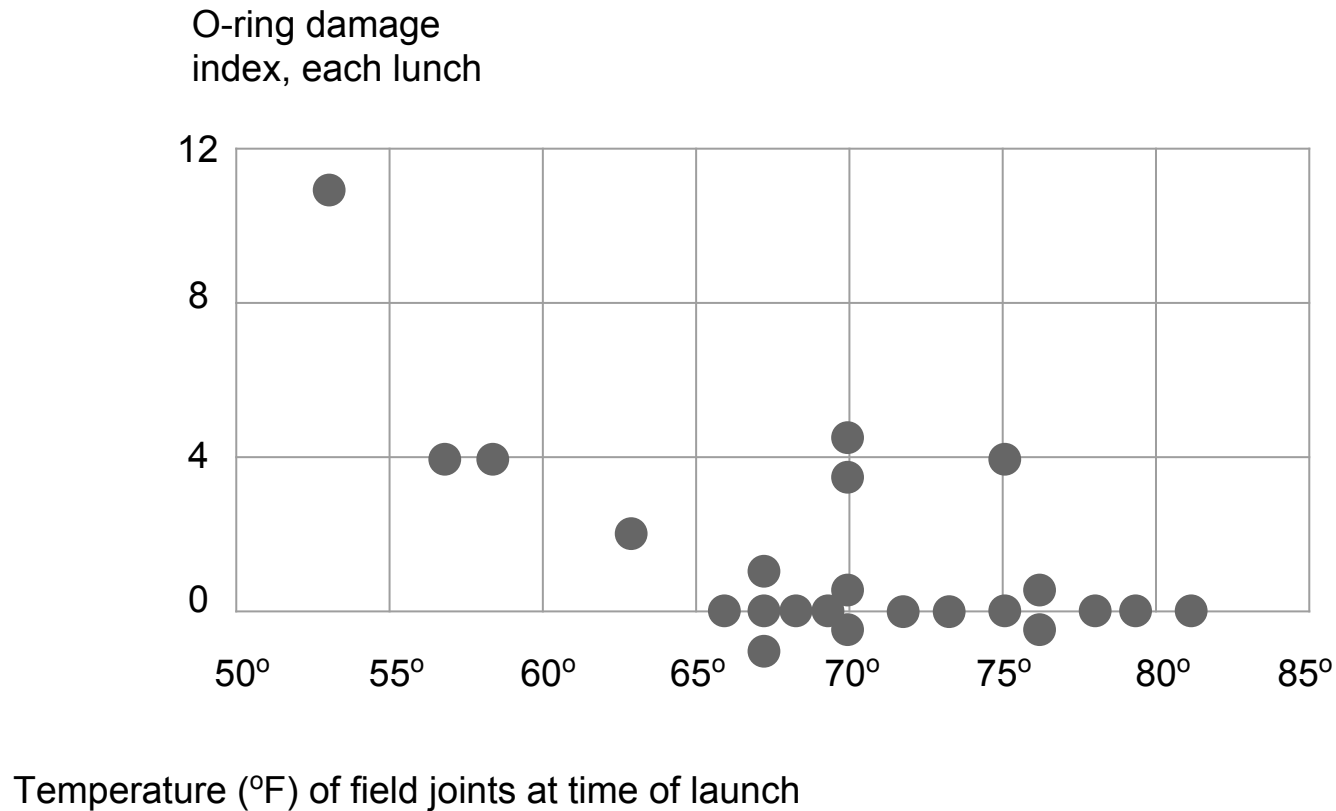
Values in red were exhibited at some point in the 13 pre-launch charts; those in black were not included



## 7 launches with affected O-rings prior to the Challenger



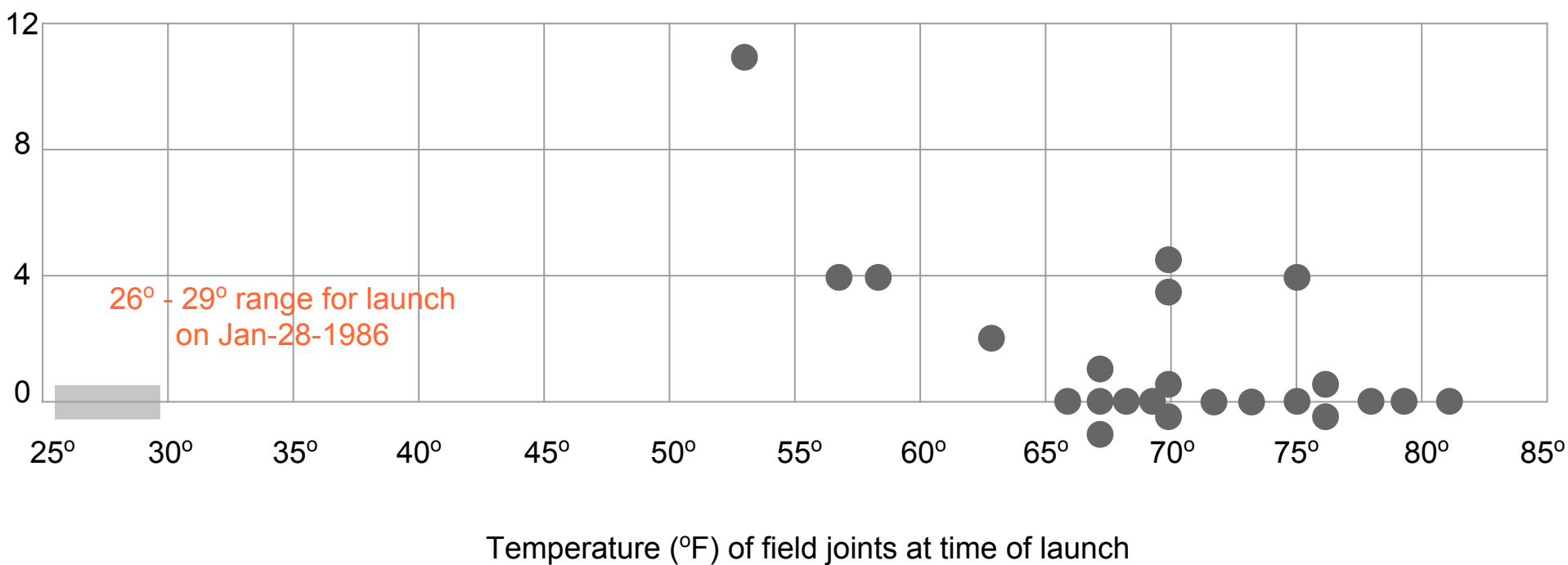
## 24 launches with affected O-rings prior to the Challenger



## 24 launches prior to the Challenger

O-ring damage  
index, each launch

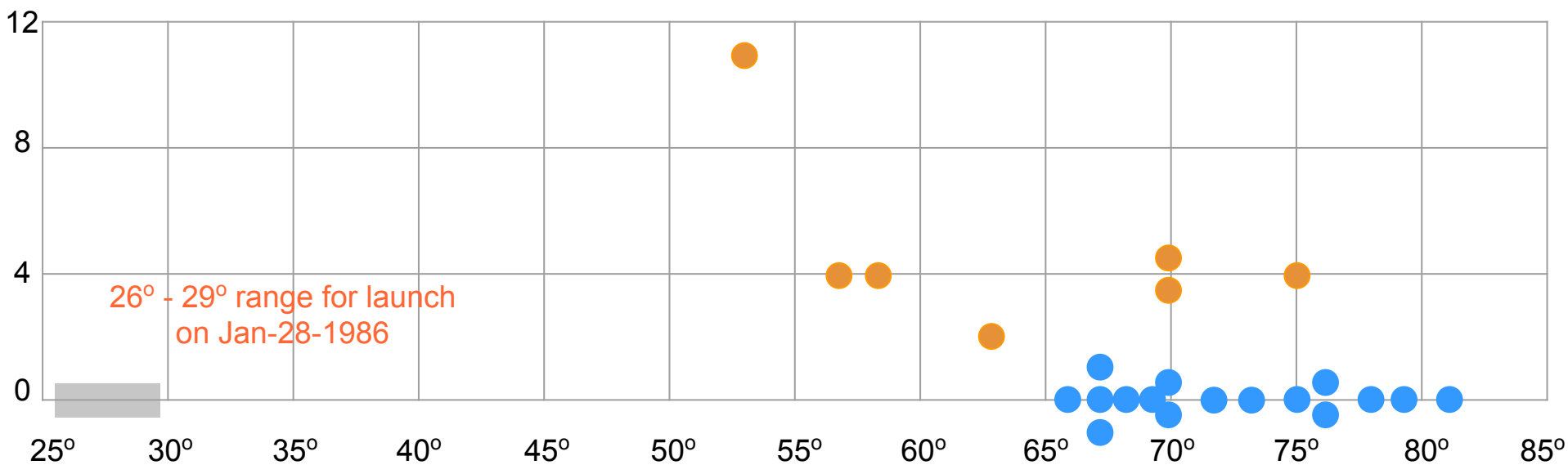
$r = -0.6415$



## 24 launches prior to the Challenger

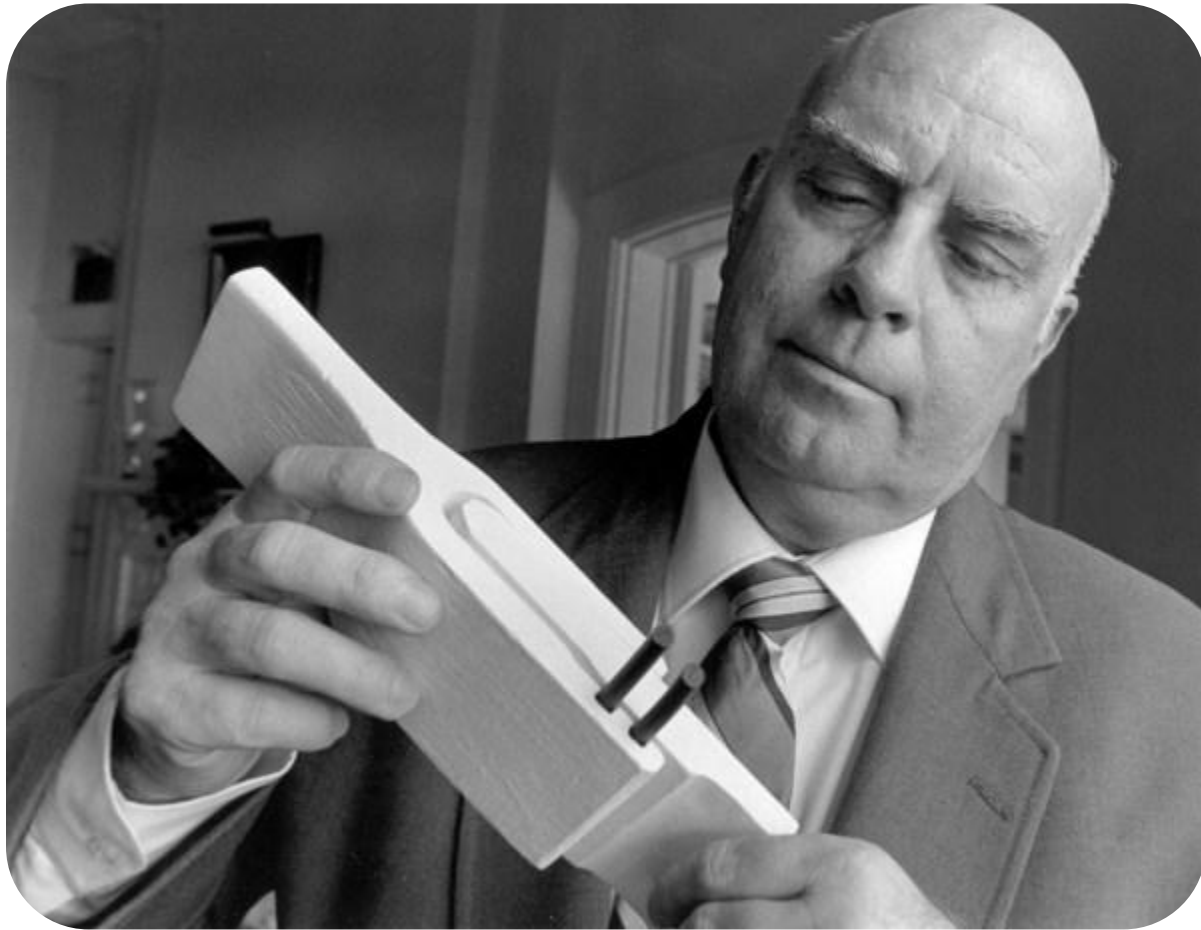
O-ring damage  
index, each launch

$r = -0.6415$



Temperature (°F) of field joints at time of launch





Roger Boisjoly ~ 1991  
(former Morton-Thiokol engineer)



Bob Ebeling ~ 2016  
(former Morton-Thiokol engineer)

## Some info

- 13 charts were prepared for making the decision to launch
- 6 charts contained no tabled data about either O-ring temp, blow-by, or damage.
- The rest of charts contained no info about relation between temp and O-ring anomalies
- They all failed to reveal the risks of launching at very low temperatures

## Some sources

### Space Shuttle Challenger Accident

<https://www.youtube.com/watch?v=fSTrmJtHLFU>

### Inside Space Shuttle Challenger STS-51L During The Accident

<https://www.youtube.com/watch?v=NnmSdVbgQ4M>

### NPR article about Bob Ebeling

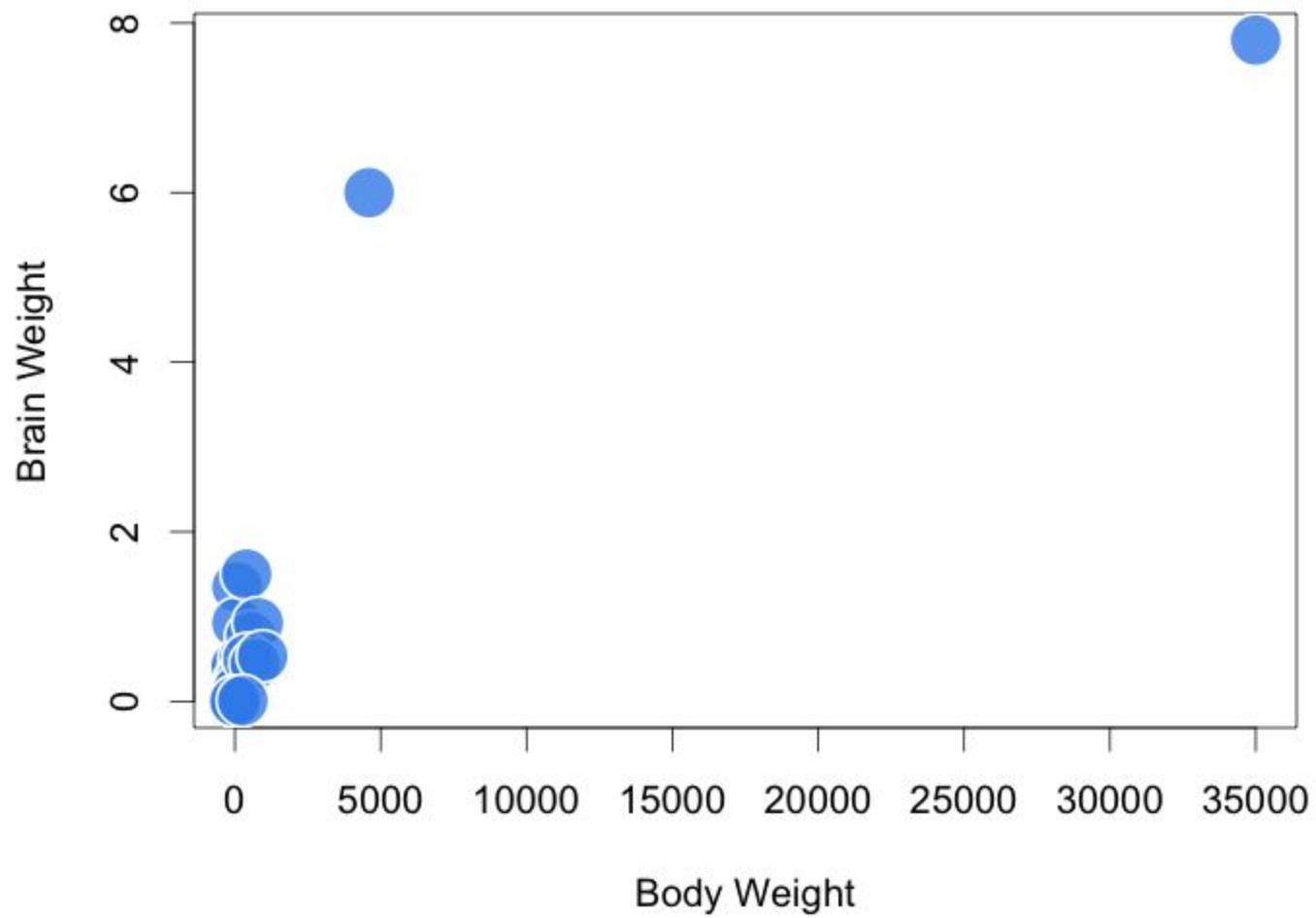
<http://www.npr.org/sections/thetwo-way/2016/01/28/464744781/30-years-after-disaster-challenger-engineer-still-blames-himself>

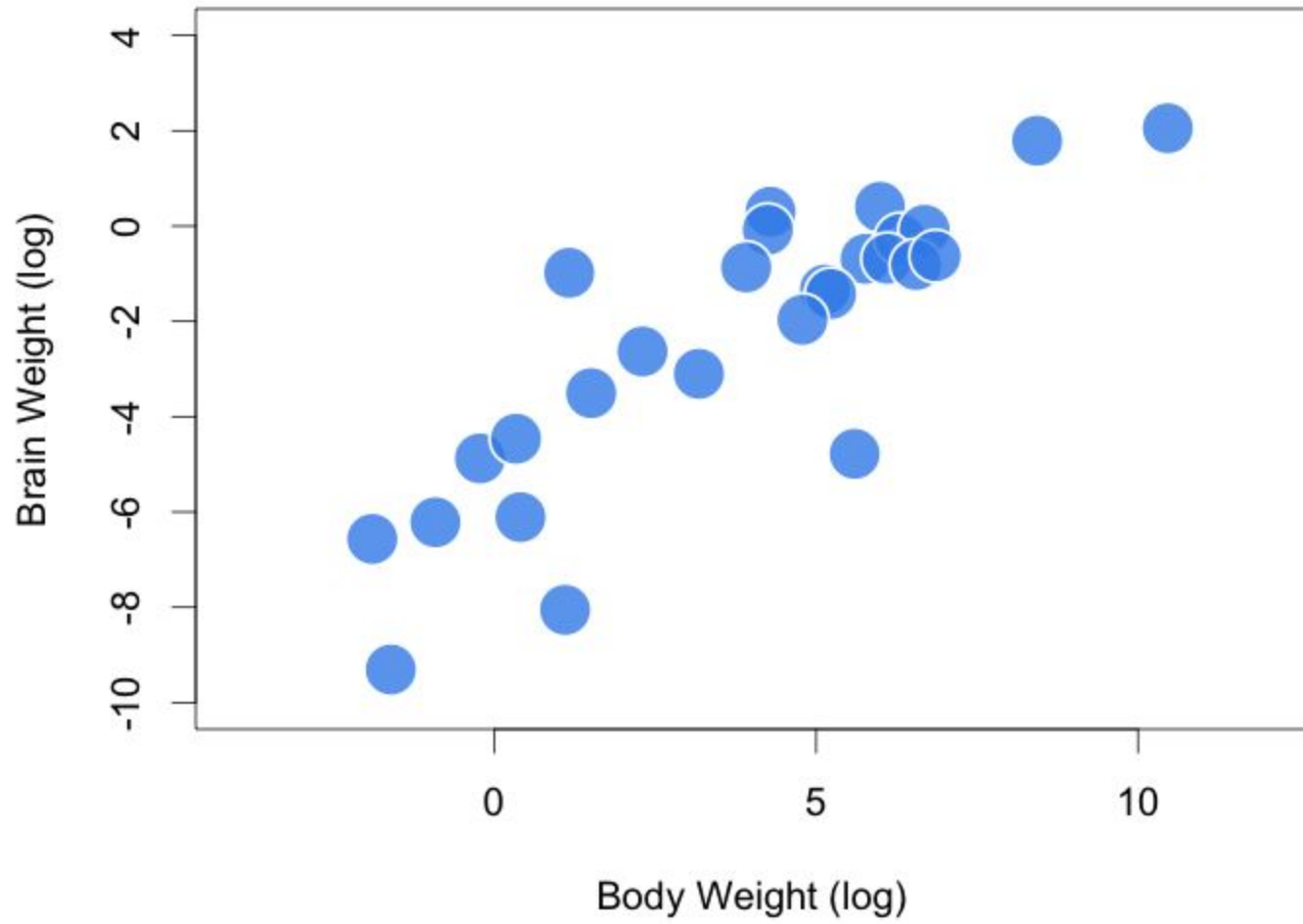


Sometimes  
transformations  
are useful

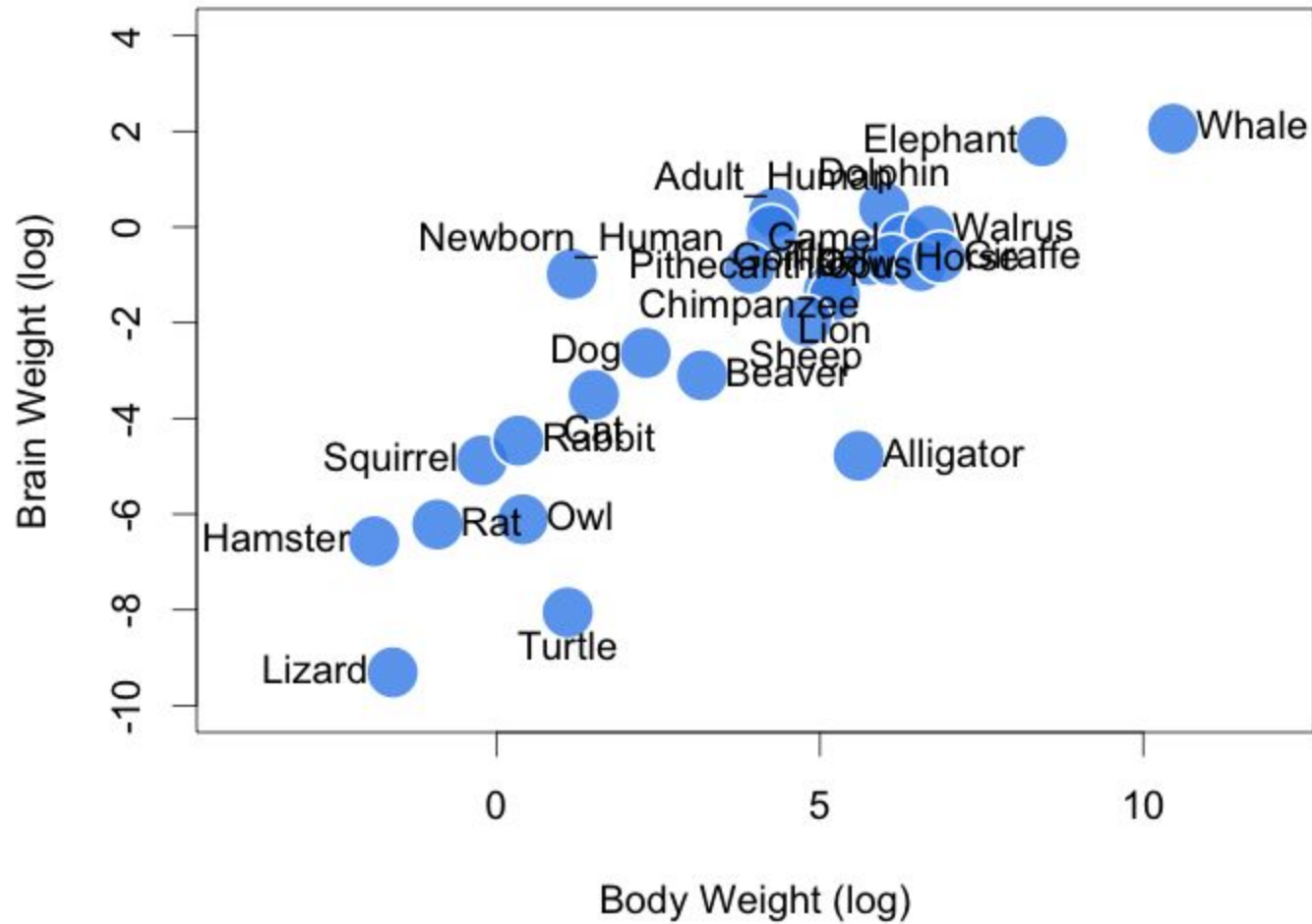
species	bodywgt	brainwgt
Newborn_Human	3.2	0.374984813
Adult_Human	73	1.349981613
Pithecanthropus	70	0.925010921
Squirrel	0.8	0.007620352
Hamster	0.15	0.001406136
Chimpanzee	50	0.419981176
Rabbit	1.4	0.011521246
Dog	10	0.071985109
Cat	4.5	0.029982456
Rat	0.4	0.001995806
Dolphin	400	1.49998461
Beaver	24	0.044996363
Gorilla	320	0.502489628

species	bodywgt	brainwgt
Tiger	170	0.263491808
Owl	1.5	0.002222603
Camel	550	0.761989823
Elephant	4600	5.999983798
Lion	187	0.239995723
Sheep	120	0.139978605
Walrus	800	0.925010921
Horse	450	0.502489628
Cow	700	0.441481454
Giraffe	950	0.532018491
Lizard	0.2	9.07185E-05
Whale	35000	7.799974401
Turtle	3	0.000317515
Alligator	270	0.008391459









# Ecological Correlation

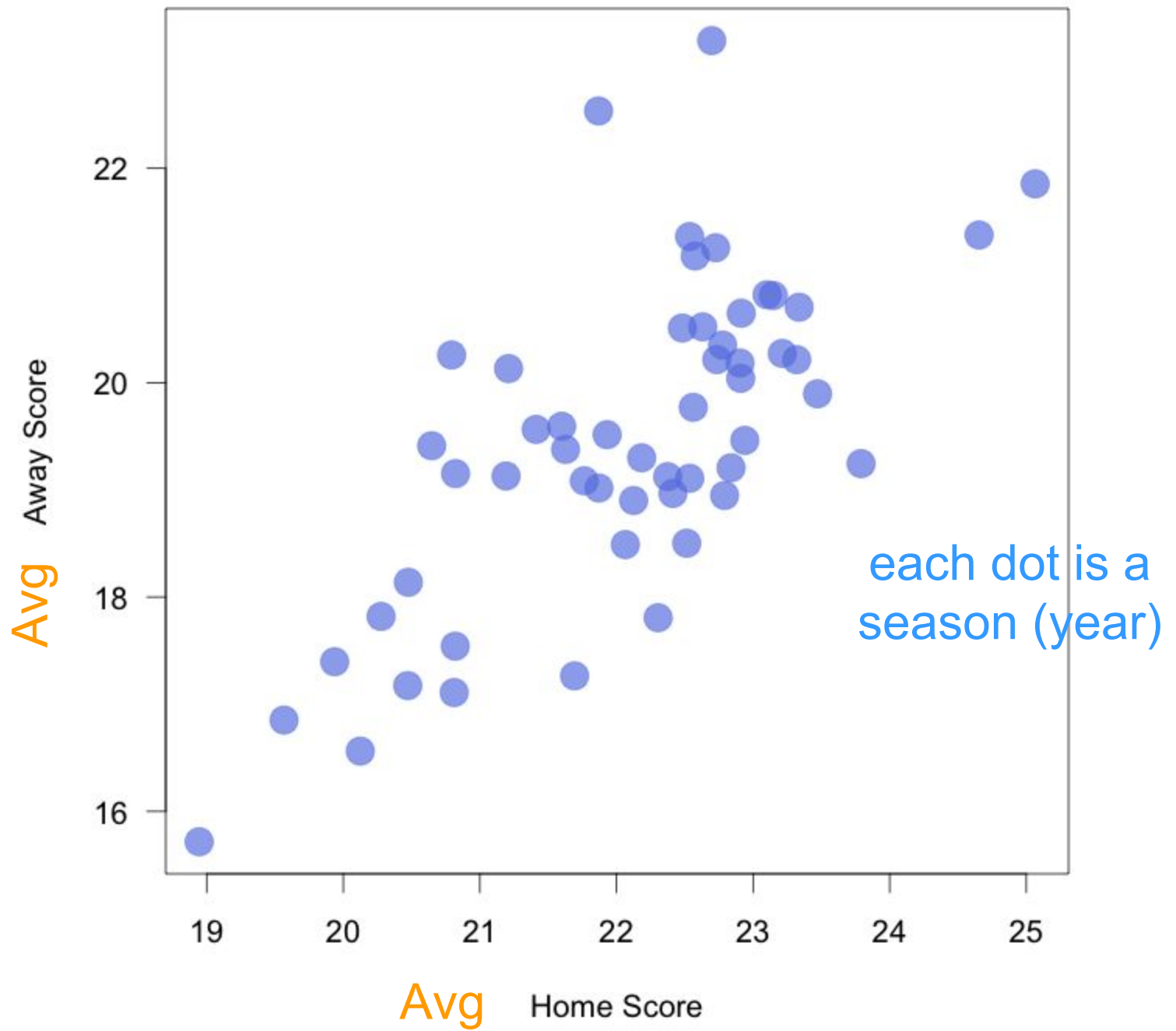
# Ecological Correlation

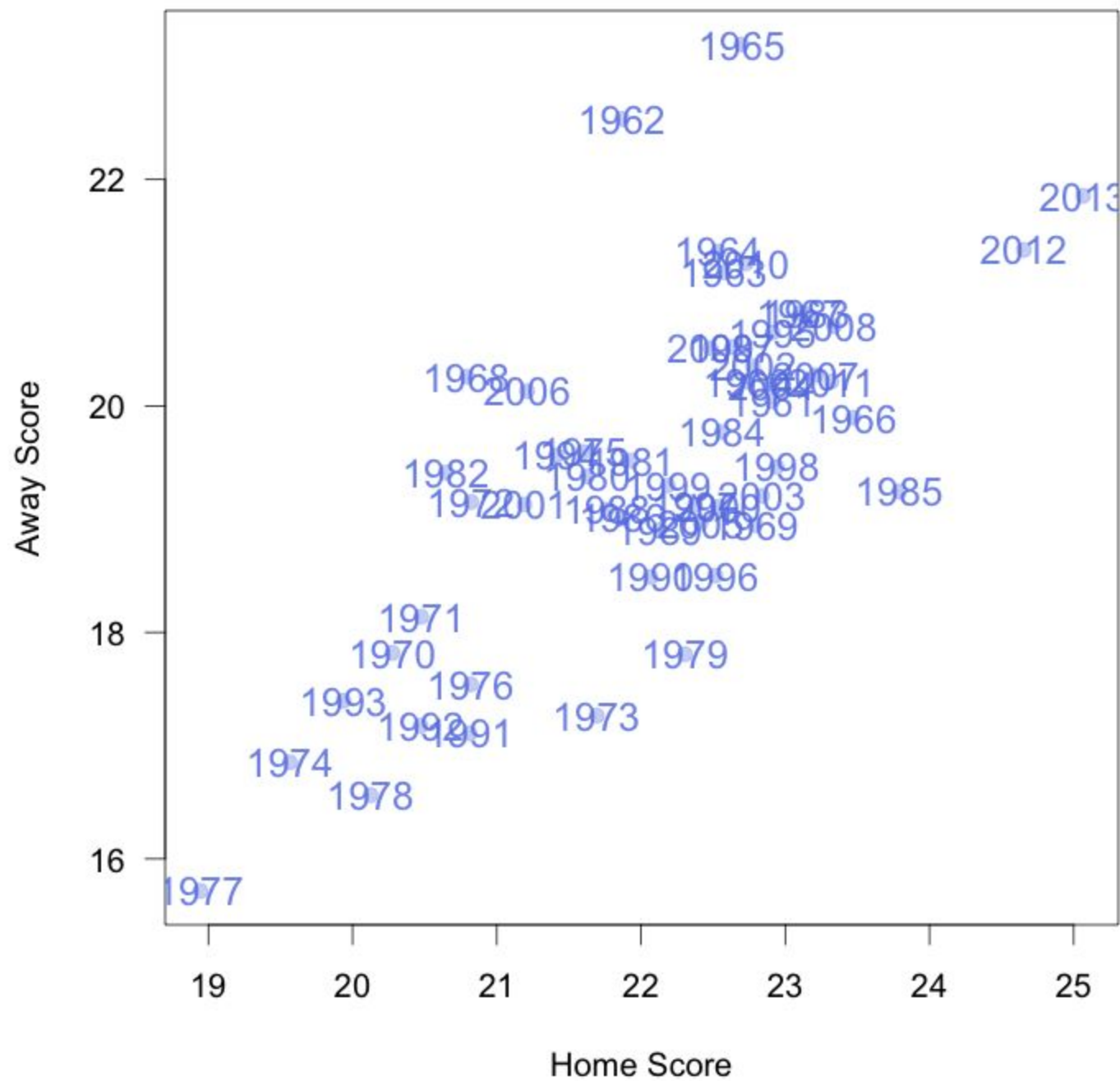
Measures correlation where  $X$  and  $Y$  are averages (or medians) of subgroups

Also known as aggregated correlation

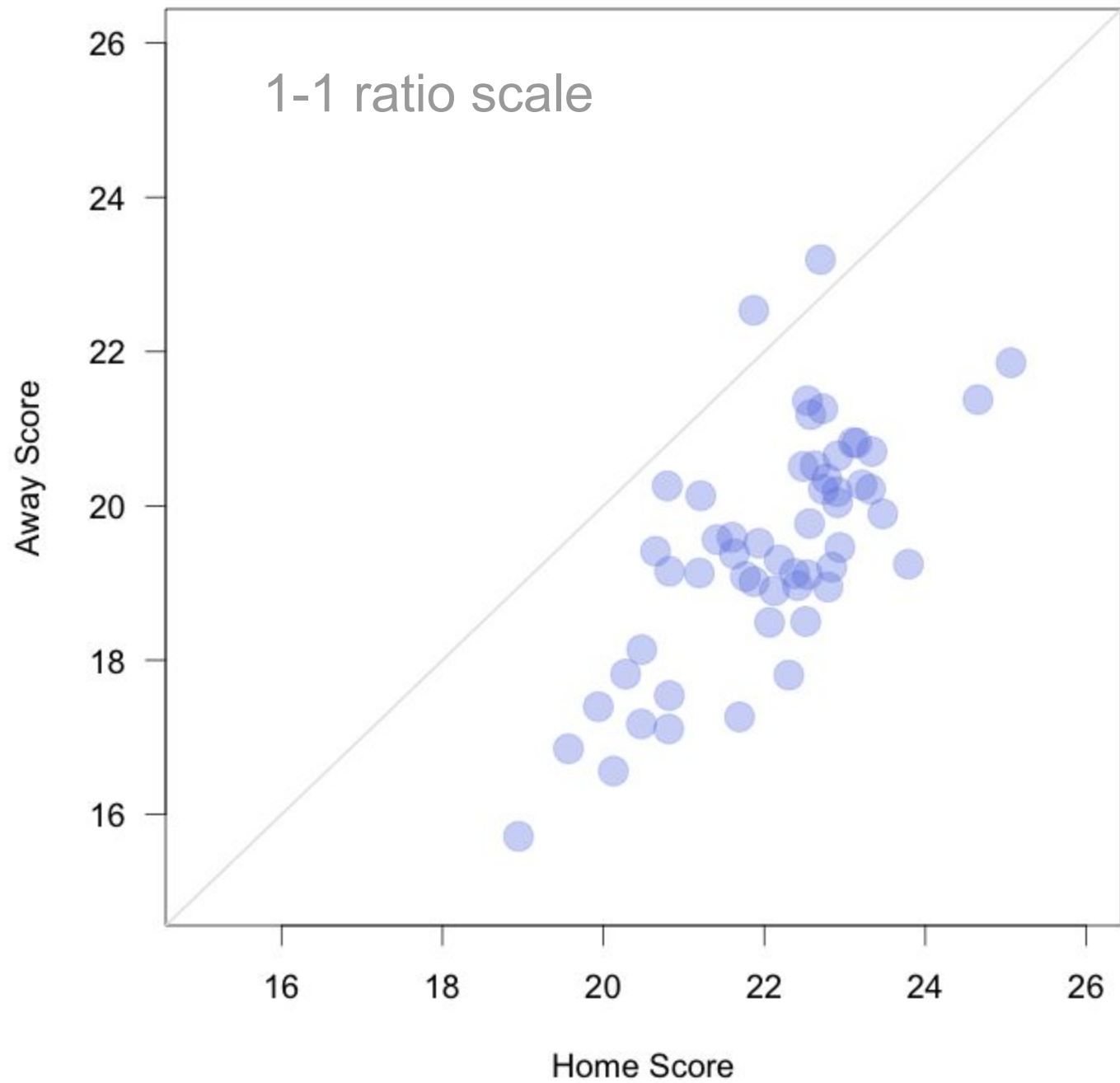
In general, this tends to overstate relationships for individuals

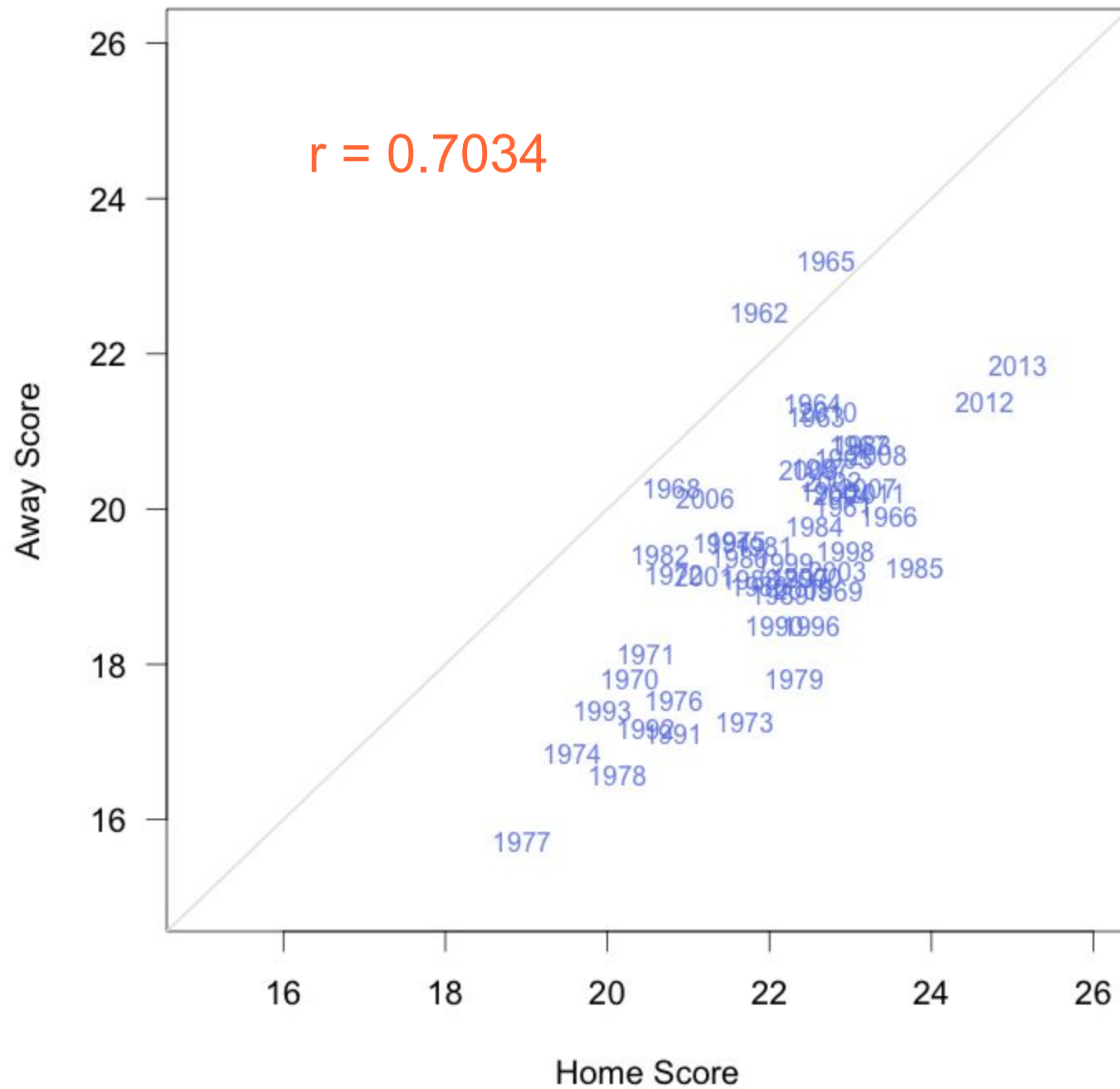
# Average scores of NFL games (1960-2013)





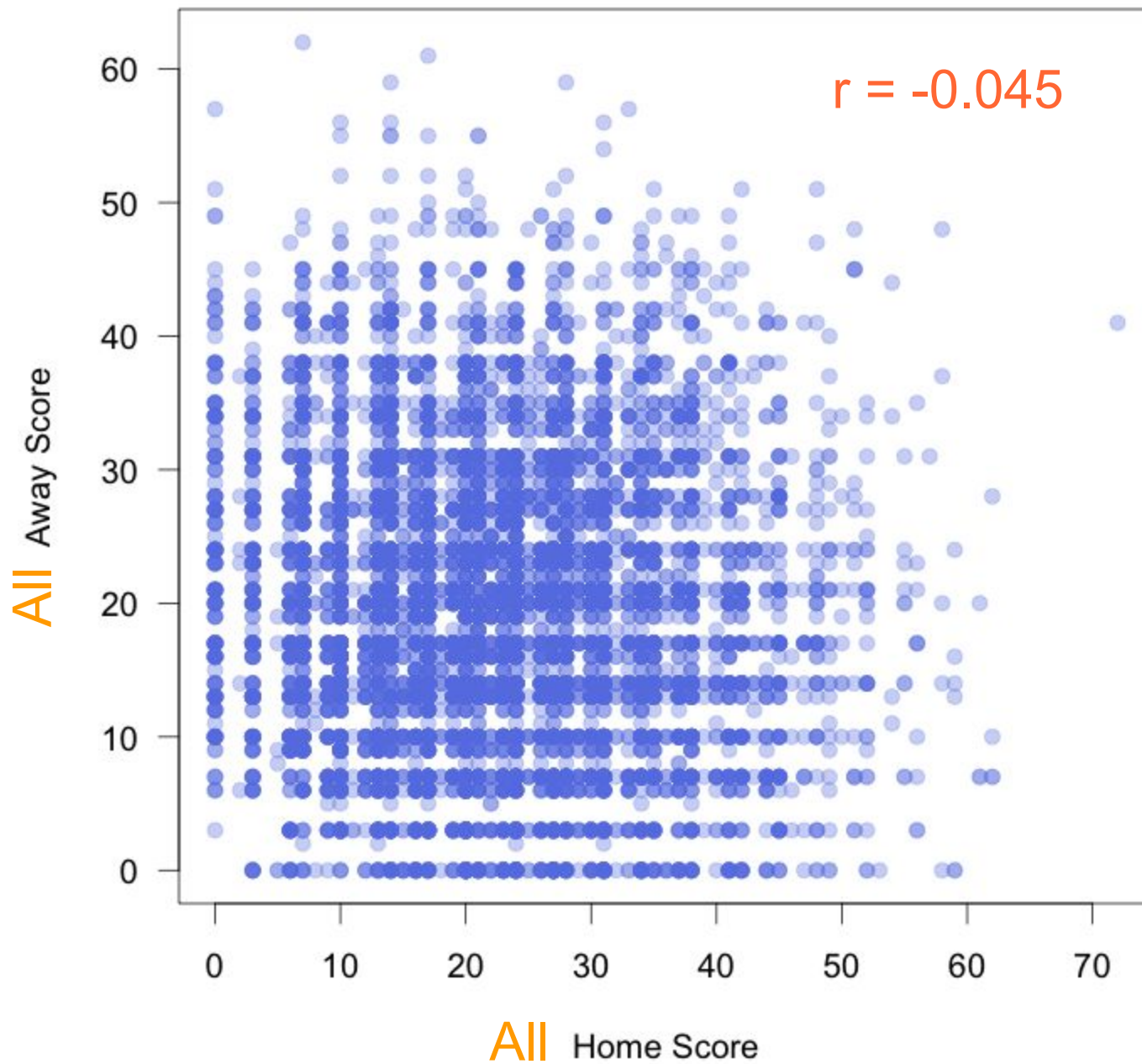






What about looking at all  
the points?  
(not just year averages)

Scores of NFL games 1960 - 2013



Correlation doesn't  
mean Causation

Do storks bring babies?

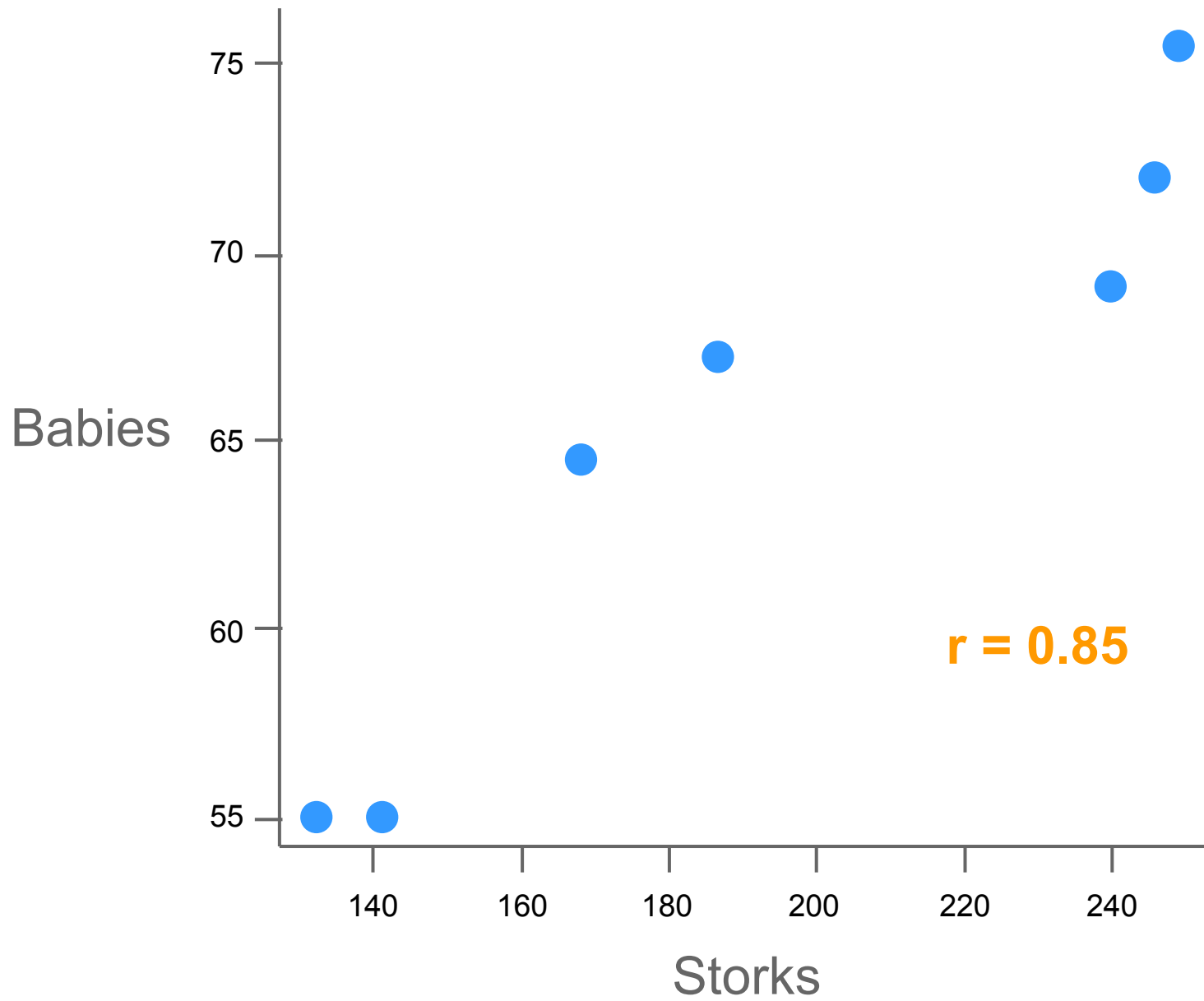


# Data set: Storks and Babies

Annual counts made in 1930-1936

From Oldenburg, Germany

by Dr. Gustav Fischer





# Correlation $\neq$ Causation

# THE SCIENCE NEWS CYCLE

Start Here



## Your Research

Conclusion: A is correlated with B ( $p=0.56$ ), given C, assuming D and under E conditions.



...is translated by...

## UNIVERSITY PR OFFICE (YES, YOU HAVE ONE)

FOR IMMEDIATE RELEASE:  
SCIENTISTS FIND  
POTENTIAL LINK  
BETWEEN A AND B  
(UNDER CERTAIN CONDITIONS).



...which is then  
picked up by...

## NEWS WIRE ORGANIZATIONS

A CAUSES B, SAY  
SCIENTISTS.



...who are  
read by ...

## THE INTERNETS

[Scientists out to kill us again.](#)

POSTED BY RANDOM DUDE

Comments (377)

OMG! i kneeeew itt!!

WTH???????

...then noticed by...



We saw it on a Blog!

A causes B all the time  
What will this mean for Obama?

BREAKING NEWS BREAKING NEWS BREA

## CNC Cable NEWS

...and caught  
on ...



## 4 LOCAL EYEWITLESS NEWS

WHAT YOU DON'T  
KNOW ABOUT "A"...  
CAN KILL YOU!  
MORE AT 11...



...eventually  
making it to...

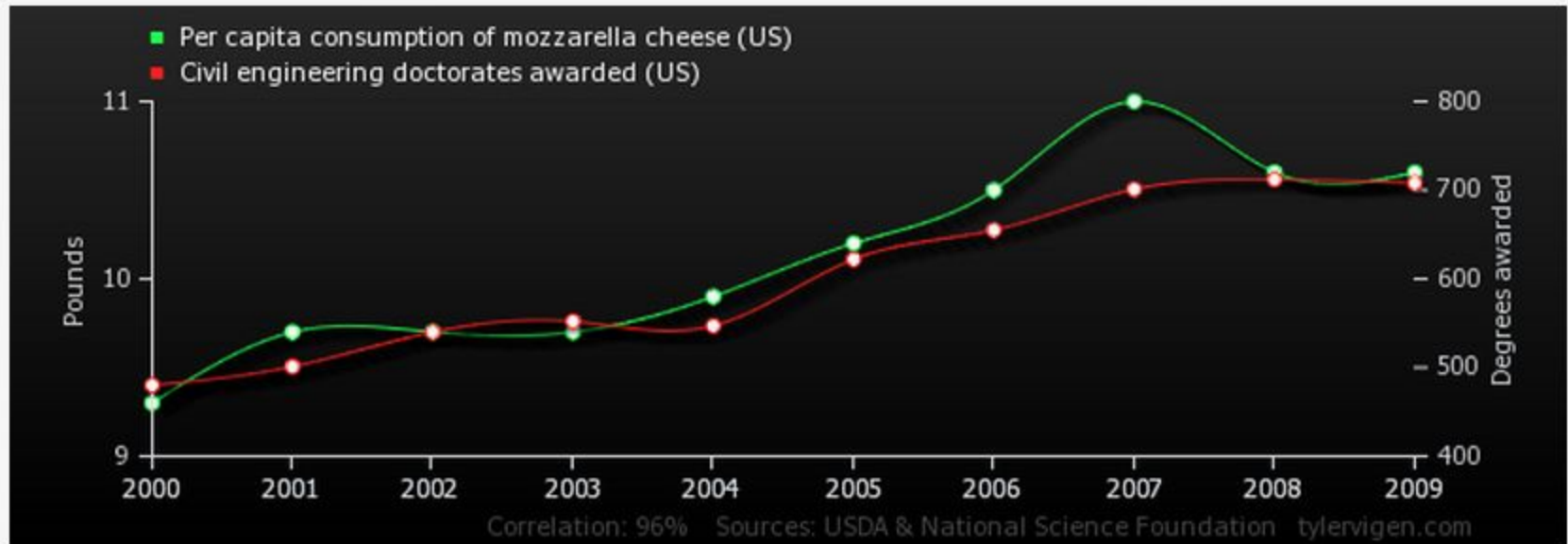


# Curious Examples

**Per capita consumption of mozzarella cheese (US)**  
correlates with  
**Civil engineering doctorates awarded (US)**

eating mozzarella ...  
produces more civil engineering doctorates?

# Per capita consumption of mozzarella cheese (US) correlates with Civil engineering doctorates awarded (US)



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Per capita consumption of mozzarella cheese (US) Pounds (USDA)	9.3	9.7	9.7	9.7	9.9	10.2	10.5	11	10.6	10.6
Civil engineering doctorates awarded (US) Degrees awarded (National Science Foundation)	480	501	540	552	547	622	655	701	712	708
Correlation: 0.958648										

**Honey producing bee colonies (US)**  
inversely correlates with  
**Juvenile arrests for possession of marijuana (US)**

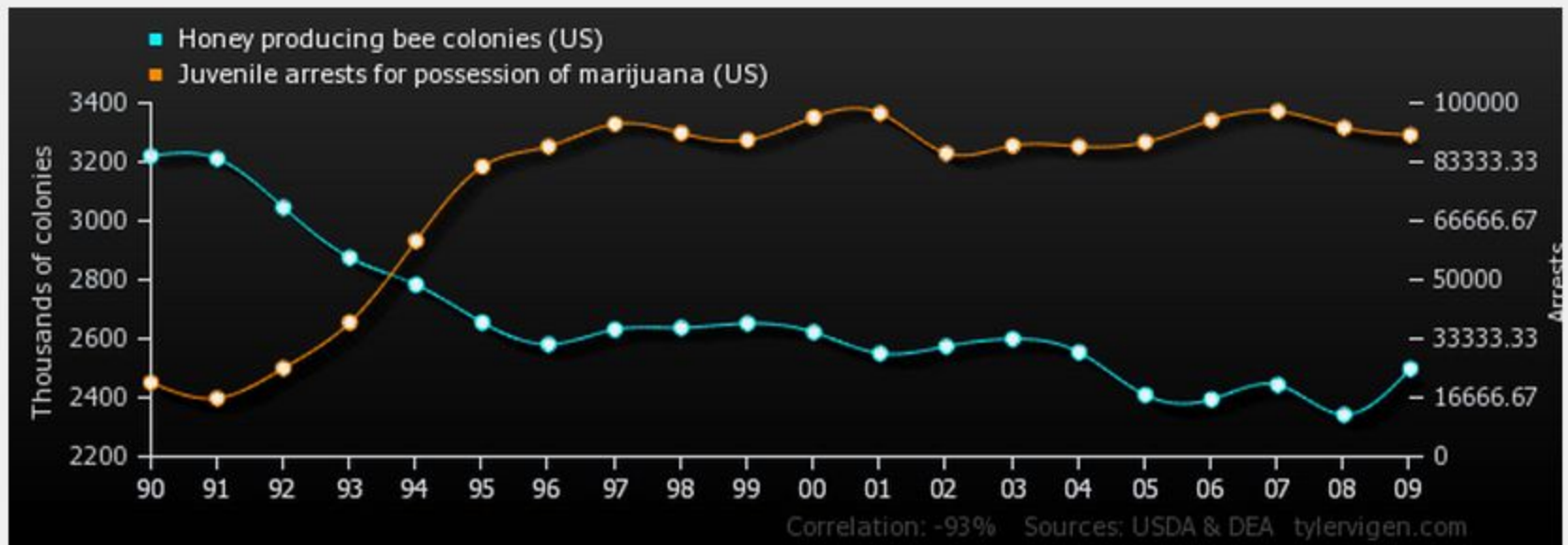
decrease in honey bee colonies ...  
increases marijuana possession?



# Honey producing bee colonies (US)

inversely correlates with

## Juvenile arrests for possession of marijuana (US)



**Honey producing bee colonies (US)**  
Thousands of colonies (USDA)

'90: 3,220; '91: 3,211; '92: 3,045; '93: 2,875; '94: 2,783; '95: 2,655; '96: 2,581; '97: 2,631; '98: 2,637; '99: 2,652; '00: 2,622; '01: 2,550; '02: 2,574; '03: 2,599; '04: 2,554; '05: 2,409; '06: 2,394; '07: 2,443; '08: 2,342; '09: 2,498

**Juvenile arrests for possession of marijuana (US)**  
Arrests (DEA)

'90: 20,940; '91: 16,490; '92: 25,004; '93: 37,915; '94: 61,003; '95: 82,015; '96: 87,712; '97: 94,046; '98: 91,467; '99: 89,523; '00: 95,962; '01: 97,088; '02: 85,769; '03: 87,909; '04: 87,717; '05: 88,909; '06: 95,120; '07: 97,671; '08: 93,042; '09: 90,927

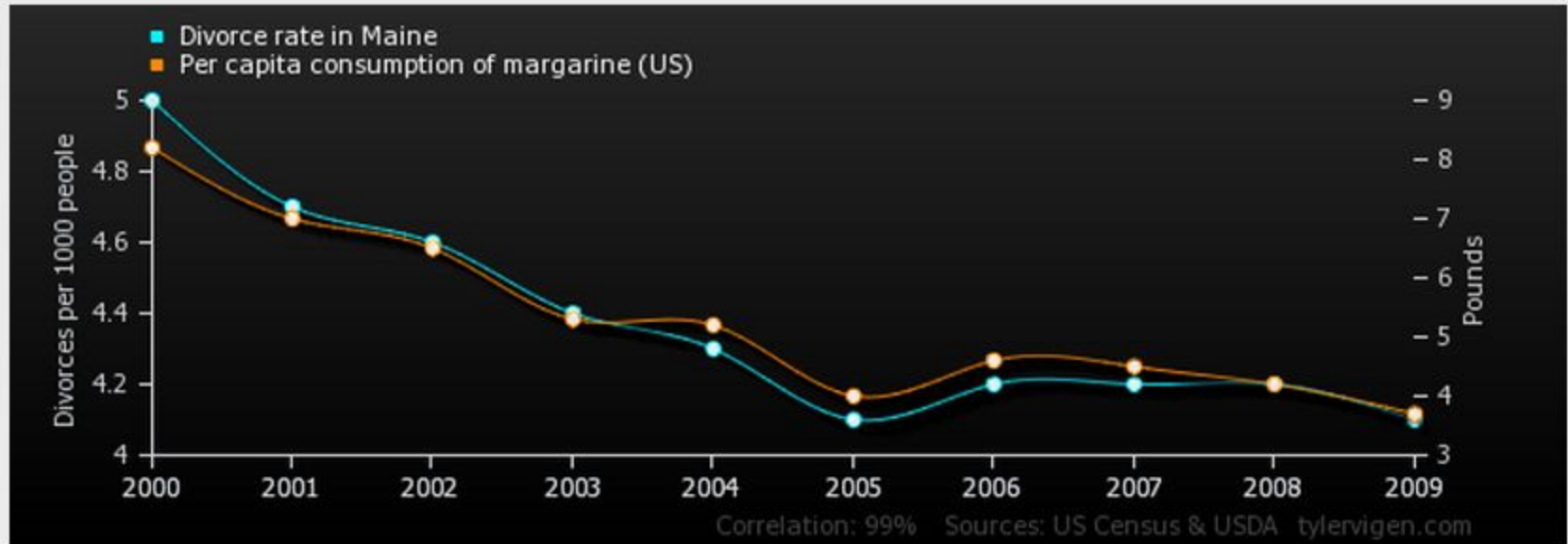
**Correlation: -0.933389**

**Divorce rate in Maine**  
correlates with  
**Per capita consumption of margarine (US)**

consuming margarine ...  
decrease divorces in Maine?



# Divorce rate in Maine correlates with Per capita consumption of margarine (US)



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Divorce rate in Maine Divorces per 1000 people (US Census)	5	4.7	4.6	4.4	4.3	4.1	4.2	4.2	4.2	4.1
Per capita consumption of margarine (US) Pounds (USDA)	8.2	7	6.5	5.3	5.2	4	4.6	4.5	4.2	3.7
Correlation: 0.992558										

**Per capita consumption of cheese (US)**

correlates with

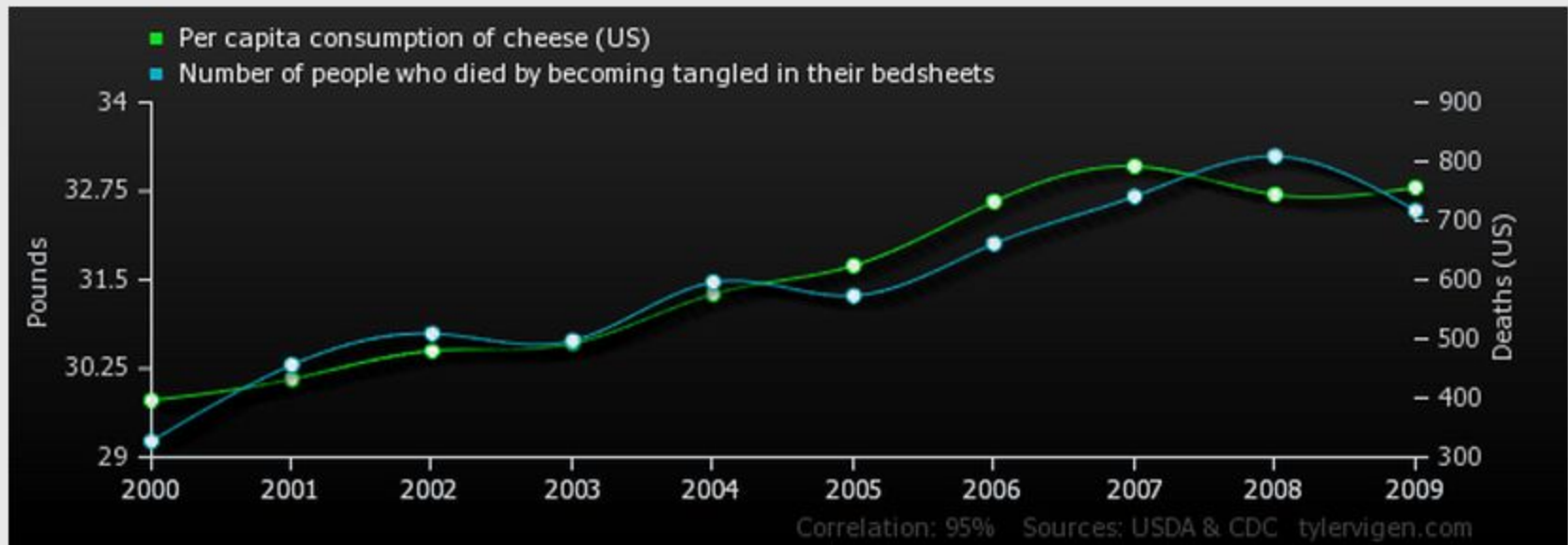
**Number of people who died by becoming tangled in their  
bedsheets**

consuming cheese ...  
produces nightmares ...  
with fatal consequences?

# Per capita consumption of cheese (US)

correlates with

## Number of people who died by becoming tangled in their bedsheets



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Per capita consumption of cheese (US) Pounds (USDA)	29.8	30.1	30.5	30.6	31.3	31.7	32.6	33.1	32.7	32.8
Number of people who died by becoming tangled in their bedsheets Deaths (US) (CDC)	327	456	509	497	596	573	661	741	809	717

**Correlation: 0.947091**