1. Introduction/Overview

Readings: Benjamin et al (2017)
Goodman (1999)

R: Lab 0 and Lab 1

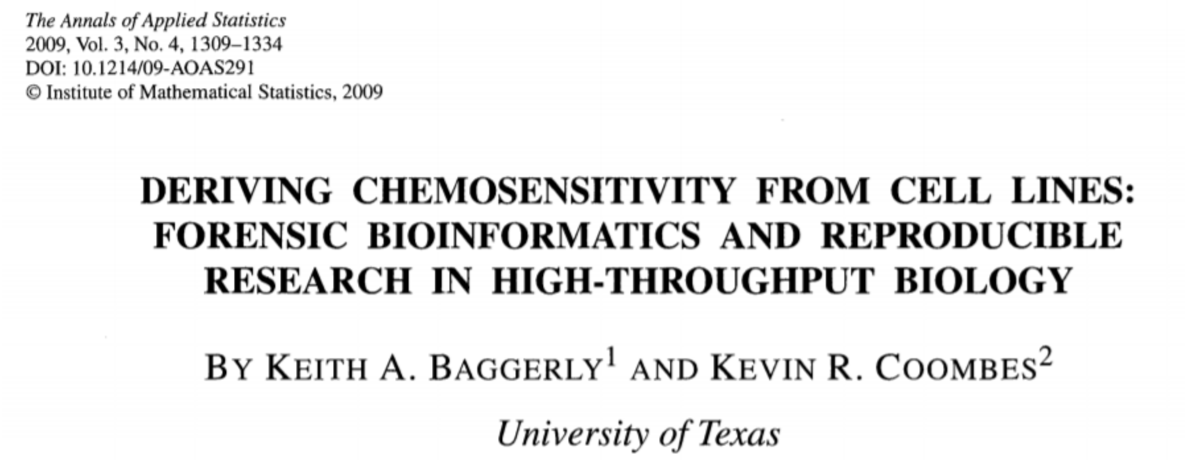
Overview

- Statistics as a discipline arose from the need to use data to answer scientific questions in the face of uncertainty

- Statistical concepts are at the heart of scientific inquiry in the health sciences

- Your mastery of fundamental concepts will facilitate:
  - a better understanding of published research
  - a better understanding of how to structure effective scientific research
  - interpretation and presentation of results
  - collaboration with other biostatisticians and scientific investigators

Compelling example that underscores the need for careful design, data handling, and analysis:



The Annals of Applied Statistics
2009, Vol. 3, No. 4, 1309–1334
DOI: 10.1214/09-AOAS291
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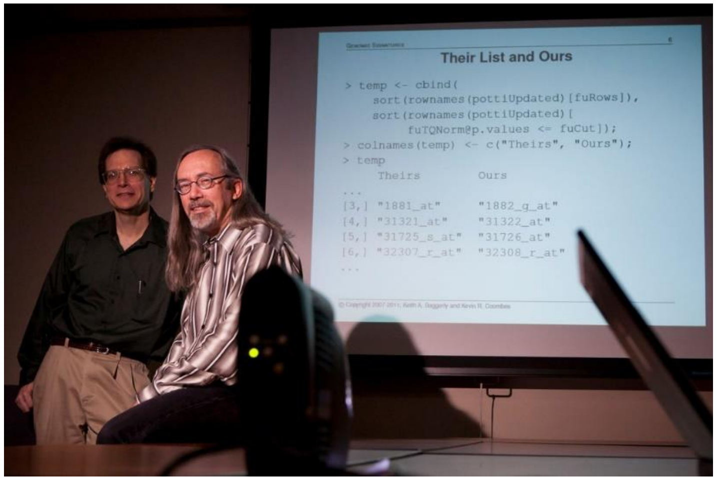
DERIVING CHEMOSENSITIVITY FROM CELL LINES: FORENSIC BIOINFORMATICS AND REPRODUCIBLE RESEARCH IN HIGH-THROUGHPUT BIOLOGY

BY KEITH A. BAGGERLY[1] AND KEVIN R. COOMBES[2]

University of Texas



Their List and Ours

```
> temp <- cbind(
    sort(rownames(pottiUpdated)[fuRows]),
    sort(rownames(pottiUpdated)[
         fuTQNorm@p.values <= fuCut]);
> colnames(temp) <- c("Theirs", "Ours");
> temp
      Theirs          Ours
...
[3,] "1881_at"      "1882_g_at"
[4,] "31321_at"     "31322_at"
[5,] "31725_s_at"   "31726_at"
[6,] "32307_r_at"   "32308_r_at"
...
```

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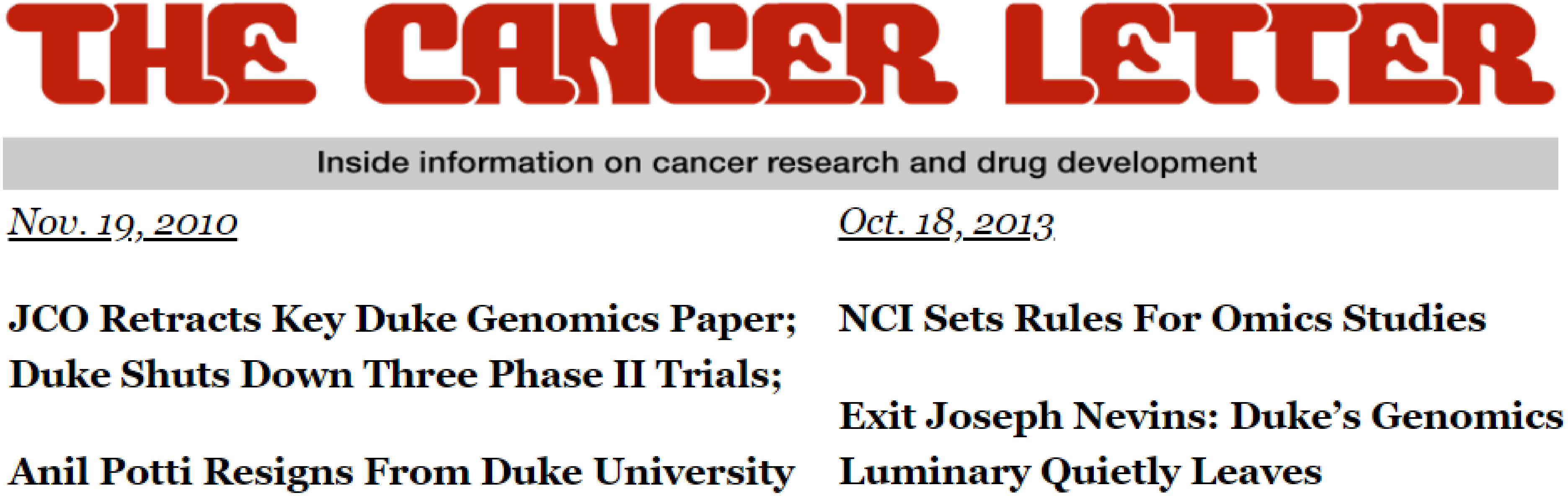
Source: New York Times



THE CANCER LETTER

Inside information on cancer research and drug development

Nov. 19, 2010

JCO Retracts Key Duke Genomics Paper; Duke Shuts Down Three Phase II Trials;

Anil Potti Resigns From Duke University

Oct. 18, 2013

NCI Sets Rules For Omics Studies

Exit Joseph Nevins: Duke's Genomics Luminary Quietly Leaves

Algorithms vs. Inference

Types of algorithms

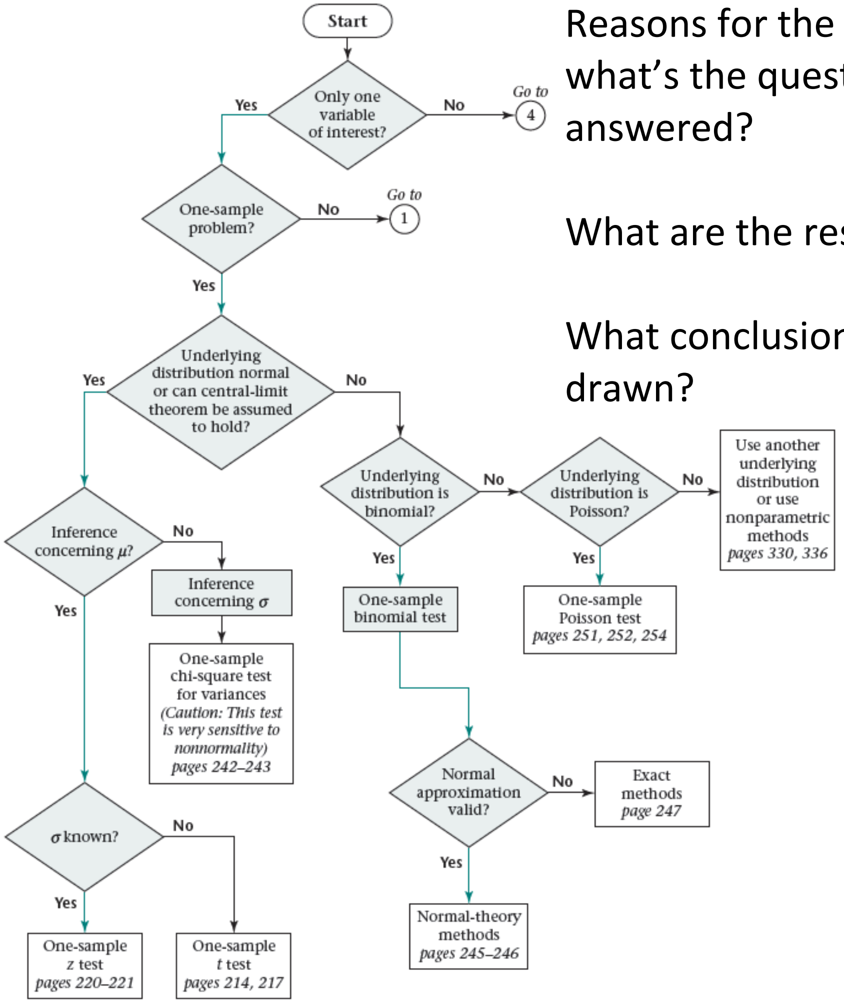
Dip the lasagna sheets in boiling water + salt + olive oil
prevent pasta from sticking
Drain
put the lasagna sheets in cold water
100% virgin (no egg no dairy products)
Olive Oil
3rd stage
Boil the lasagna sheets
breadcrumbs
put all the ingredients together
4th stage
Assemble & Bake
Layers
1 - tomato sauce
2 - Lasagna sheets
3 - tomato sauce mushrooms green peas radicchio & béchamel sauce
Repeat 1 - 2 - 3
On top: tomato sauce and breadcrumbs
Finally put your Vegan Pasticcio in the oven - preheated at 180C - for 45 min.
ISI©13

Inference

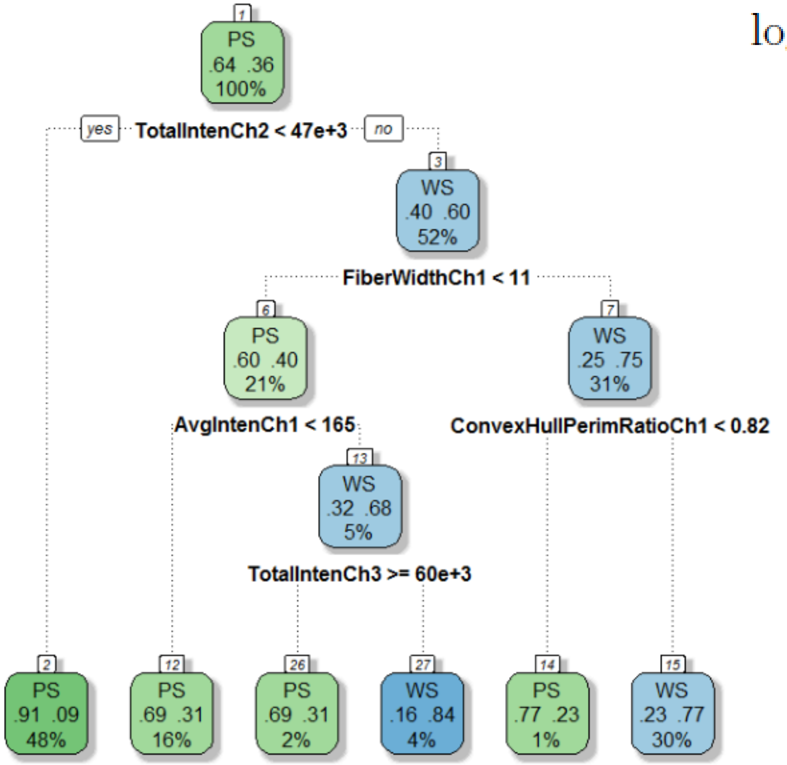
Inference
Reasons for the algorithm – what's the question being answered?

What are the results?

What conclusions can be drawn?


Start
Only one variable of interest?
Yes
No
Go to 4
One-sample problem?
No
Go to 1
Yes
Underlying distribution normal or can central-limit theorem be assumed to hold?
Yes
No
Inference concerning μ?
No
Yes
Inference concerning σ
One-sample chi-square test for variances (Caution: This test is very sensitive to nonnormality) pages 242–243
σ known?
Yes
No
One-sample z test pages 220–221
One-sample t test pages 214, 217
Underlying distribution is binomial?
No
Yes
One-sample binomial test
Normal approximation valid?
No
Yes
Exact methods page 247
Normal-theory methods pages 245–246
Underlying distribution is Poisson?
No
Yes
One-sample Poisson test pages 251, 252, 254
Use another underlying distribution or use nonparametric methods pages 330, 336

Algorithms vs. Models



Rattle 2013-Jun-19 15:43:30 Joe.Rickert

$$
\begin{aligned}
\text{logit}(\mathbb{E}[Y_i|x_{1,i}, \ldots, x_{m,i}]) &= \text{logit}(p_i) \\
&= \log\left(\frac{p_i}{1-p_i}\right) \\
&= \beta_0 + \beta_1 x_{1,i} + \cdots + \beta_m x_{m,i}
\end{aligned}
$$

$$
\begin{aligned}
\text{logit}(\mathbb{E}[Y_i|\mathbf{X}_i]) &= \text{logit}(p_i) \\
&= \log\left(\frac{p_i}{1-p_i}\right) \\
&= \beta\mathbf{X}_i
\end{aligned}
$$

Randomness

Randomness is fundamental to statistical inference

Control of randomness is key to experimentation and the scientific method

Random Number Generation

True Random Number Generator (TRNG) vs. Pseudo Random Number Generator (PRNG)

Characteristic	**PRNG**	**TRNG**
Efficiency	Excellent	Poor
Determinism	Deterministic	Nondeterministic
Periodicity	Periodic	Aperiodic

Application	**Most Suitable Generator**
Lotteries and Draws	TRNG
Games and Gambling	TRNG
Random Sampling (e.g., drug screening)	TRNG
Simulation and Modelling	PRNG
Security (e.g., generation of data encryption keys)	TRNG
The Arts	Varies

Source: www.random.org/randomness

Applications of random number generation

A. Research Design

Randomization/random allocation, random sampling

1. **Random Digits:** (Combinations of) 0, 1, …, 9 occur with the same relative frequency (uniformly distributed).
    a. Digits occur independently of occurrence of other digits
    b. Use these sequences for random selection or allocation
    c. For example, a random number table

2. **Random Selection (Sampling):** Selecting random portion of large population (e.g., select 10 units randomly from 1000)
    a. Tools in R include the “runif” and “sample” functions
    b. Simple random sampling, cluster sampling, stratified sampling

3. **Random Allocation:** Assigning treatments randomly to individual units or groups of units
    a. Tools in R include the “blockTools” package

Applications of random number generation

B. Random Sampling from Theoretical Distributions

Also known as *simulation*

Overview

- Simulation is a fundamental and powerful tool in statistical practice
- Simulation for understanding
- Simulation for experimentation
- https://www4.stat.ncsu.edu/~davidian/st810a/simulation_handout.pdf

IRReproducibility

Reliance on p-values –

- long-term trends leading up to the data + evidence provided by data; conflation of these has resulted in current approach which generally satisfies neither (Goodman, 1999)
- < 0.05 actually provides weak evidence against H_0 (Benjamin et al. 2017)

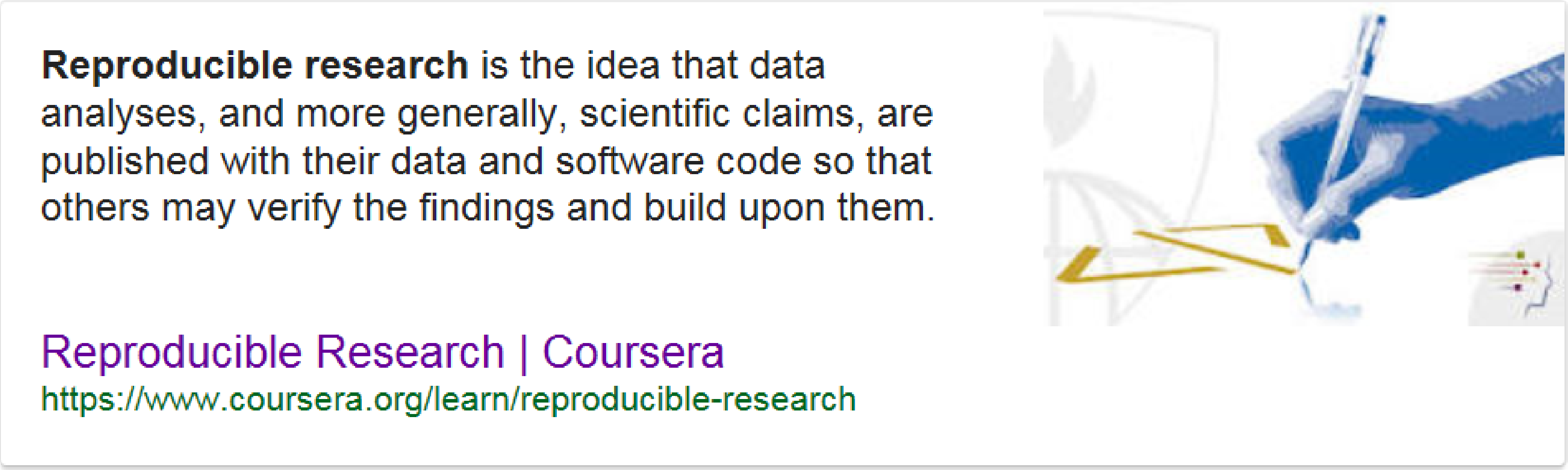
Multiplicity – leads to *selection* of results and this has an *effect* on observed ability to replicate results (see 2005 *JAMA* paper by Ioannidis on course website)

- Multiple variables, endpoints, time points, subgroups, comparisons
- Multiple hypothesis testing, multiple looks at the data
- Multiple models and adjustments
- Fishing expeditions, mountains of output without *a priori* thought and justification - *…what exactly was my (their) research hypothesis or question?…p-hacking …*

Publication bias – file drawer problem, publish or perish, sensationalism

Cognitive biases – preconceived notions about what effects are real, what effects could be real, what effects are likely not to be real

Reproducible Research



Reproducible research is the idea that data analyses, and more generally, scientific claims, are published with their data and software code so that others may verify the findings and build upon them.

Reproducible Research | Coursera

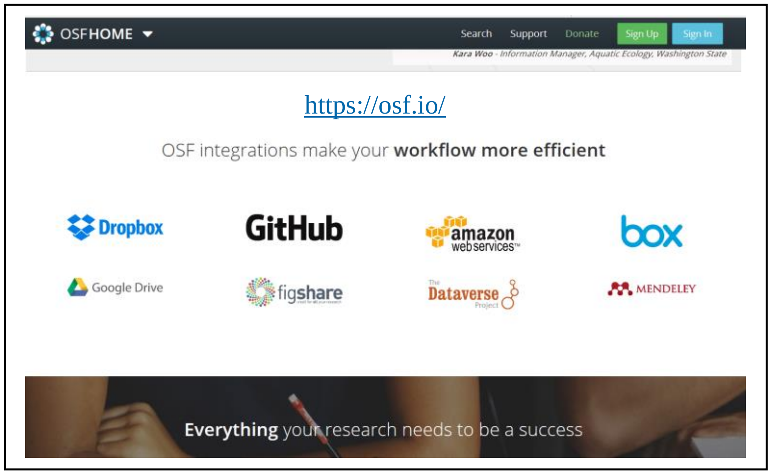
https://www.coursera.org/learn/reproducible-research

Open Science Paradigm

Open Access - Publications

Public access – free to anyone with an internet connection

Free: Use, reuse, remix



Kara Woo - Information Manager, Aquatic Ecology, Washington State

https://osf.io/

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Pre-study: Study registration

Post-study: Preprints

Open Data

Known Provenance

Confidentiality assured

Portability (interoperability) built in

Excel-free, reproducible data manipulation/management best practices applied

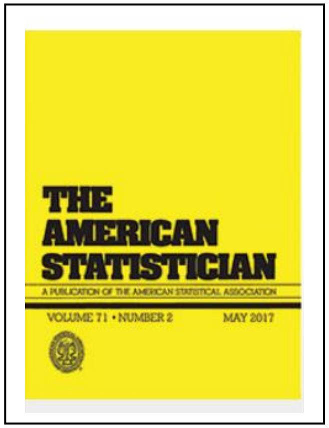
Open Code

Version control used to track changes

Collaborative model – team science

Crowd sourcing – best solutions openly available

Miscellaneous


THE AMERICAN STATISTICIAN
A PUBLICATION OF THE AMERICAN STATISTICAL ASSOCIATION
VOLUME 71 • NUMBER 2
MAY 2017

Throughout semester we’ll:

Read

The statistical methods literature

Practice Reproducible Research Principles

“Lite” version …move towards compliance

Appreciate

(“Peak”) science writing – WIRED, Quanta, your favorites

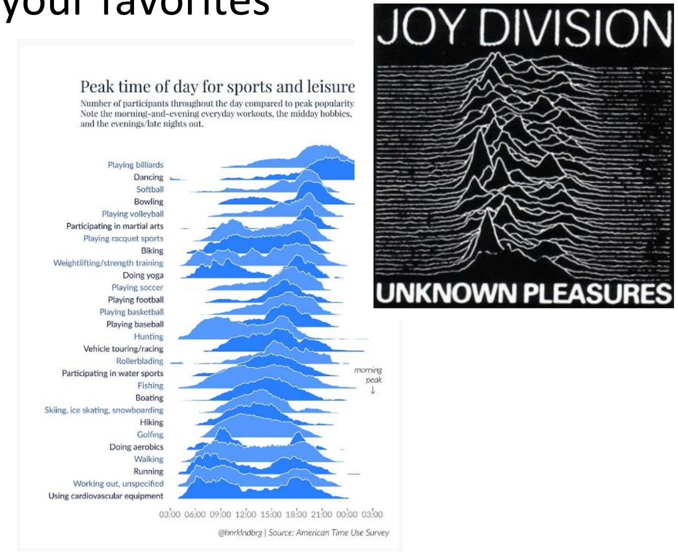
Be on the lookout for cool, innovative graphics

ggjoy – R package

https://cran.r-project.org/web/packages/ggjoy/vignettes/introduction.html

R Gallery:

https://cran.r-project.org/web/packages/ggjoy/vignettes/gallery.html



Share

Resources …using Canvas