Observational Study

and

Experiment

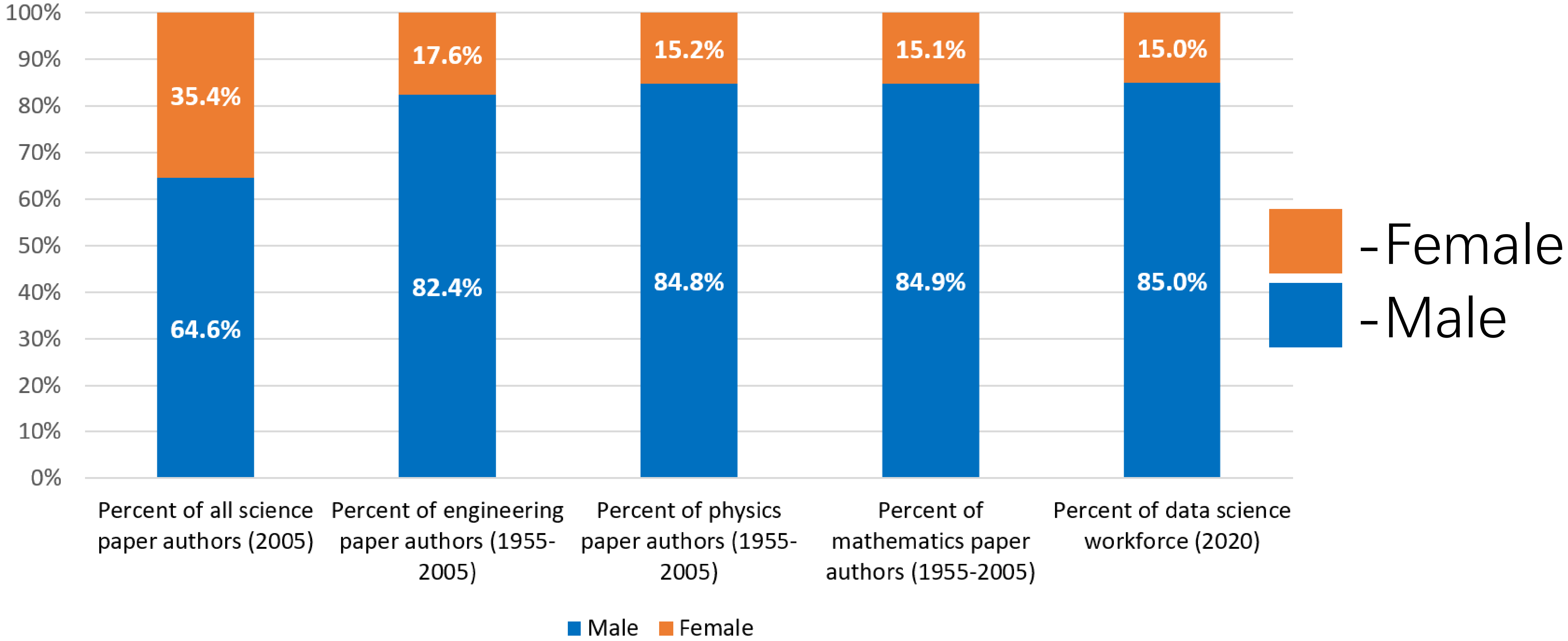
Topics

1. Observational studies vs. experiments
2. Components of experiments
3. Principles of experimental design
4. Describing a completely randomized design

Topics

1. **Observational studies vs. experiments**
2. Components of experiments
3. Principles of experimental design
4. Describing a completely randomized design

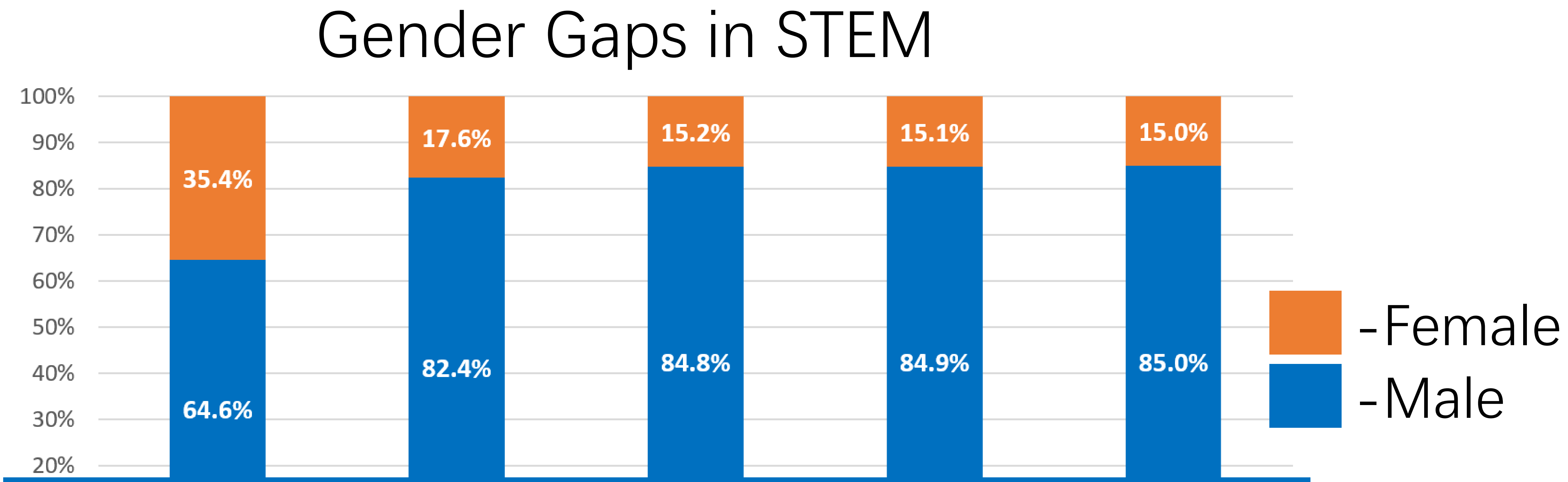
Gender Gaps in STEM



Sources:

-Huang, J. et al. “Historical comparison of gender inequality in scientific careers across countries and disciplines.” *Proceedings of the National Academy of Sciences,* Mar 2020, 117 (9) 4609-4616; DOI: 10.1073/pnas.1914221117

-*Boston Consulting Group,* “What’s Keeping Women out of Data Science?” bcg.com/publications/2020/what-keeps-women-out-data-science.aspx



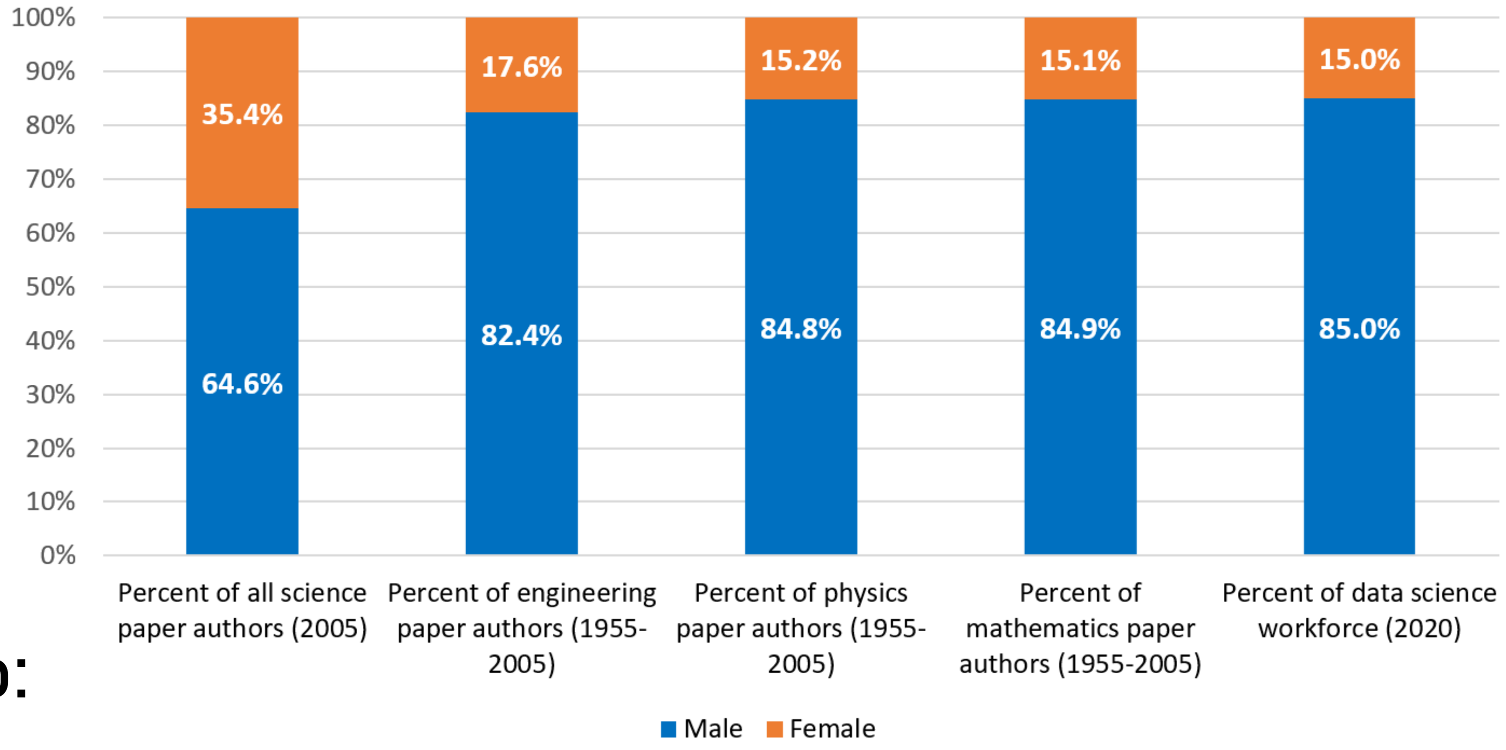
Today’s Key Analysis

Is it possible to find the true cause of these gender gaps in science?

What causes this trend?

Possible Cause:
Hiring Discrimination

Women are given fewer research and workforce opportunities in STEM due to:

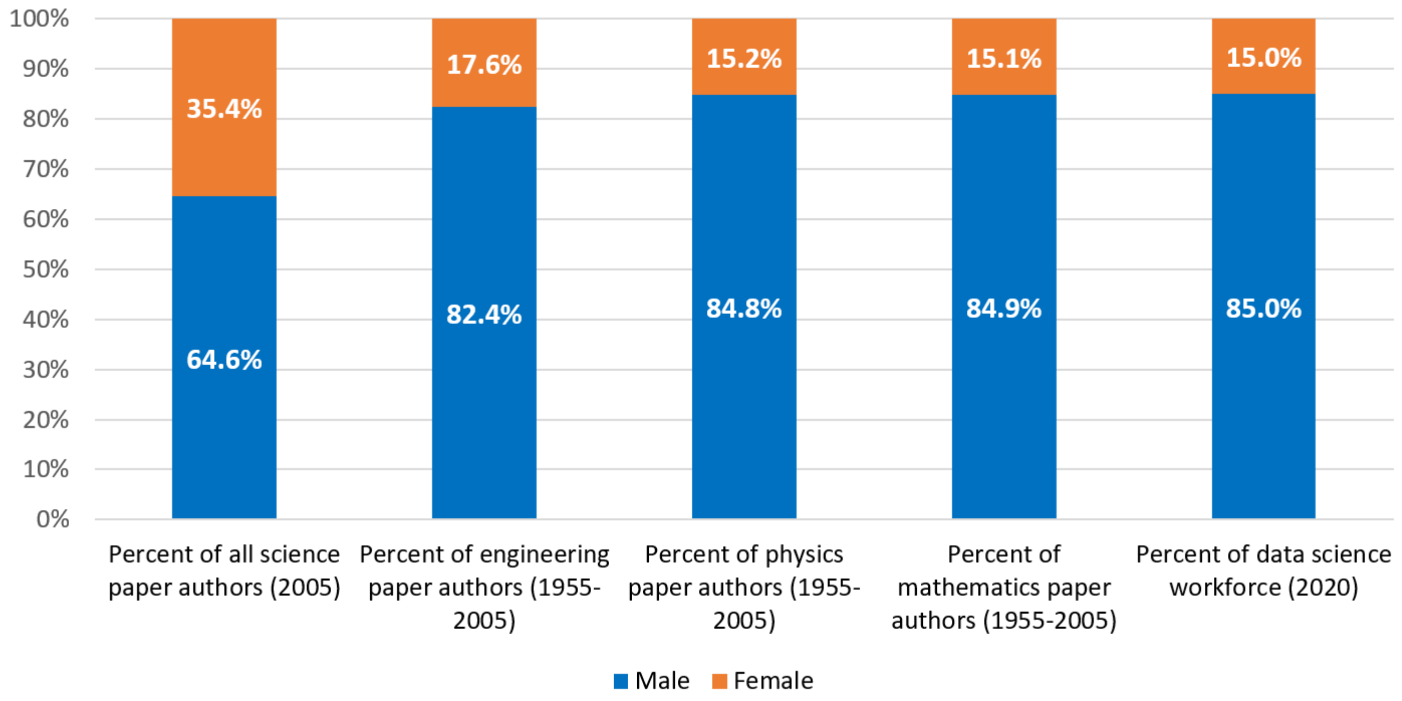


discriminatory practices in research/industry hiring, therefore, fewer women can enter or succeed in the field.

Can we prove this cause?

From this **observed** data alone, we **cannot** prove that hiring discrimination is the cause.

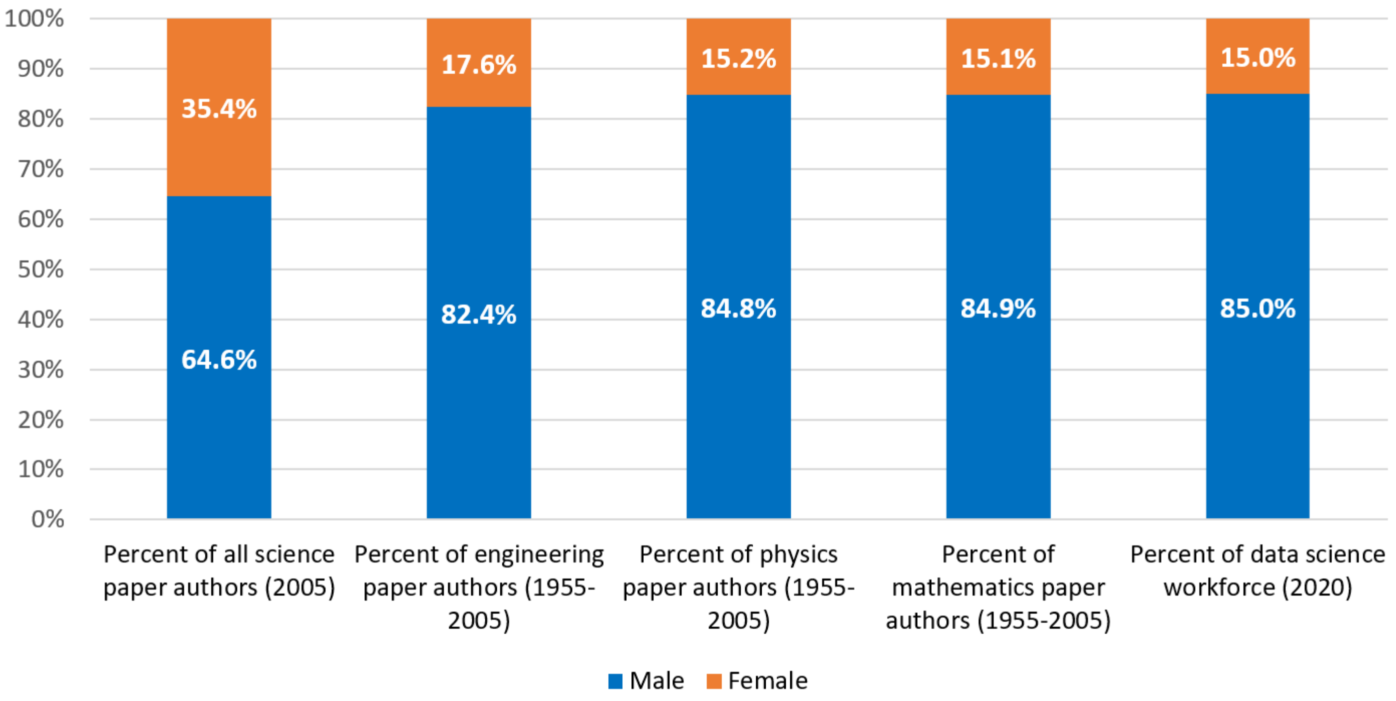
Why?



Can we prove this cause?

Drownings & Ice cream sales
Confounding variable: temperature

Attendance & GPA
Confounding variable: Poverty



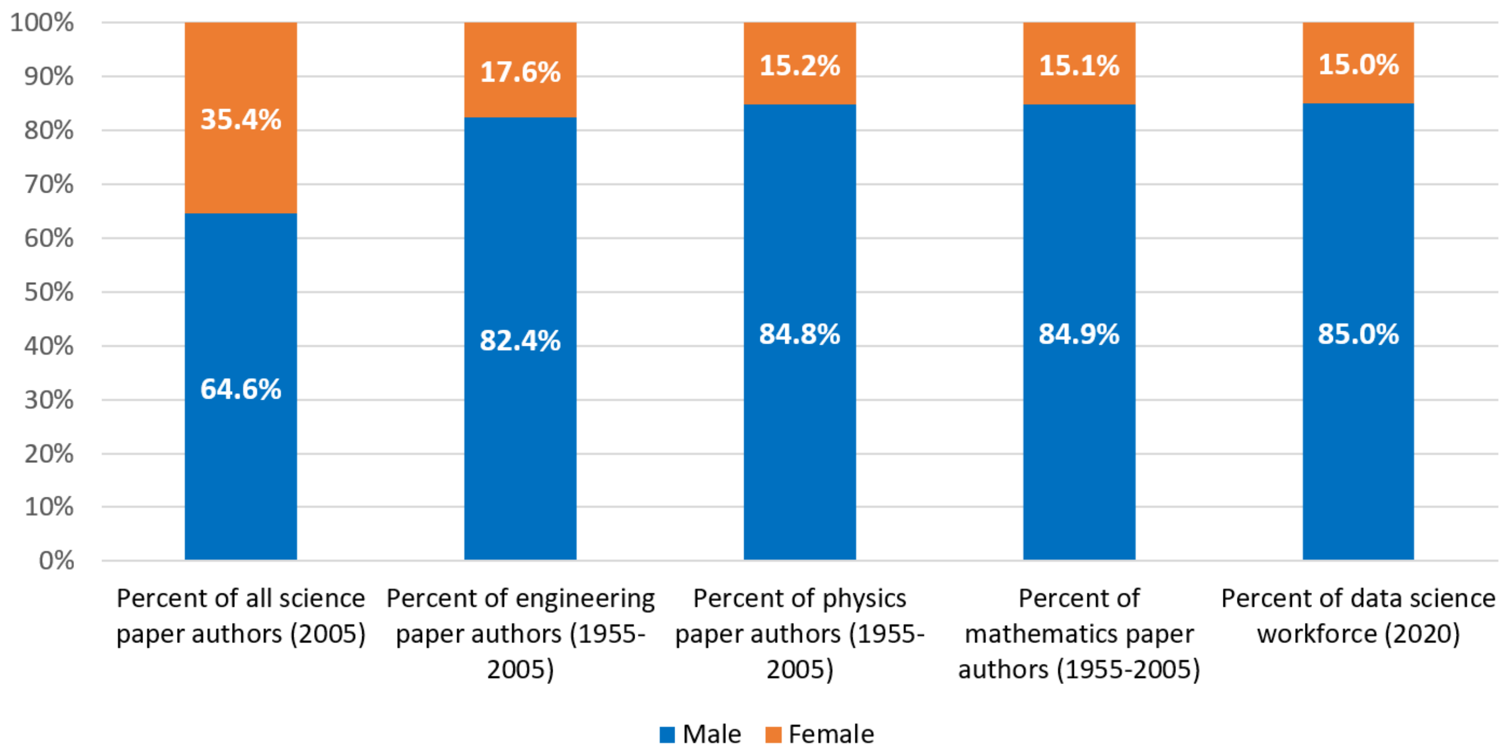
<u>Confounding variables:</u>

Provide **alternative** explanations for trends between explanatory (gender) and response (hiring rates) variables.

Possible Confounding Variable

Confounding: Socialization

Women are given fewer research and workforce opportunities in STEM due to:

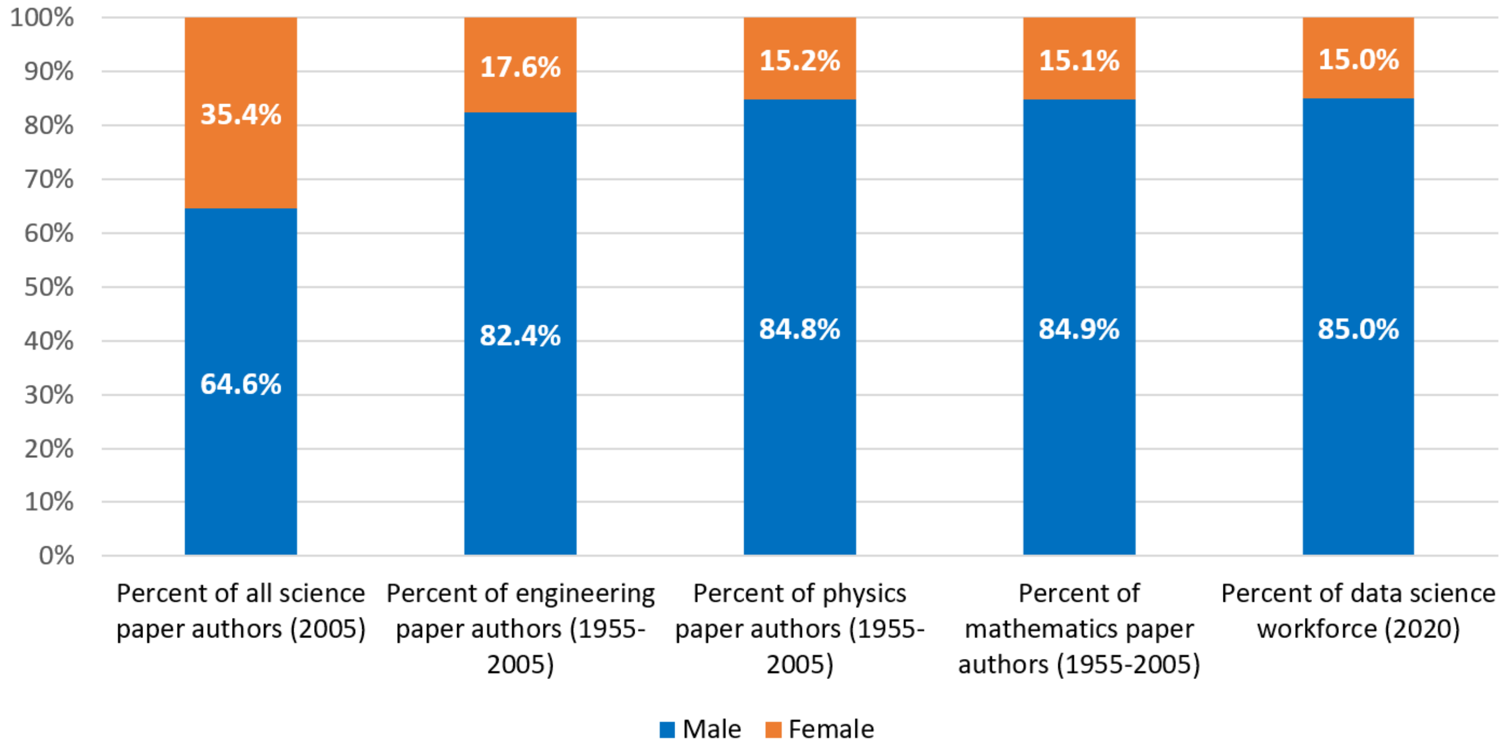


Many girls are not encouraged to pursue STEM subjects when they are growing up. Therefore, fewer women choose to pursue STEM as adults.

Possible Confounding Variable

Confounding: Socialization

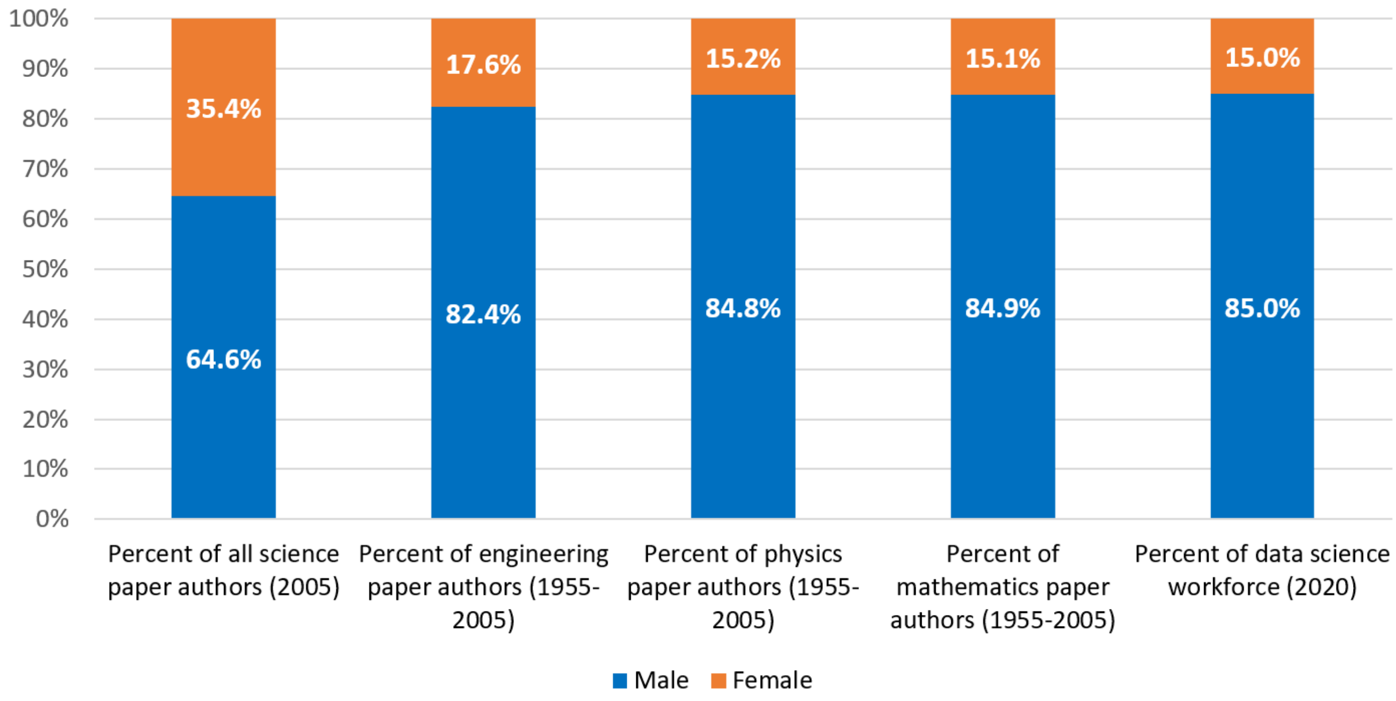
Women are given fewer research and workforce opportunities in STEM due to:



Additionally, We tend to foster boys' belief of talent in STEM which leads more men pursue STEM as adults.

What causes this trend?

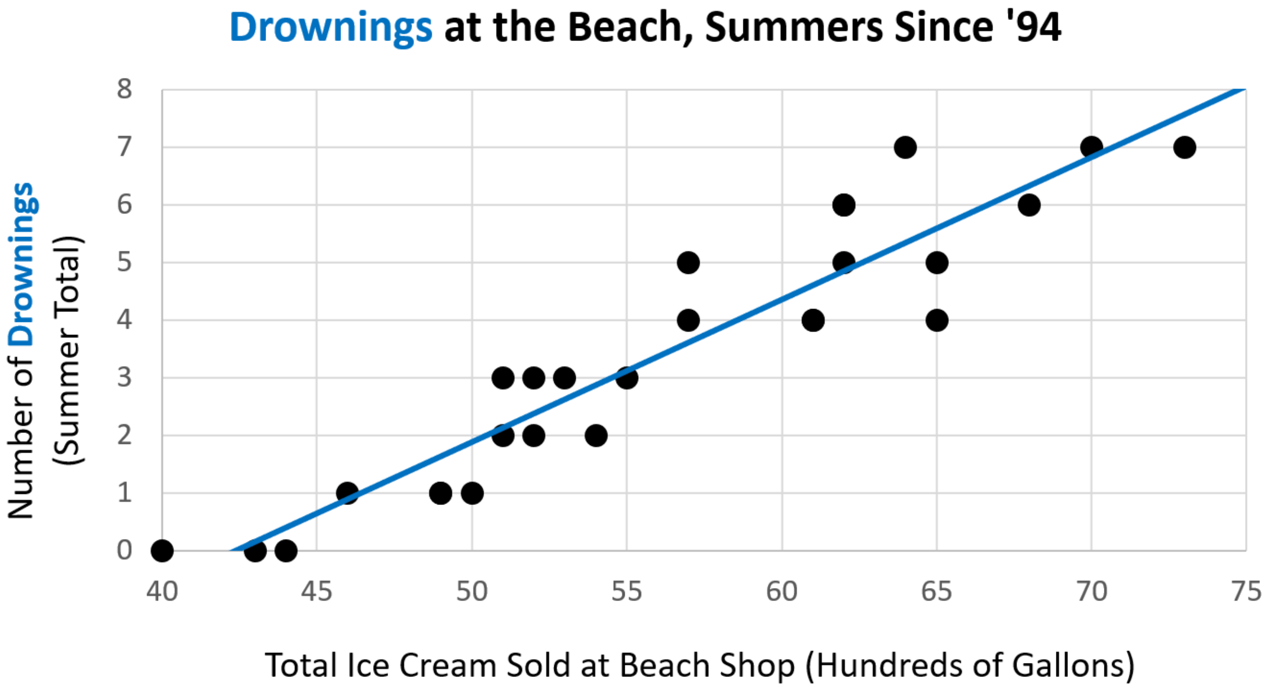
1. Hiring discrimination?
2. Socialization?
3. A combo of #1 and #2?
4. Other causes?
5. A combo of #1, #2, and other causes?...

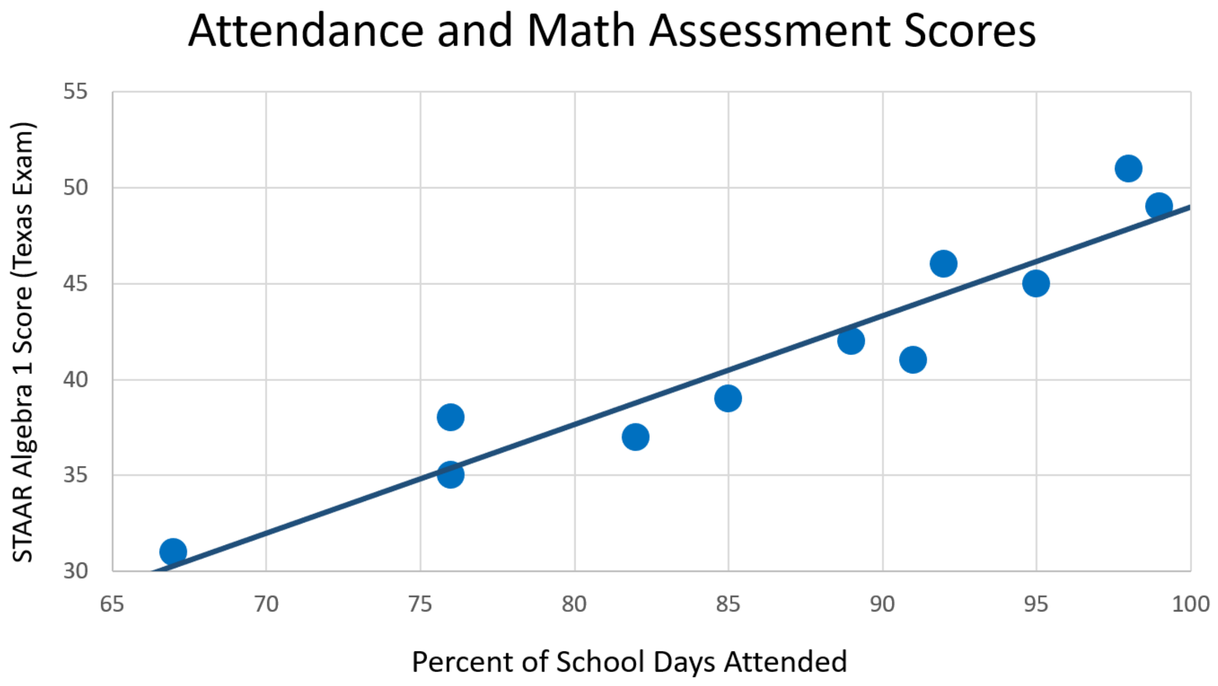


We don’t know! But maybe we can **test** it…

DEFINITION Observational study

An **observational study** observes individuals and measures variables of interest but does not attempt to influence the responses.





Cannot show cause and effect!

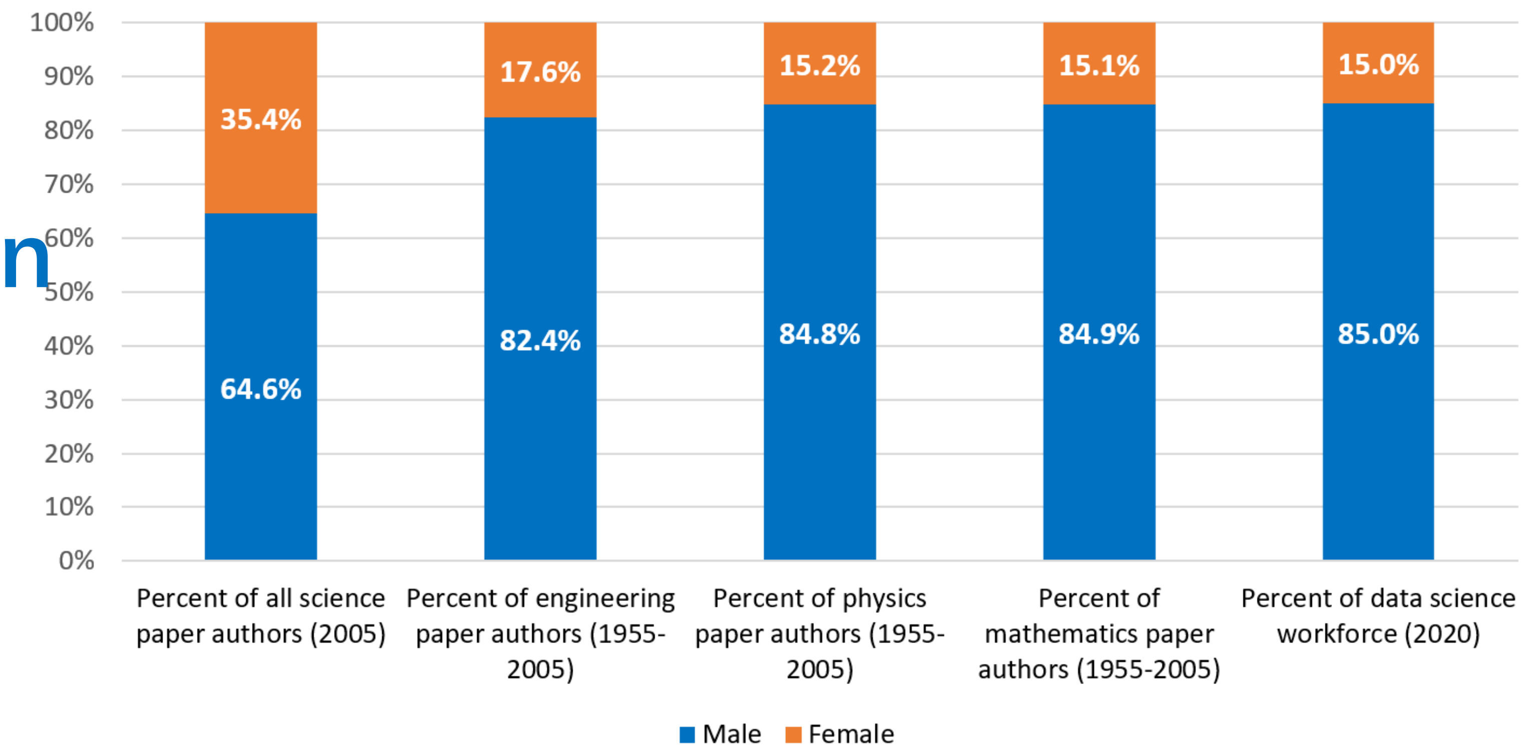
Experimental studies

Experiments: a study in which treatment is **imposed** on subjects.

-If well designed, experiments **can show** cause-effect relationships by **controlling** for confounding variables.

What causes this trend?

Possible Cause:
Hiring Discrimination



How can we design an experiment to test this?

Observational Studies & Experiments

- Observational Studies **cannot** show cause and effect because they do not control for confounding!
- If well designed, experiments **can** show cause and effect by controlling for confounding variables.

Topics

1. Observational studies vs. experiments
2. **Components of experiments**
3. Principles of experimental design
4. Describing a completely randomized design

PNAS
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RESEARCH ARTICLE

Check for updates

Science faculty’s subtle gender biases favor male students

Corinne A. Moss-Racusin, John F. Dovidio, Victoria L. Brescoll, Mark J. Graham, and Jo Handelsman

PNAS October 9, 2012 109 (41) 16474-16479; https://doi.org/10.1073/pnas.1211286109

Edited* by Shirley Tilghman, Princeton University, Princeton, NJ, and approved August 21, 2012 (received for review July 2, 2012)

Researchers from Yale developed an experiment to test for gender bias in research lab hiring.

Moss-Racusin, C., Dovidio, J., et al. “Science faculty’s subtle gender biases favor male students.” *PNAS* October 9, 2012 109 (41) 16474-16479; https://doi.org/10.1073/pnas.1211286109

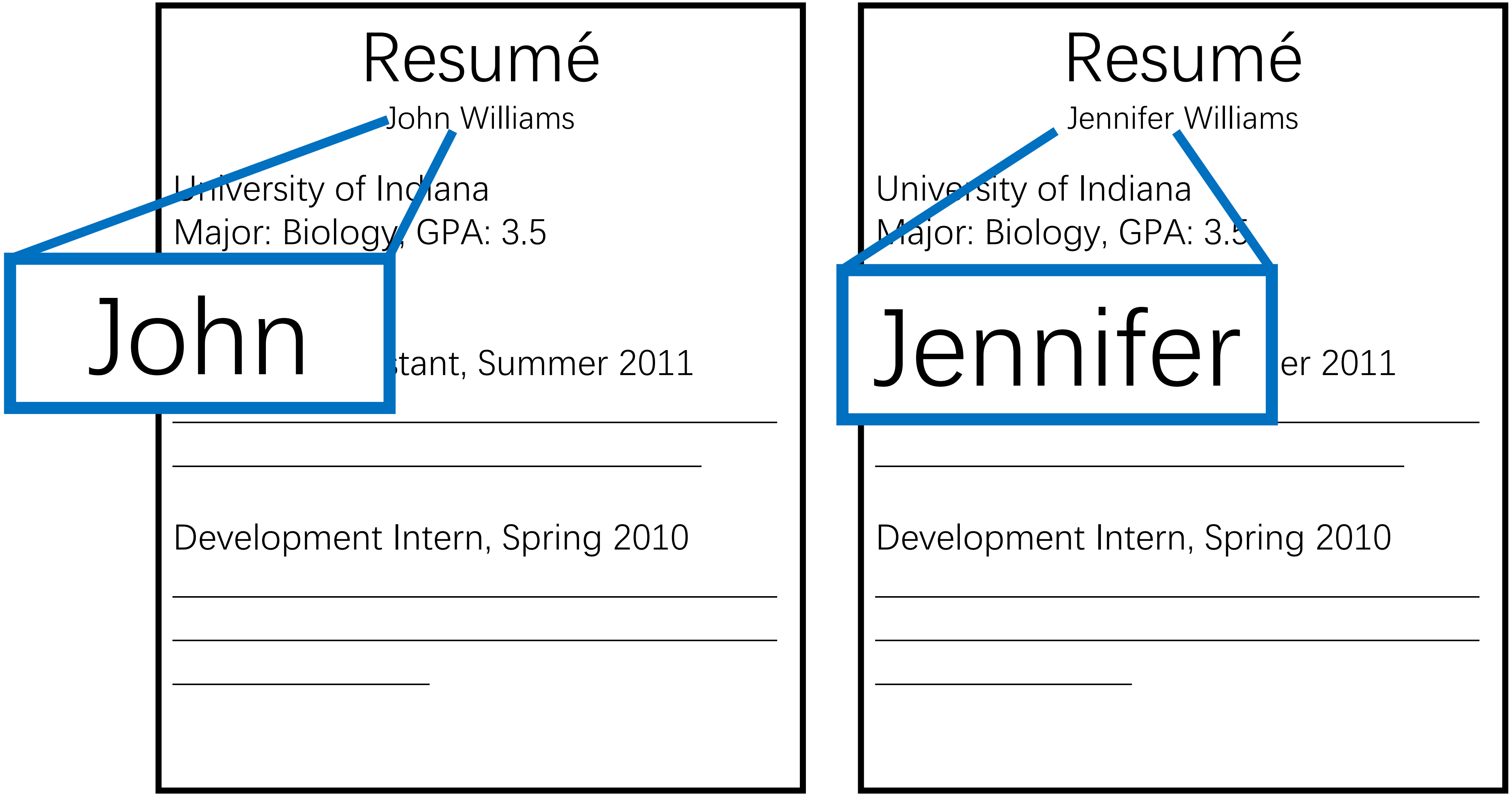
We'll discuss a simplified version of what they did (read paper for full version)

Paper: Moss-Racusin, C., Dovidio, J., et al. "Science faculty's subtle gender biases favor male students." *PNAS* October 9, 2012 109 (41) 16474-16479; https://doi.org/10.1073/pnas.1211286109

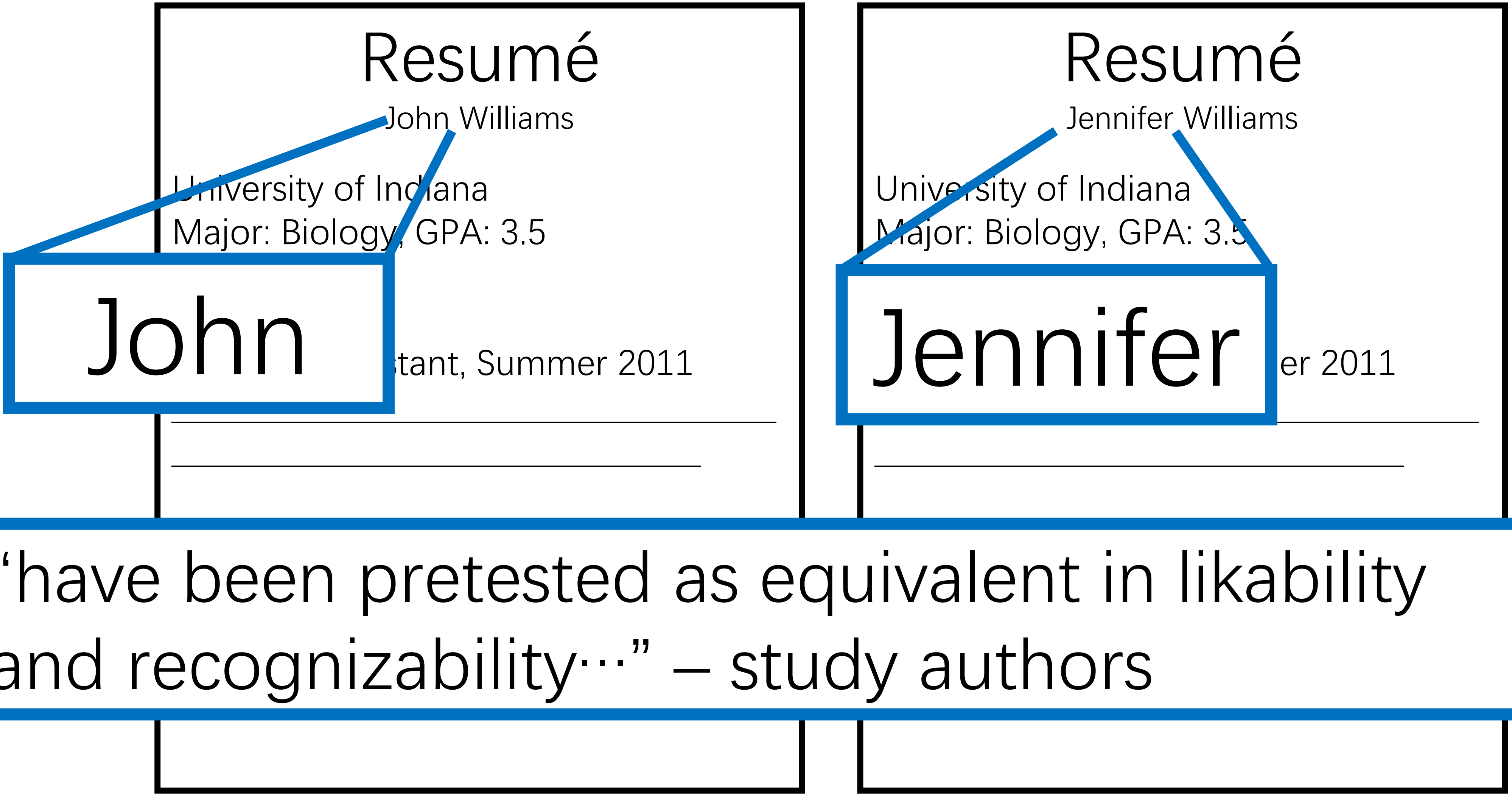
The Jenn/John Experiment

Resumé John Williams University of Indiana Major: Biology, GPA: 3.5 **Experience** Research Assistant, Summer 2011 Development Intern, Spring 2010	**Resumé** Jennifer Williams University of Indiana Major: Biology, GPA: 3.5 **Experience** Research Assistant, Summer 2011 Development Intern, Spring 2010

The Jenn/John Experiment

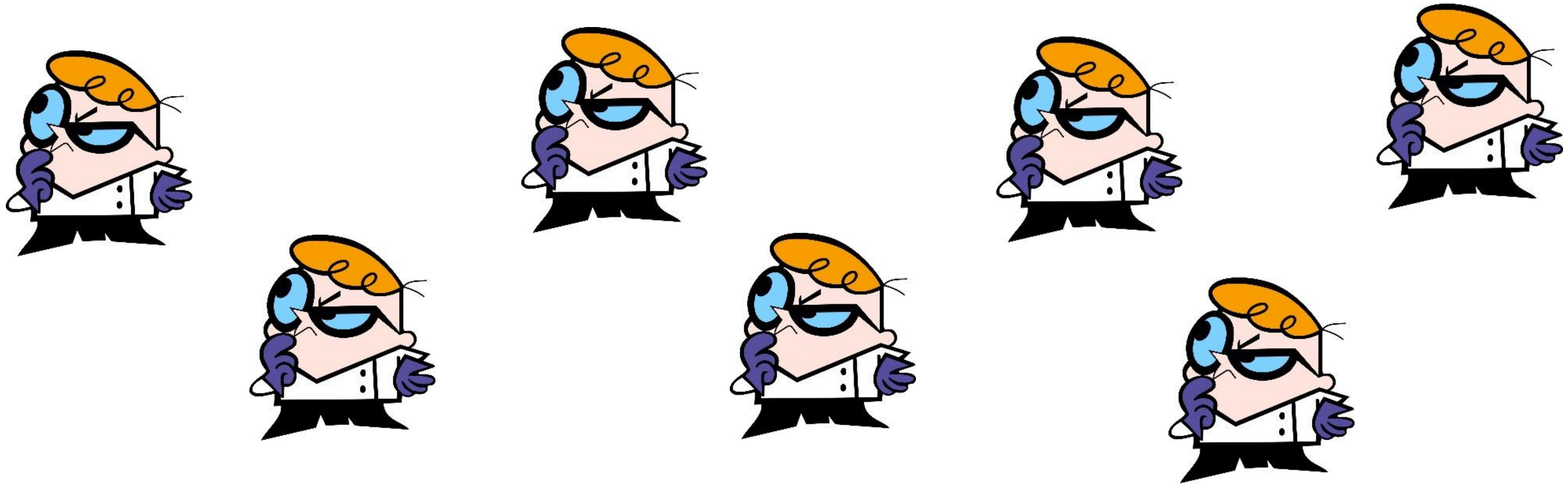


The Jenn/John Experiment



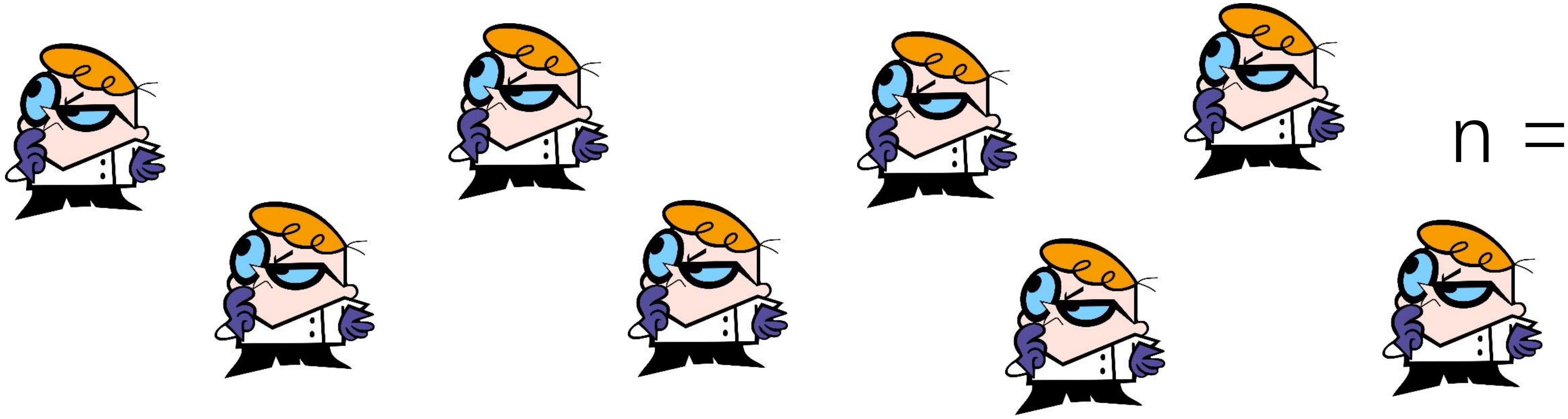
"have been pretested as equivalent in likability and recognizability…" – study authors

The Jenn/John Experiment

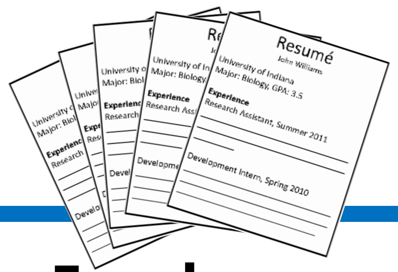


$n = 127$

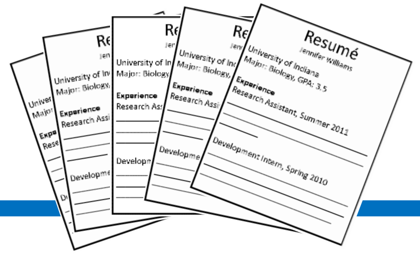
The Jenn/John Experiment



n = 127

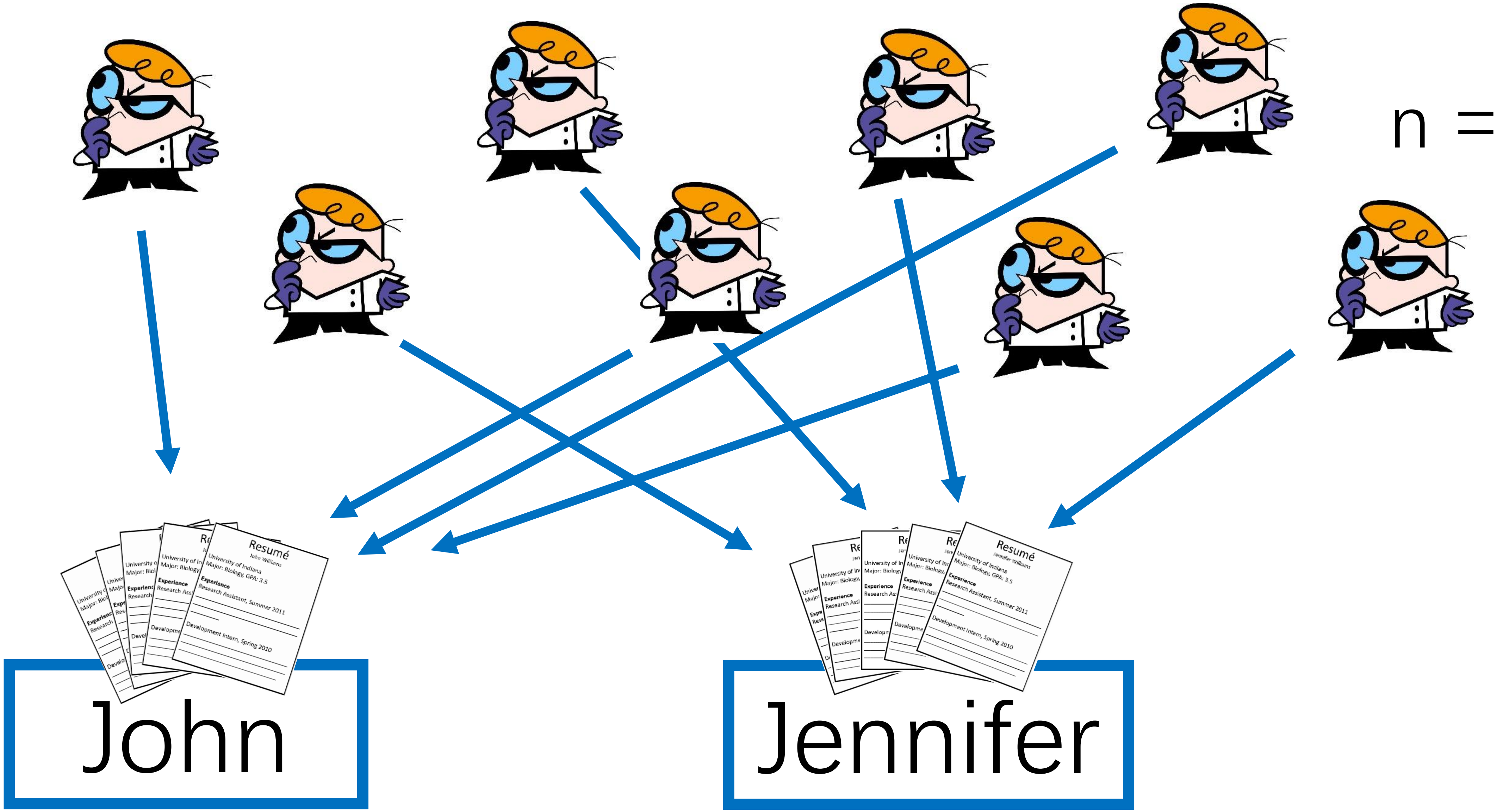


John



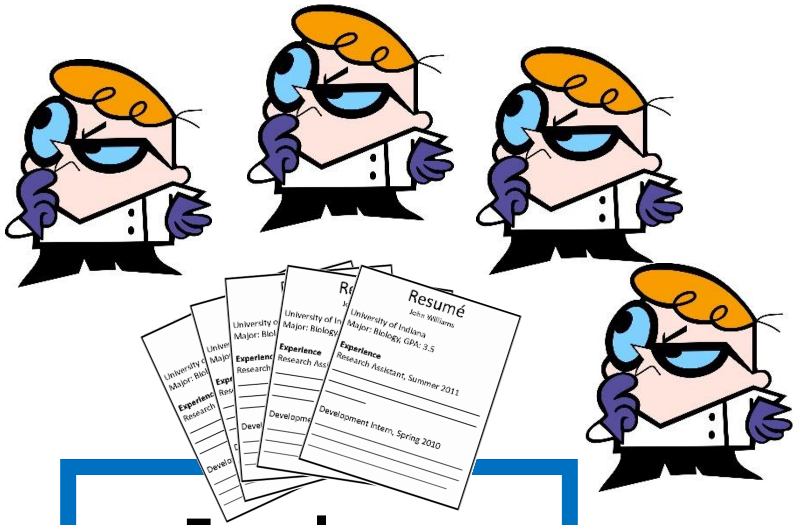
Jennifer

The Jenn/John Experiment

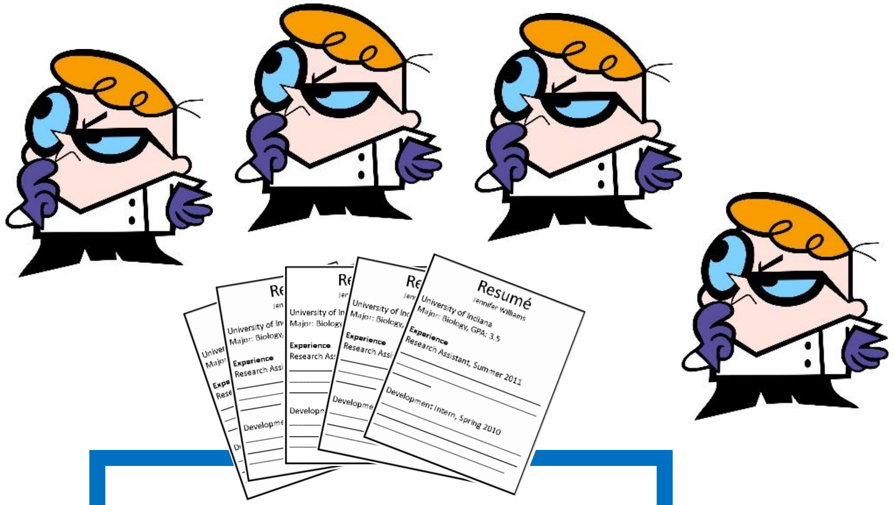


n = 127

The Jenn/John Experiment



John $n_1 = 63$



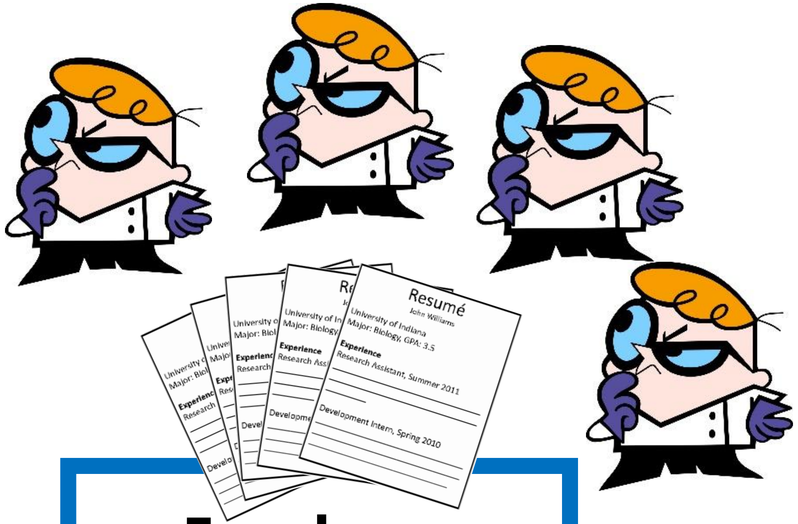
Jennifer $n_2 = 64$

The Jenn/John Experiment

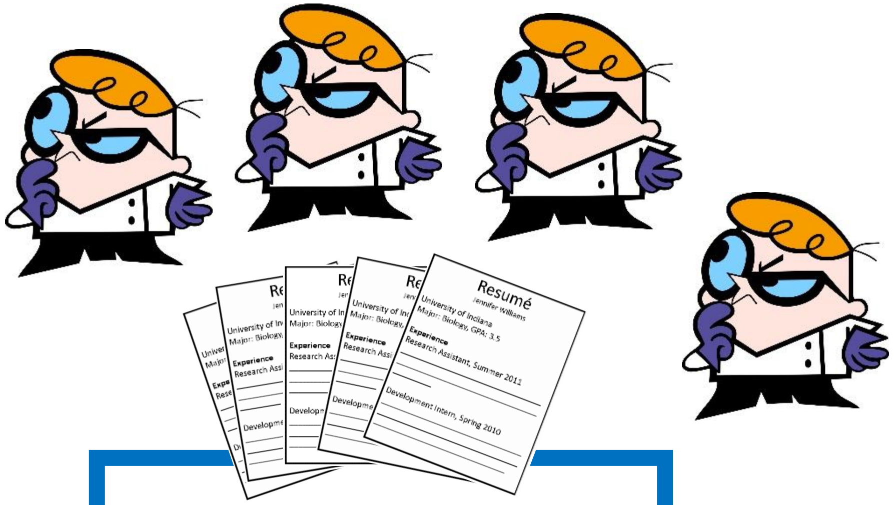
Measured which group gave the applicant …

-Better "hireability" ratings

-A higher starting salary estimate



John $n_1 = 63$



Jennifer $n_2 = 64$

Components of experiments

Experimental units: the **individuals/subjects** (person, animal, plant, virus, particle, etc.) that are assigned to different treatments.

In hiring study: **Science lab faculty**

Explanatory variable: the variable that is purposefully **manipulated**. This is also known as the factor.

In hiring study: **Applicant name**

Components of experiments

Treatments: the different **levels** of the explanatory variable in the experiment.

In hiring study: **Jennifer/John**

Response variable: the measured experiment **outcome** that is compared between treatment groups.

In hiring study: **"Hireability" rating and salary estimate**

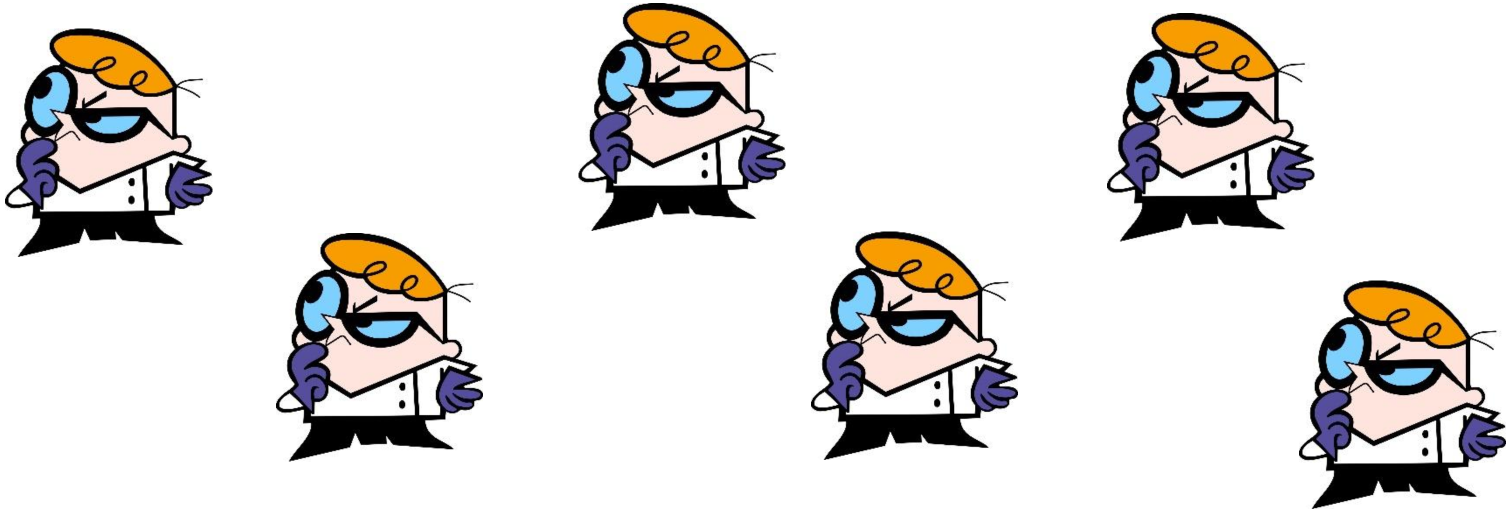
Topics

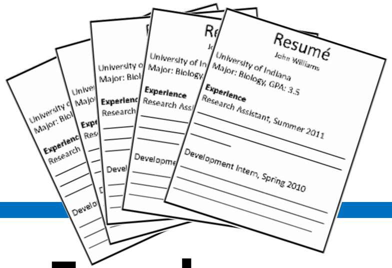
1. Observational studies vs. experiments
2. Components of experiments
3. **Principles of experimental design**
4. Describing a completely randomized design

Principles of Experimental Design

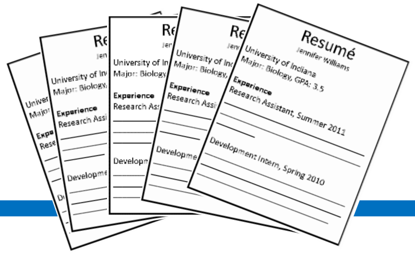
- **Comparison** of at least two treatment groups
- **Random assignment** of experimental units to treatment
- **Replication** – many experimental units in each treatment group
- **Control** of confounding variables

Comparison



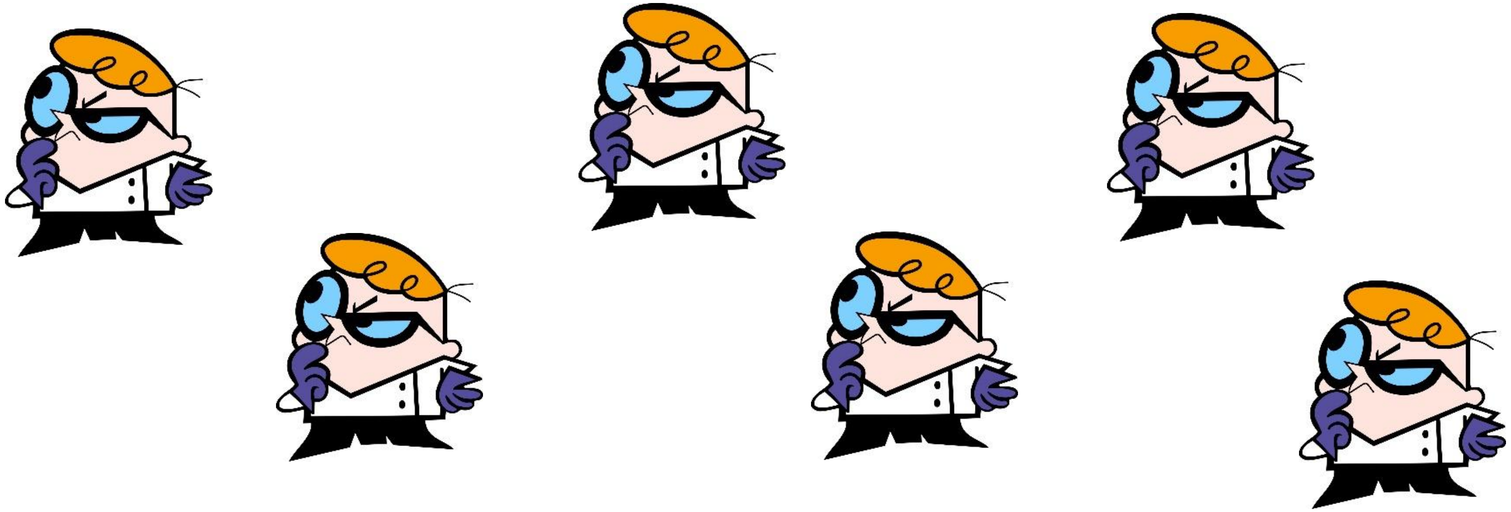


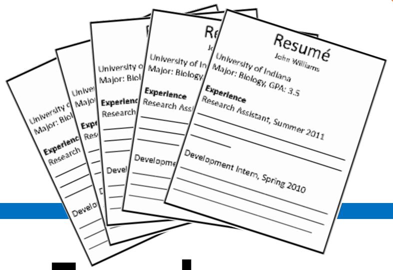
John



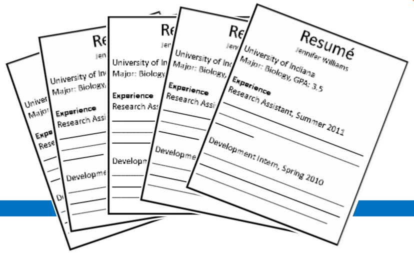
Jennifer

Comparison





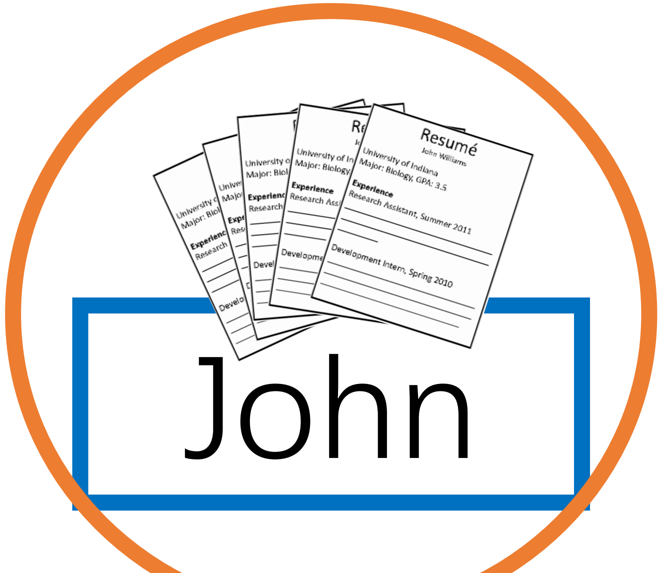
John

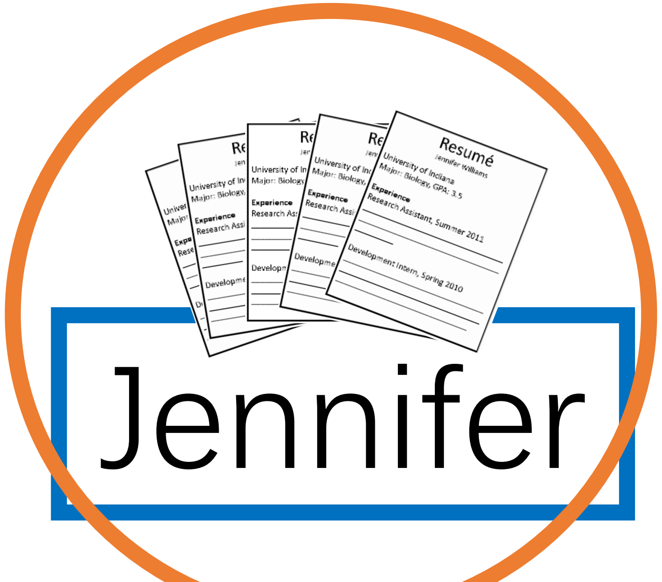


Jennifer

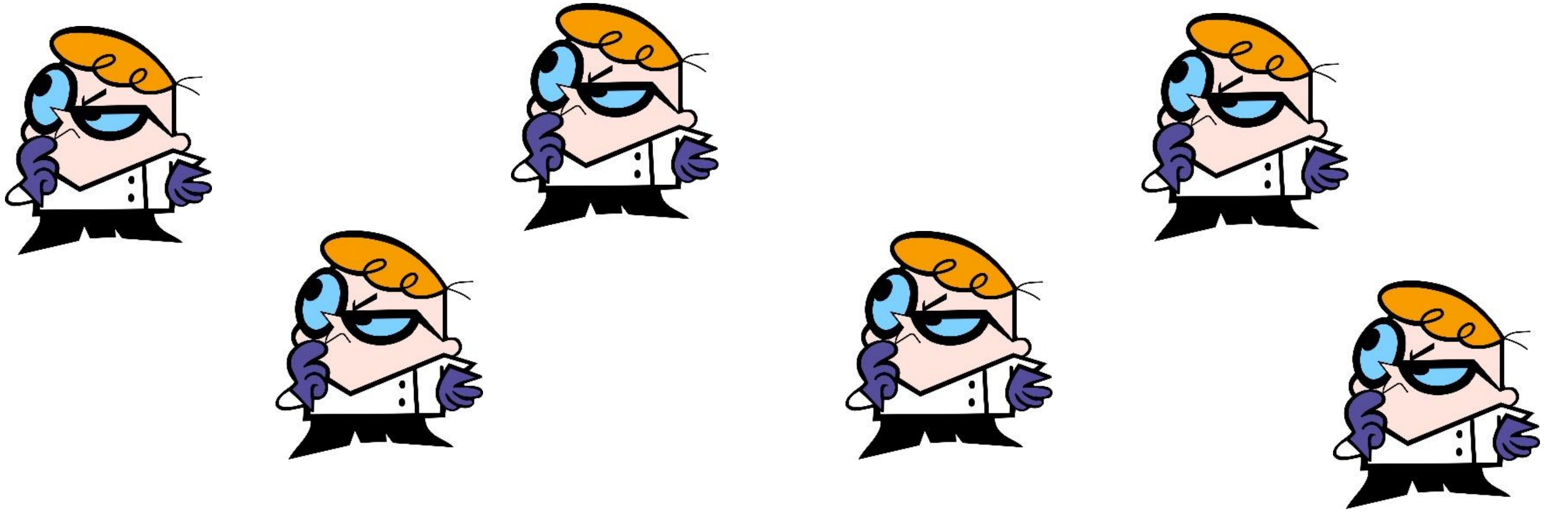
Comparison

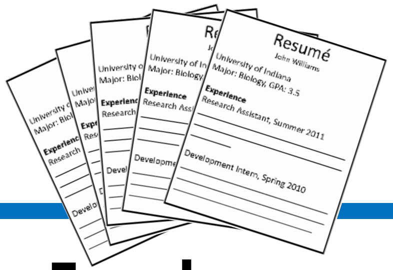
Comparing at least two treatments ✓



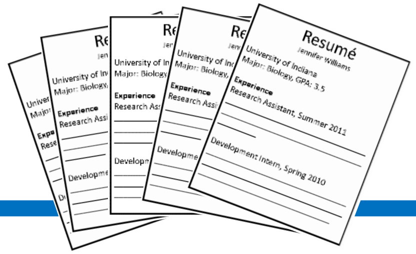


Random Assignment





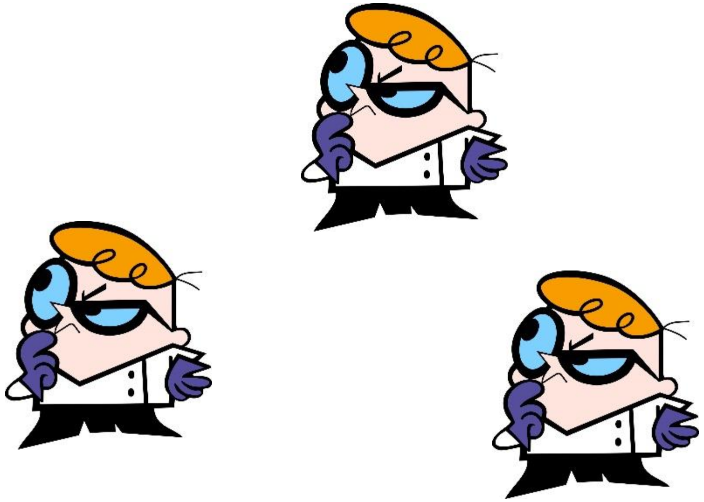
John



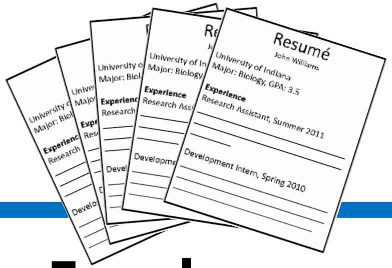
Jennifer

Random Assignment

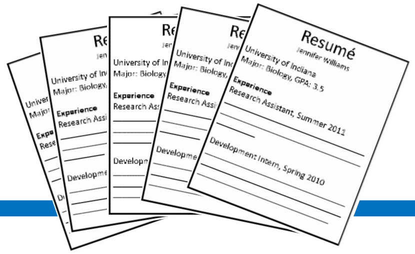
Tier 1



Tier 2



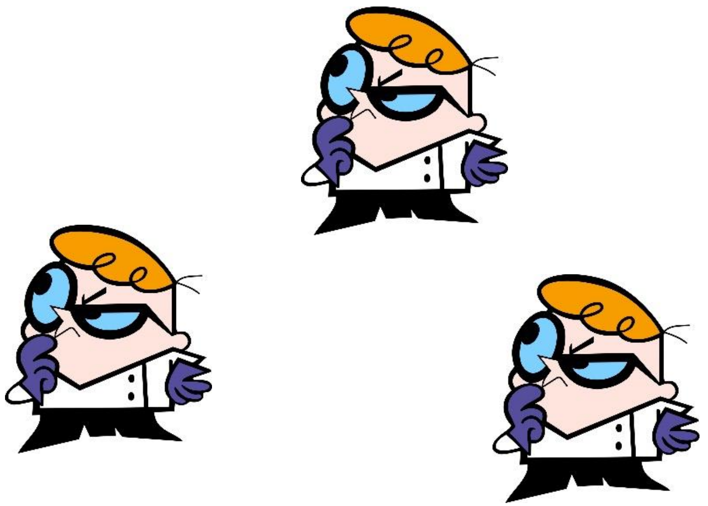
John



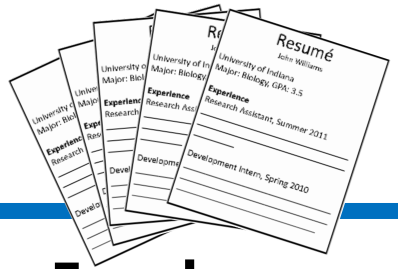
Jennifer

Random Assignment

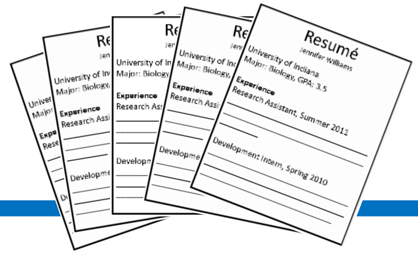
Tier 1



Tier 2



John

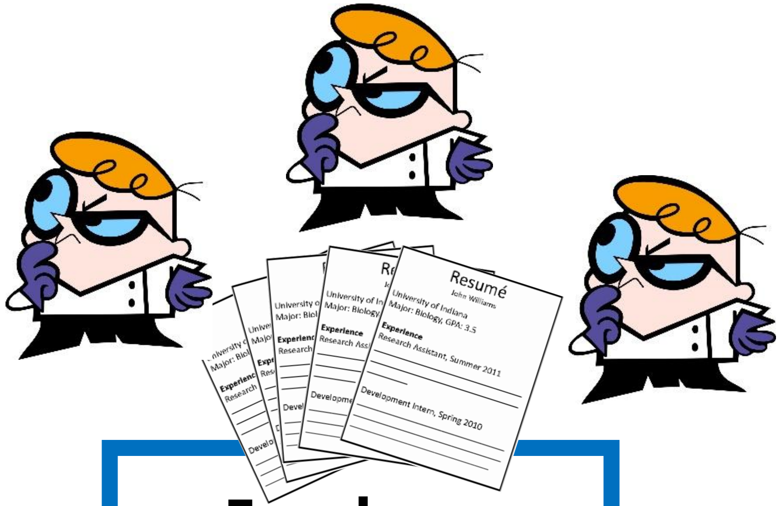


Jennifer

What if I assigned **Tier 1** University labs to get “John” and **Tier 2** labs to get “Jennifer”?

Random Assignment

Tier 1



John

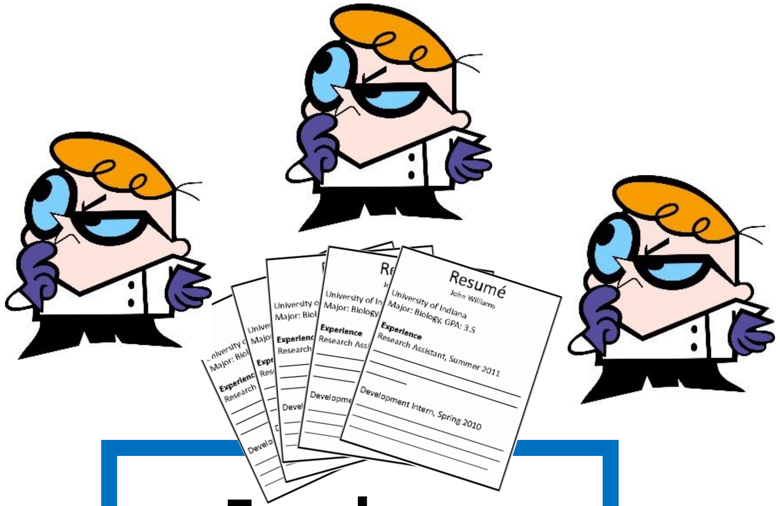
Tier 2

Jennifer

Random Assignment

Now we have confounding! Not sure if it's gender or lab quality that causes hiring outcome differences.

Tier 1

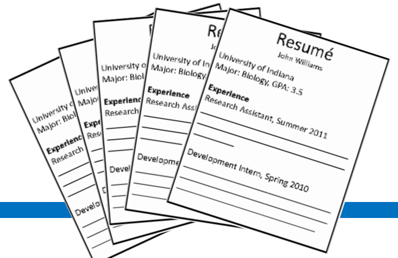


John

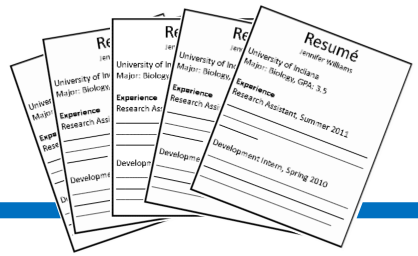
Tier 2

Jennifer

Random Assignment

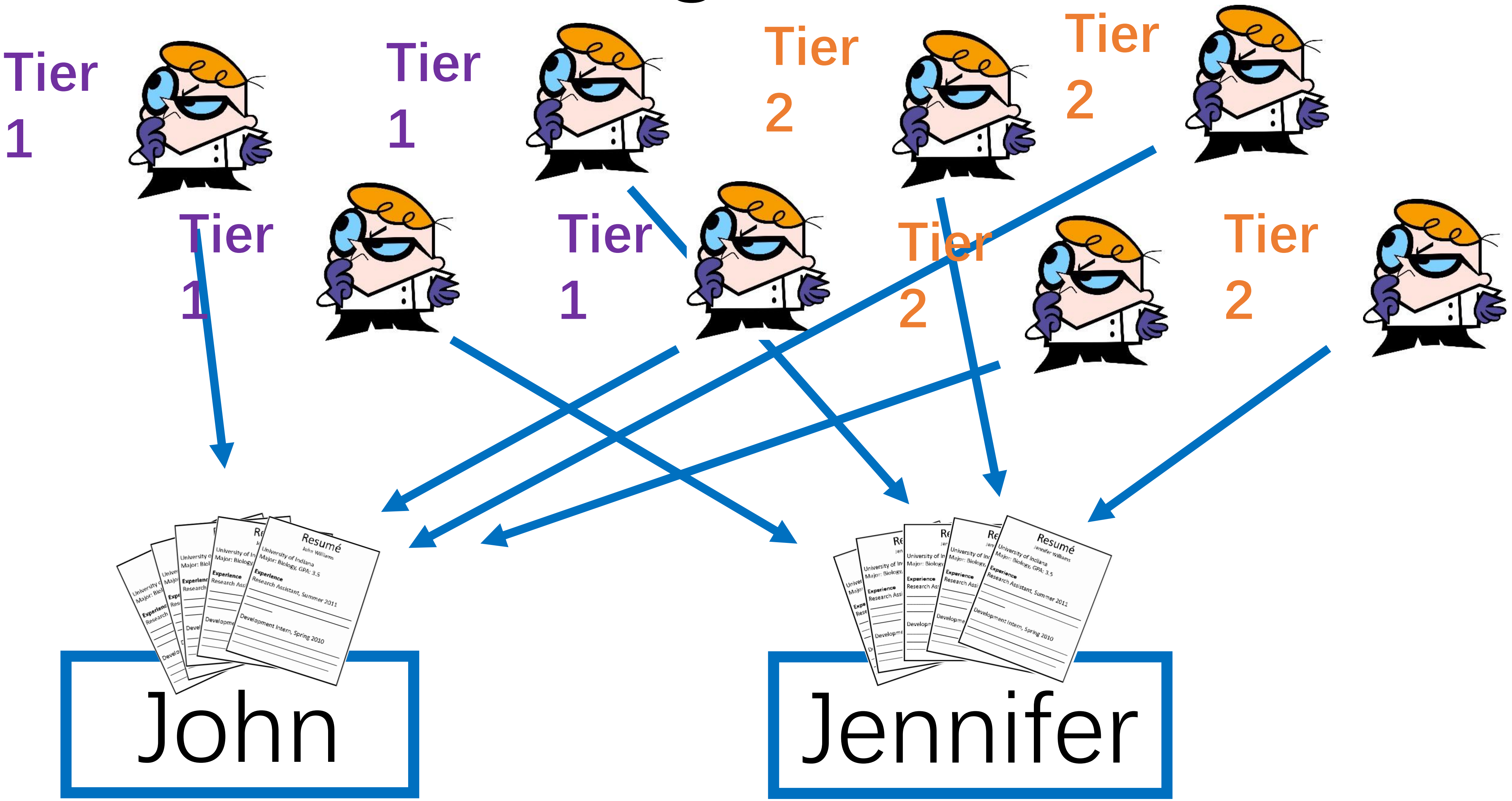


John

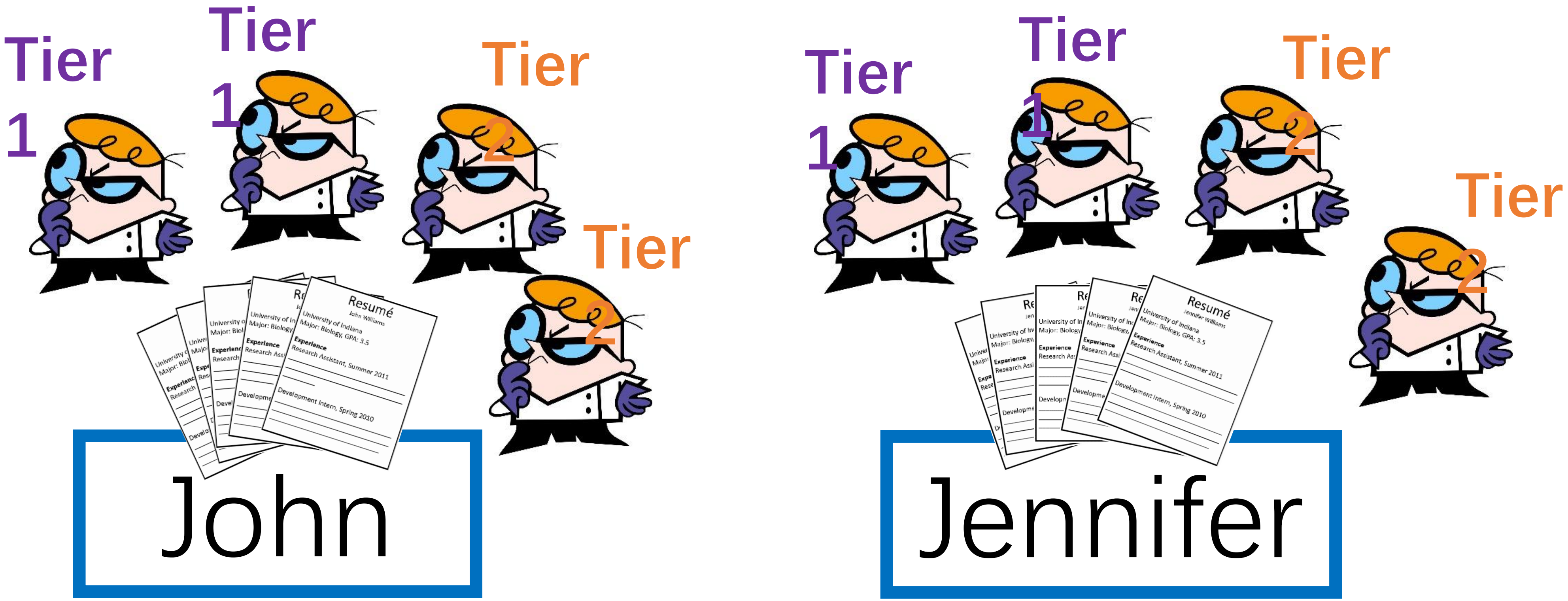


Jennifer

Random Assignment

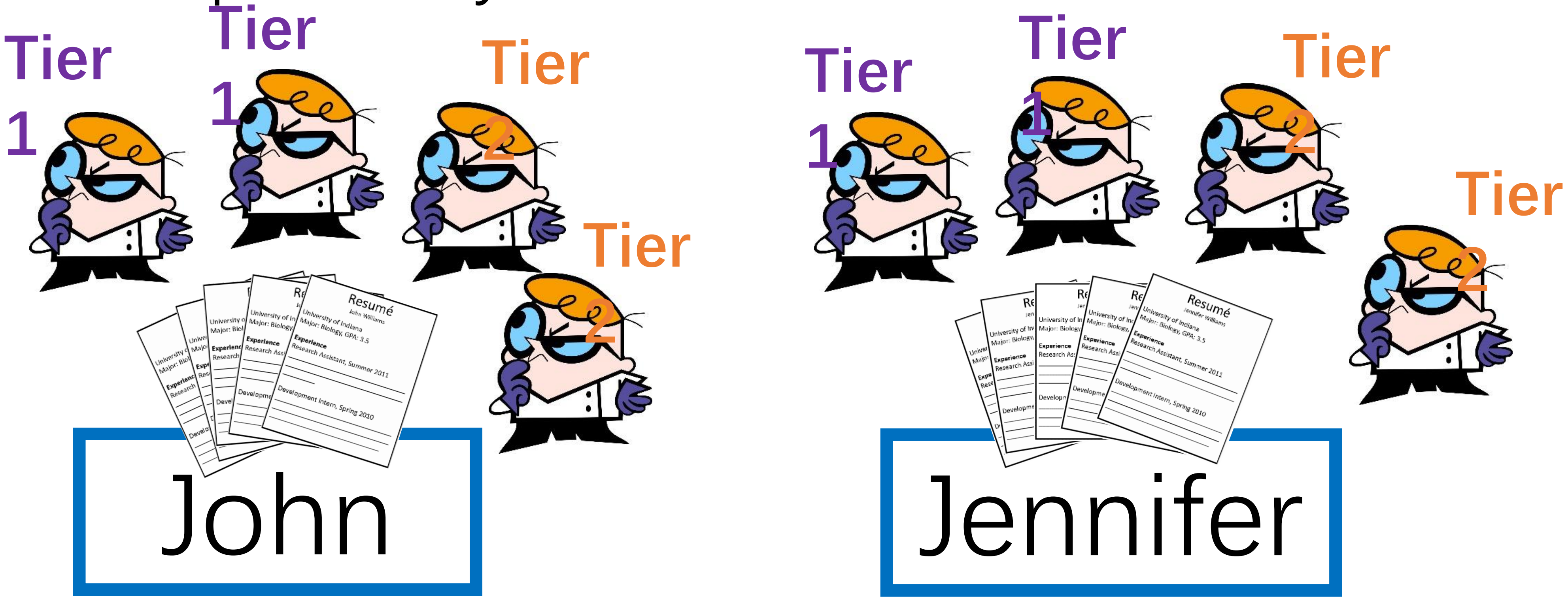


Random Assignment



Random Assignment

Random assignment tends to balance confounding factors, so inferences can be made about the explanatory variable.



Terminology

Sampling

Random **sample**

↳ Reduces **bias**

Experiments

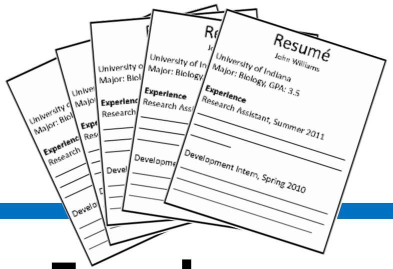
Random **assignment**

↳ Reduces **confounding**

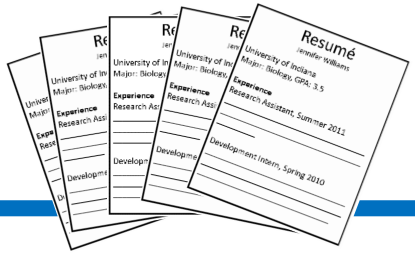
Replication

$n = 2$

Just two experimental units (two faculty). Randomly assign to treatment.



John



Jennifer

Replication

n = 2

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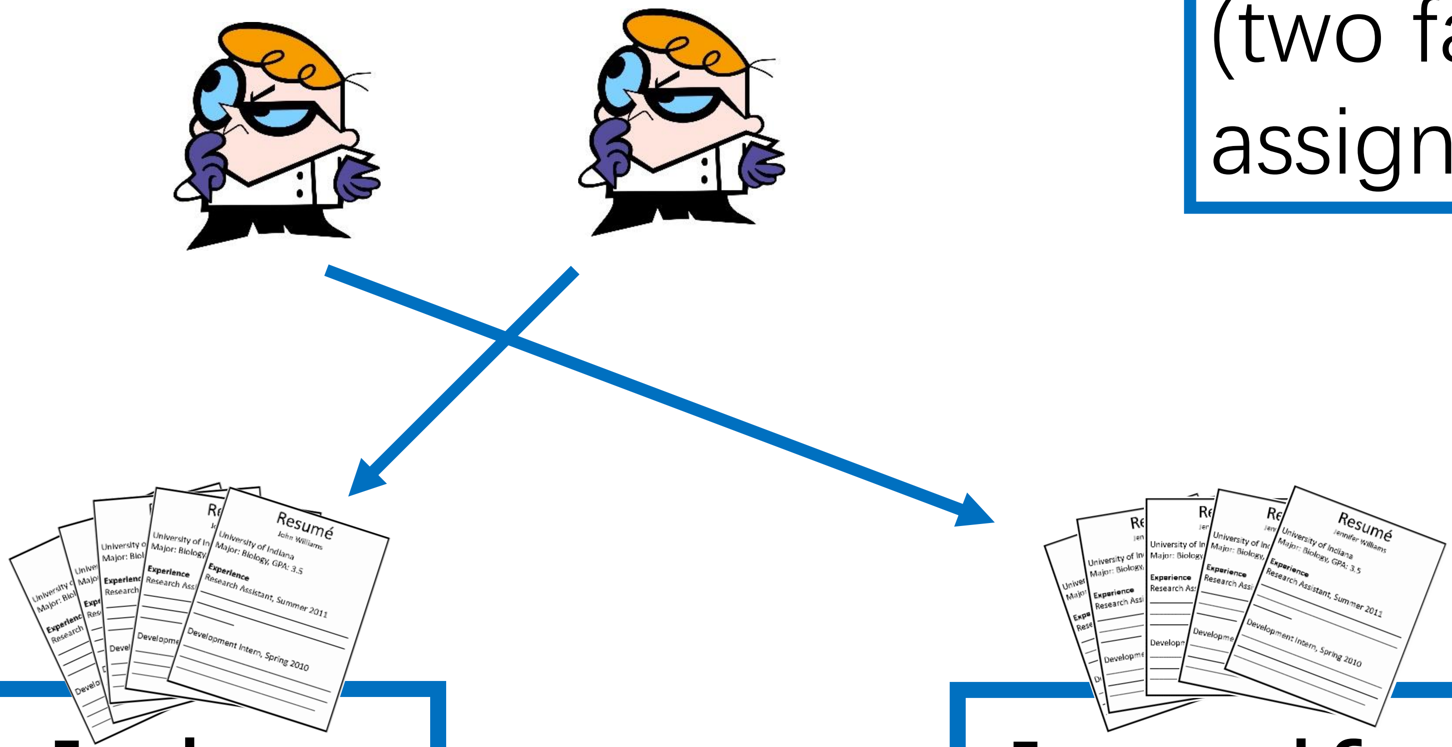
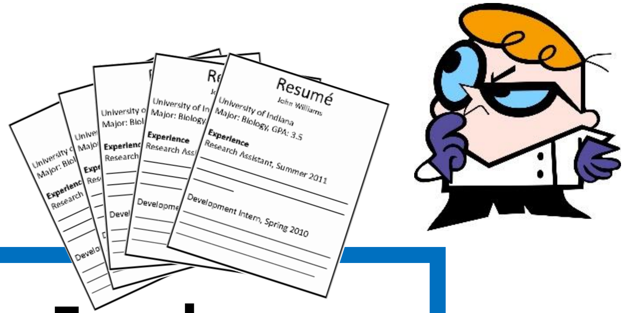


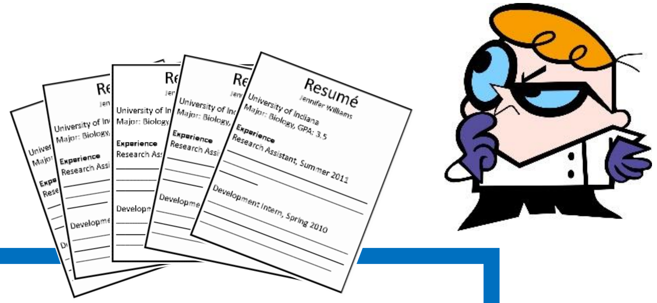
John

Jennifer

Replication



John $n_1 = 1$

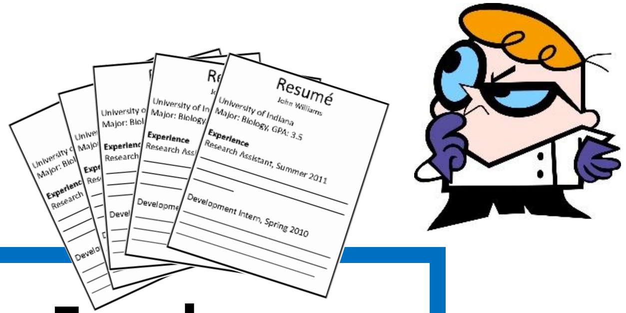


Jennifer $n_2 = 1$

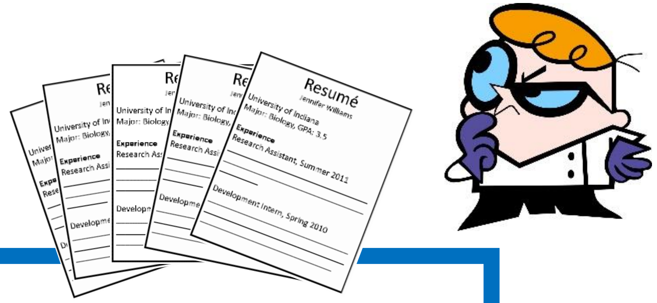
Replication

Hard to tell if differences are due to explanatory variable (gender) or chance variation between these two faculty.

Ex: maybe one of the faculty members was having a bad morning while reading applications

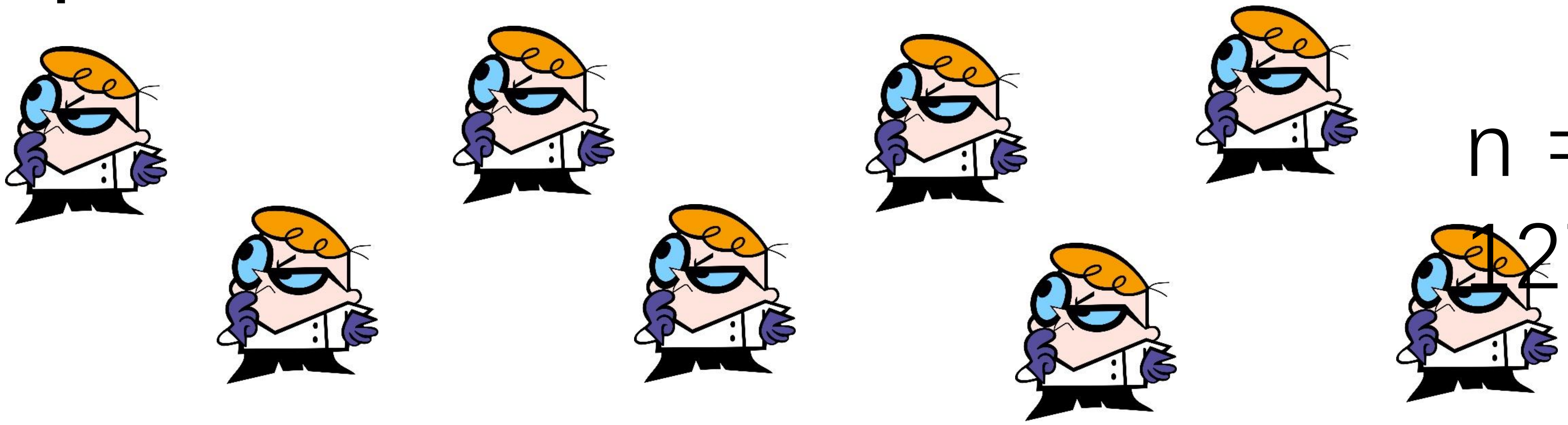


John $n_1 = 1$



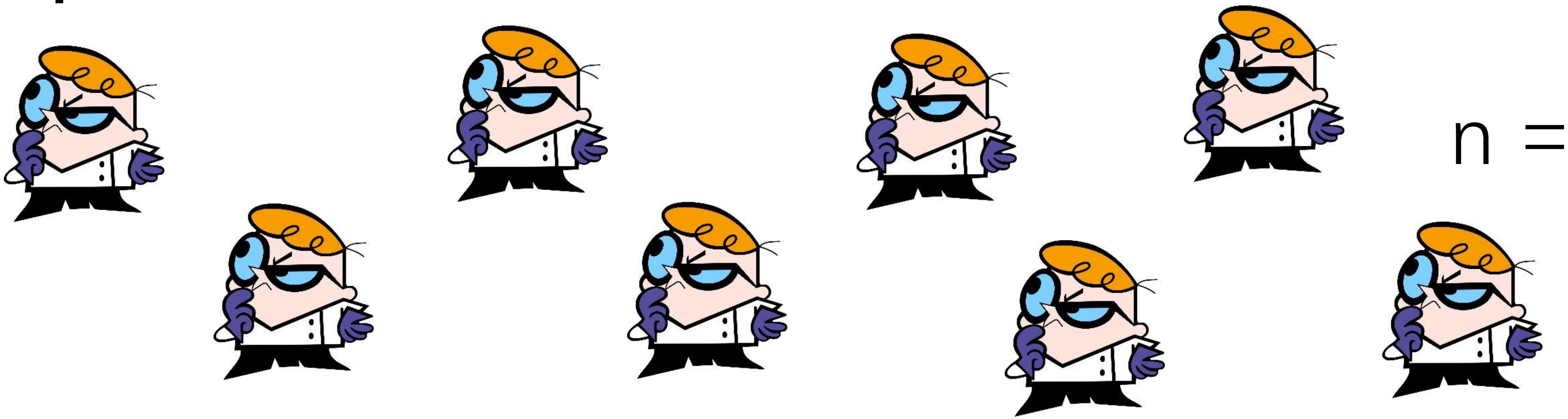
Jennifer $n_2 = 1$

Replication

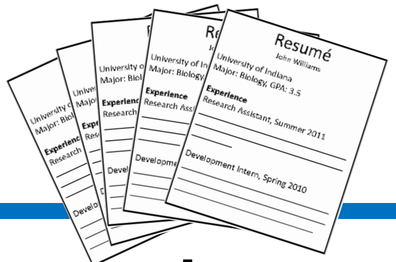


n = 127

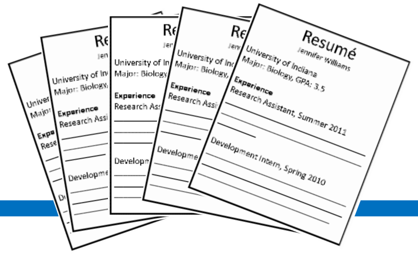
Replication



n = 127

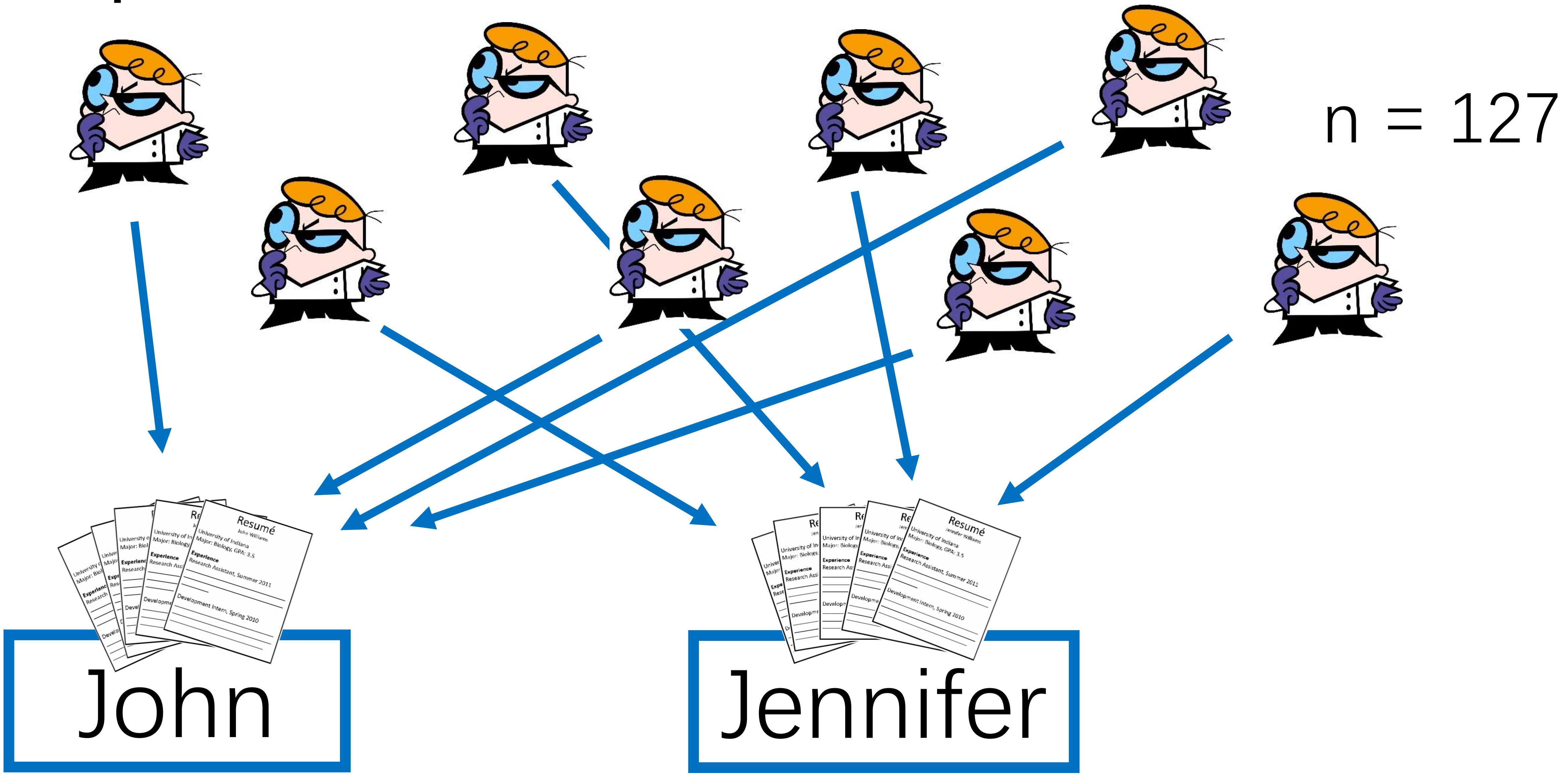


John



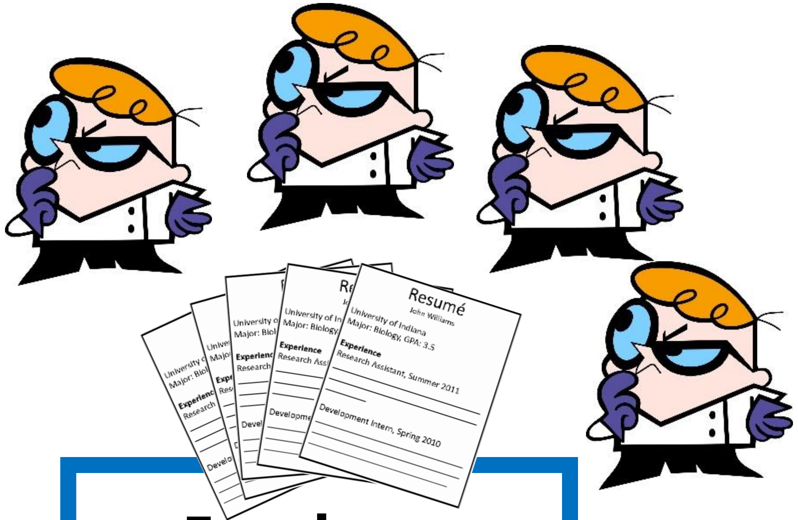
Jennifer

Replication

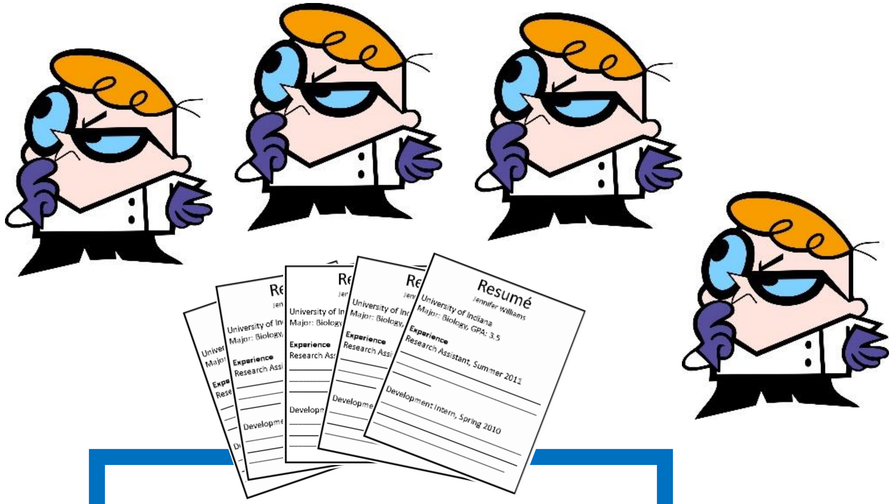


Replication

Larger treatment group size reduces the likelihood of differences arising due to chance alone. In other words, it makes our estimates of treatment effect **more precise**.



John $n_1 = 63$



Jennifer $n_2 = 64$

Control

Resumé
John Williams

University of Indiana
Major: Biology, GPA: 3.5

Experience
Research Assistant, Summer 2011

Development Intern, Spring 2010

Resumé
Jennifer Williams

University of Indiana
Major: Biology, GPA: 3.5

Experience
Research Assistant, Summer 2011

Development Intern, Spring 2010

Control

One way they control for confounding factors is by making the application materials completely identical, except for the explanatory variable (gender).

They even control for name likability:

Jennifer/ John “have been pretested as equivalent in likability and recognizability…”

Topics

1. Observational studies vs. experiments
2. Components of experiments
3. Principles of experimental design
4. **Describing a completely randomized design**

Completely Randomized Design

Completely randomized design:
An experimental design in which experimental units are assigned to treatments **completely at random**.

Describing an experiment

Describe how you would implement a completely randomized design of the Jennifer/John experiment, with 127 science faculty members.

Describing an experiment

Key Steps:

1. Assign each experimental unit a number 1 – n (sample size).
2. Write all the numbers on identical slips of paper, put into a hat, and mix well.
3. Draw out n_t (treatment group size) slips of paper, without replacement. The corresponding units are assigned treatment 1. Draw out another n_t slips of paper, assign to treatment 2, etc.
4. Compare response among treatment groups

Describing an experiment

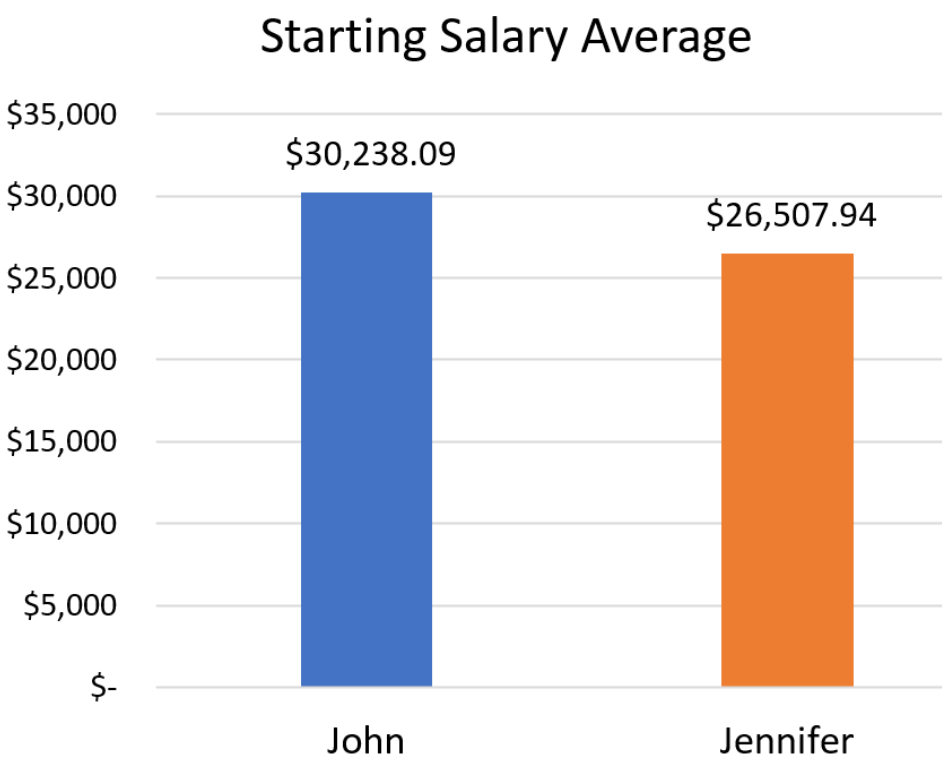
Describe how you would implement a completely randomized design of the Jennifer/John experiment, with 127 science faculty members.

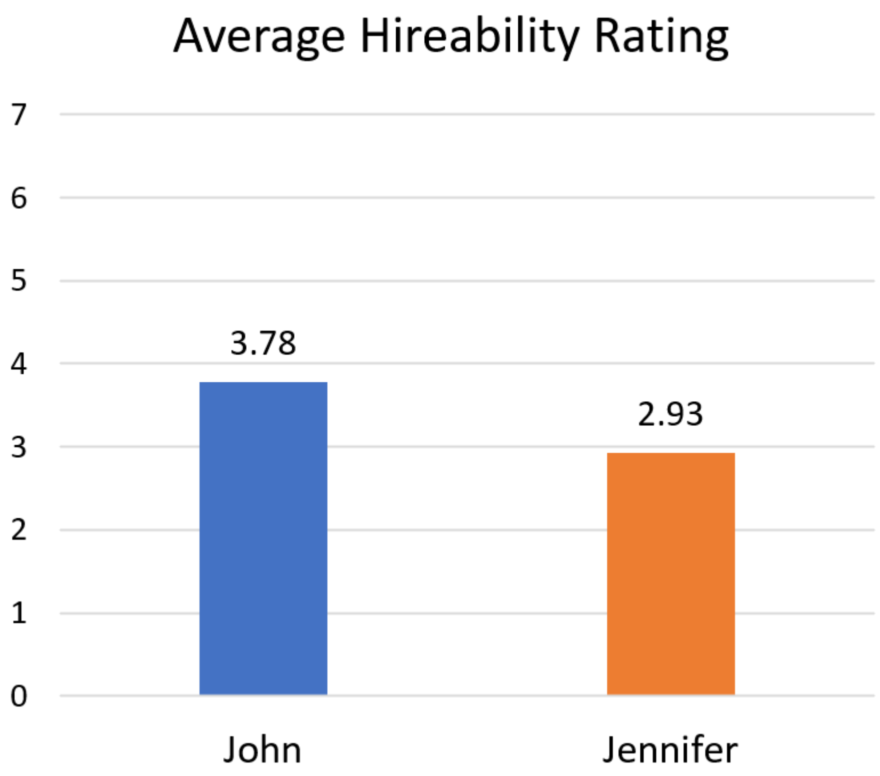
Describing an experiment

Assign each faculty member an integer, **1-127**. Write integers 1-127 on identical slips of paper, put them into a hat, and **mix well**. Draw out 63 slips (without replacement). The corresponding faculty members will receive "John" application materials. The **remaining** faculty members will receive "Jennifer" application materials. At the end of the experiment, record faculty members' rating of applicants' "hireability" and starting salary estimates. Finally, **compare** these results across the two groups.

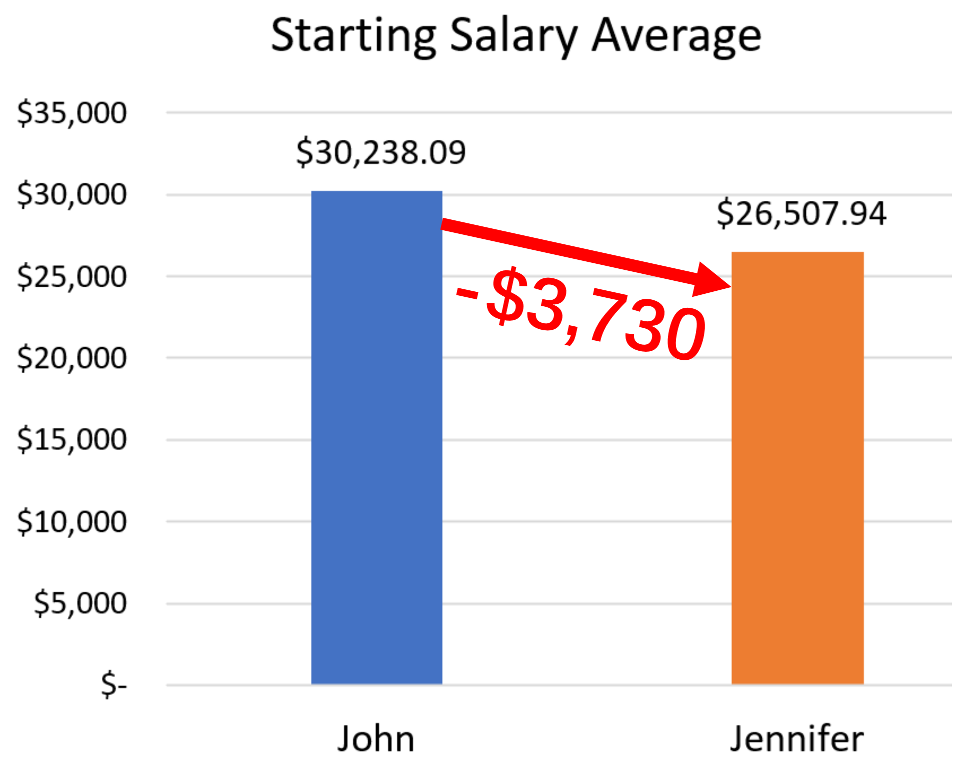
Discussion

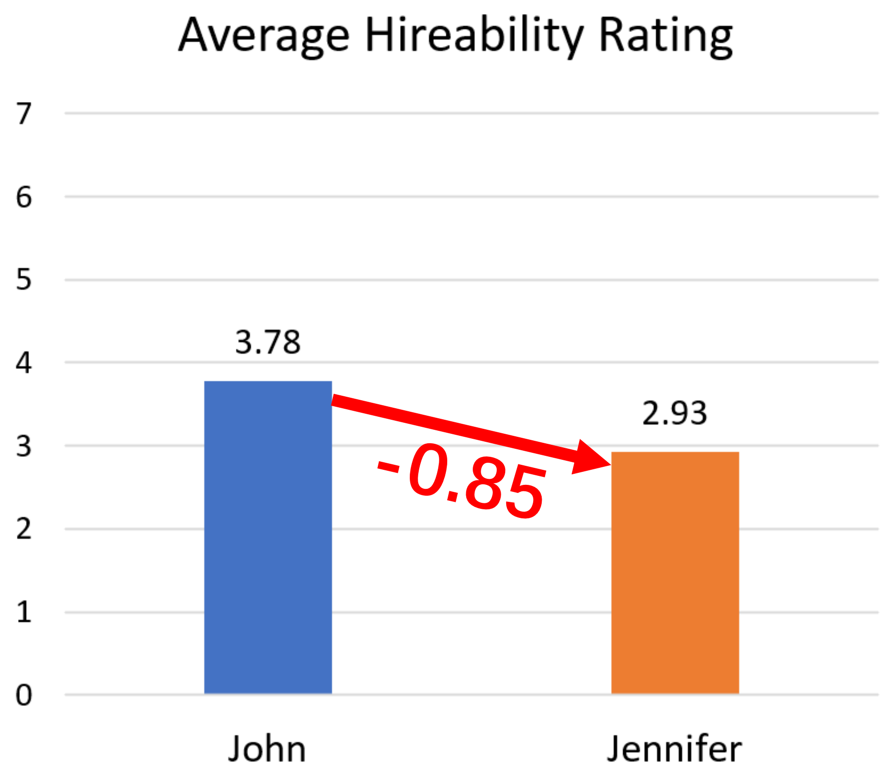
Experiment results





Experiment results

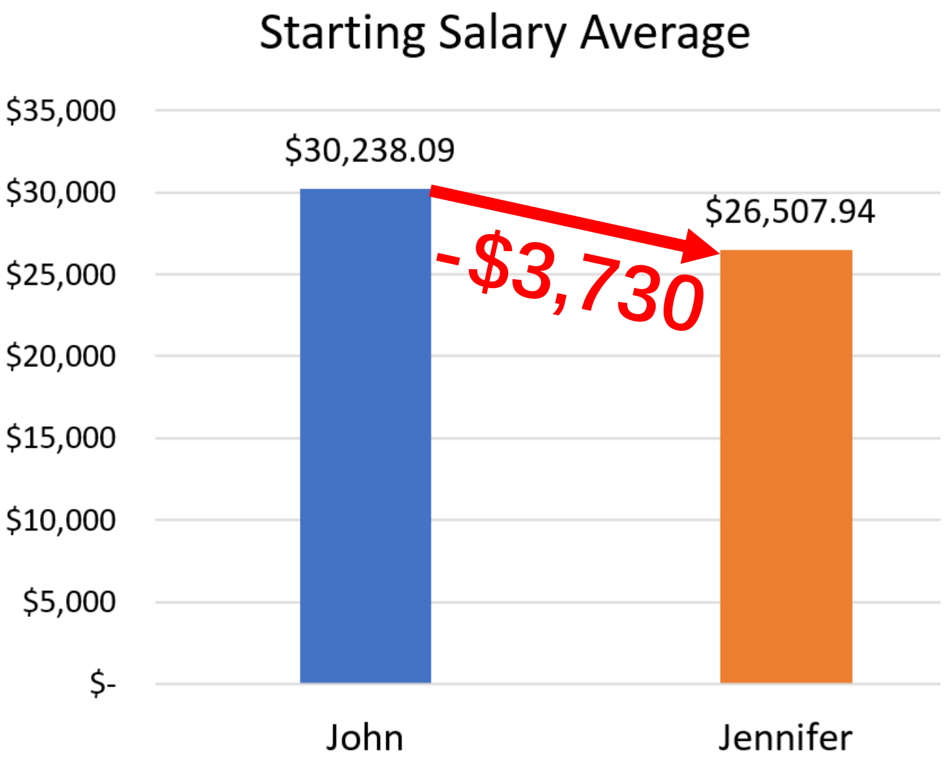


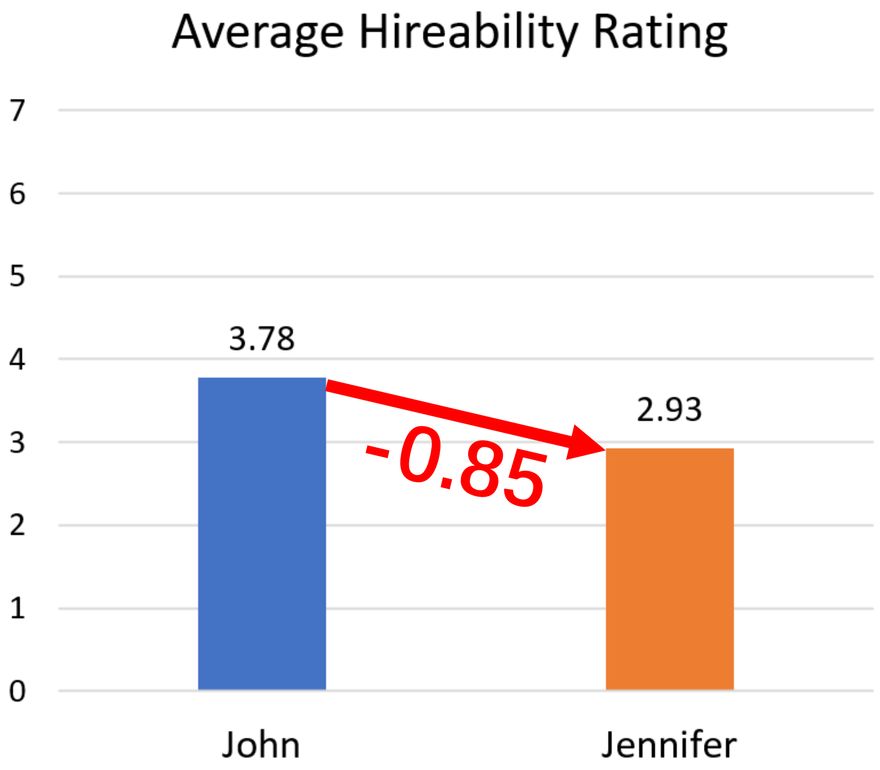


	John	Jennifer	Difference
Hireability	3.78	2.93	**-0.85**
Salary	$30,238	$26,508	**-$3,730**

Experiment results

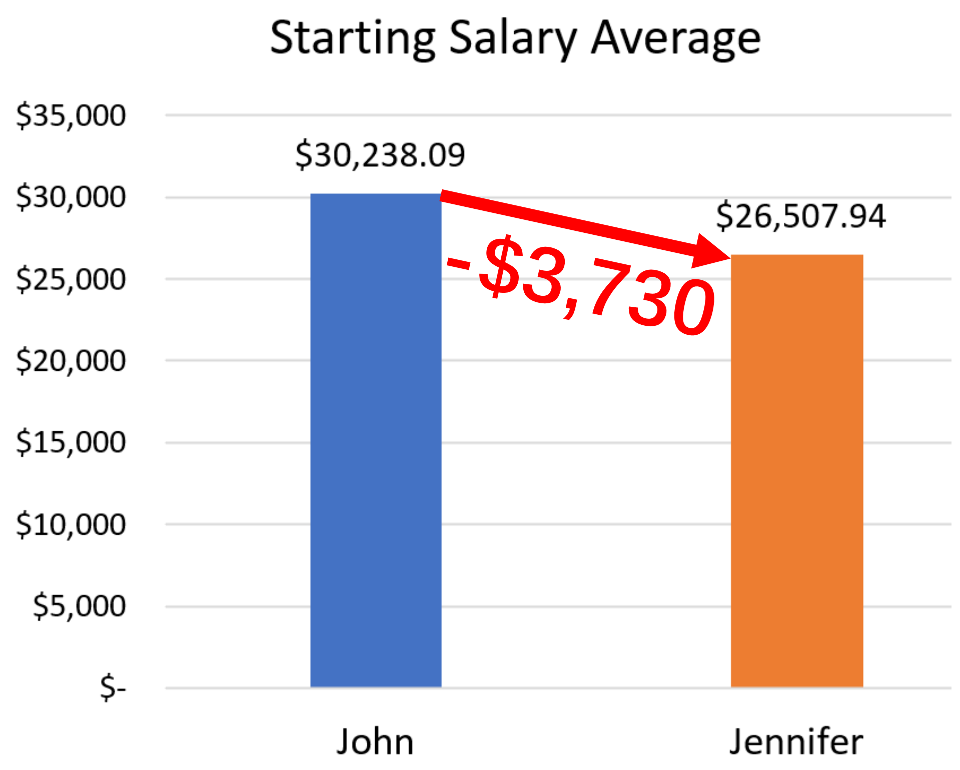
The **differences** were found to be statistically significant:
so extreme that they were unlikely to happen by **chance alone**.

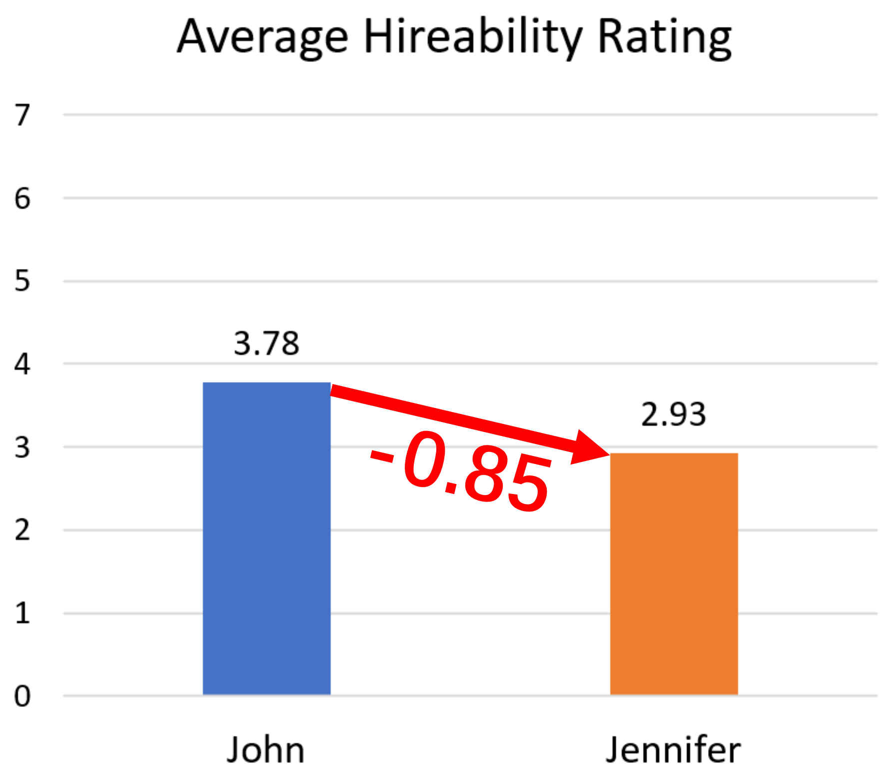




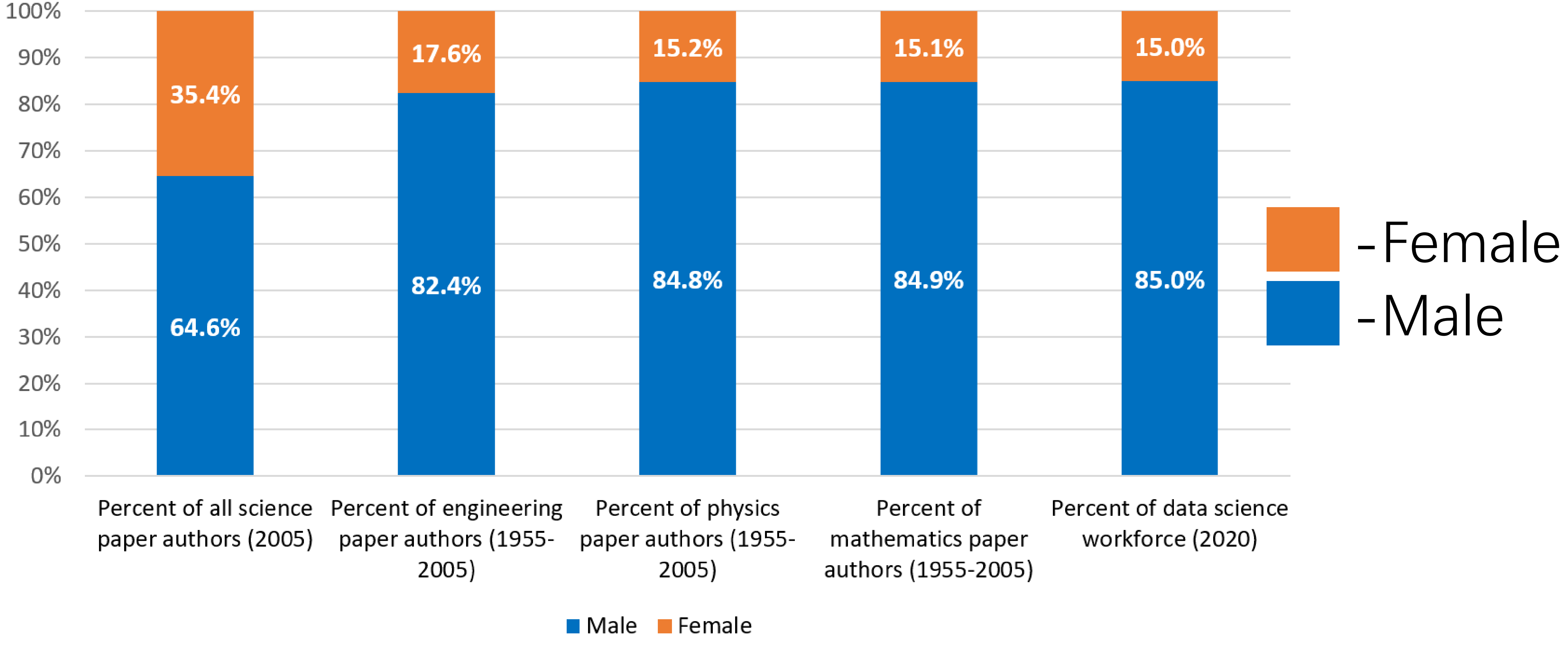
Experiment results

Since this was a well-designed experiment, we can infer that these average differences are **caused** by gender bias.

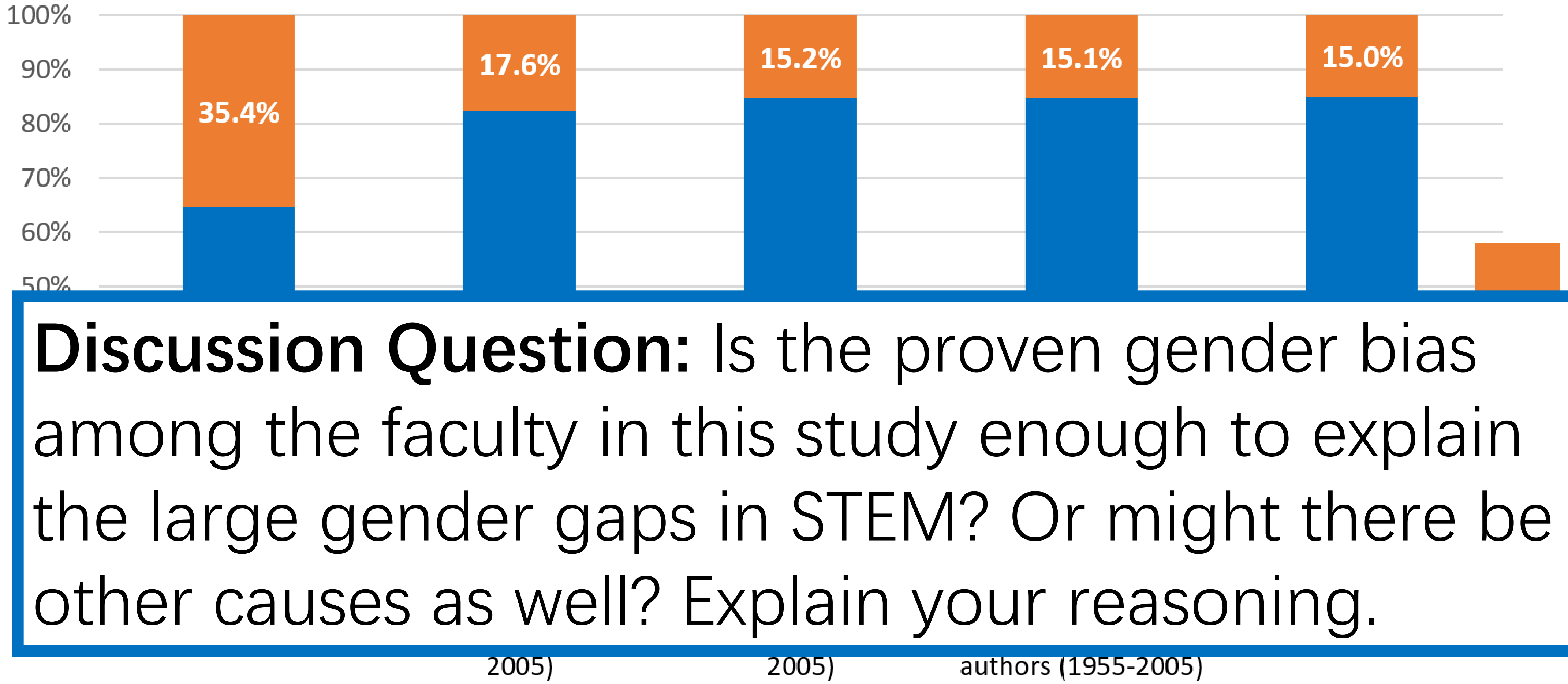




Gender Gaps in STEM



Gender Gaps in STEM



Discussion Question: Is the proven gender bias among the faculty in this study enough to explain the large gender gaps in STEM? Or might there be other causes as well? Explain your reasoning.

Researchers are investigating the effectiveness of using a fungus to control the spread of an insect that destroys trees. The researchers will create four different concentrations of fungus mixtures: 0 milliliters per liter (ml/L), 1.25 ml/L, 2.5 ml/L, and 3.75 ml/L. An equal number of the insects will be placed into 20 individual containers. The group of insects in each container will be sprayed with one of the four mixtures, and the researchers will record the number of insects that are still alive in each container one week after spraying.

(a) Identify the treatments, experimental units, and response variable of the experiment.

Treatments:

Experimental units:

Response variable:

(b) Does the experiment have a control group? Explain your answer.

(c) Describe how the treatments can be randomly assigned to the experimental units so that each treatment has the same number of units.

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Experimental units: 20 individual containers

Response variable: number of insects that are still alive in each container one week after spraying.

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(b) Yes, the containers which recieve the 0 ml/L concentration of fungus mixture. The insects in these containers will not get any of the fungus, which provides the researchers with baseline data to compare the fungus mixtures to.

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(c) Label each of the 20 containers with a number from 1 to 20. Use a random number generator to get 5 integers from 1 to 20, ignoring repeats. Assign those 5 corresponding containers to the first treatment (0 ml/L). Then use the random number generator to get 5 more integers (ignoring numbers already selected and repeats) and assign the corresponding containers to the second treatment (1.25 ml/L). Use the same process to identify 5 containers for the third treatment (2.5 ml/L) and the remaining 5 containers get the fourth treatment (3.75 ml/L).