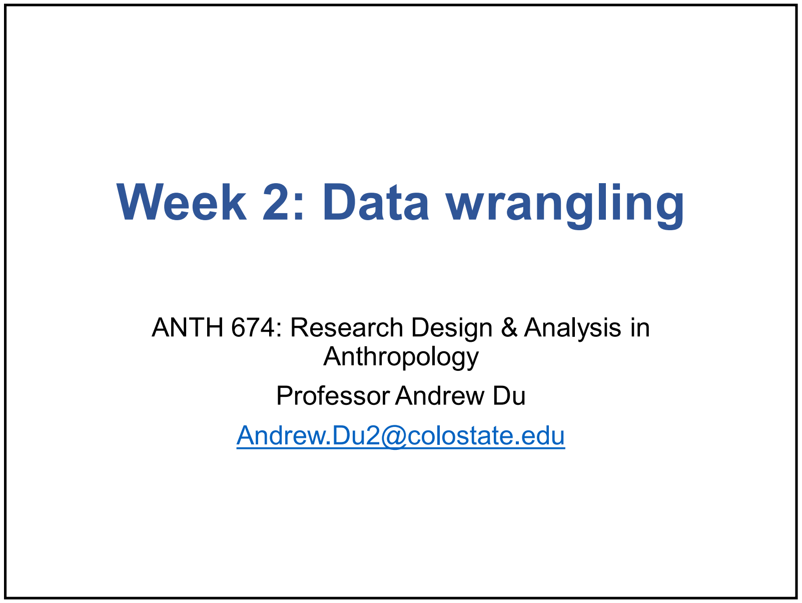


# Week 2: Data wrangling

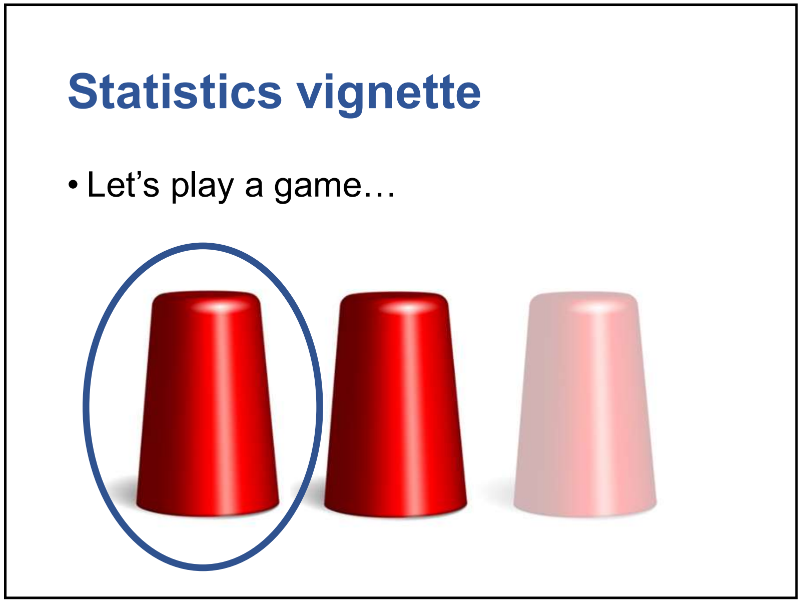
ANTH 674: Research Design & Analysis in Anthropology

Professor Andrew Du

Andrew.Du2@colostate.edu

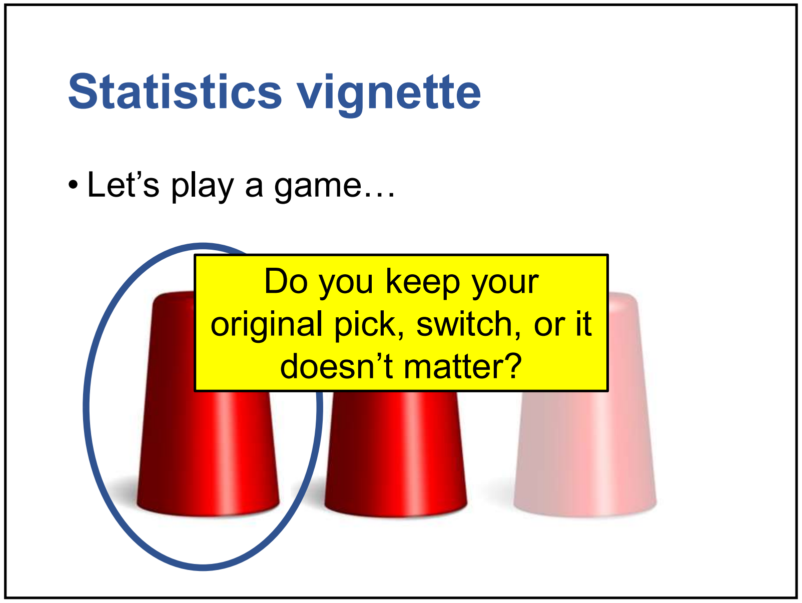
## Statistics vignette

- Let's play a game…



## Statistics vignette

- Let's play a game…



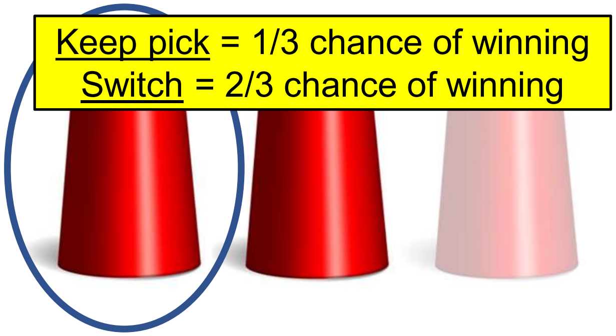
## Statistics vignette

- Let's play a game…

Do you keep your original pick, switch, or it doesn't matter?

## Statistics vignette

- Let’s play a game…

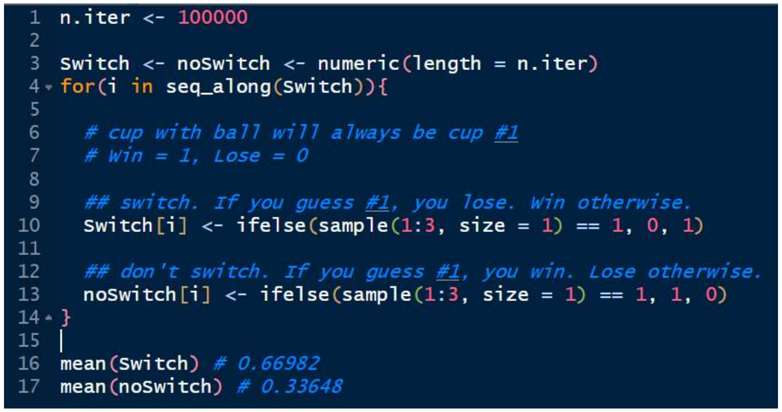


Keep pick = 1/3 chance of winning
Switch = 2/3 chance of winning

## The Monty Hall problem

Suppose you’re on a game show, and you’re given the choice of three doors: Behind one door is a car; behind the others, goats. You pick a door, say No. 1, and the host, who knows what’s behind the doors, opens another door, say No. 3, which has a goat. He then says to you, “Do you want to pick door No. 2?” Is it to your advantage to switch your choice?
—Craig F. Whitaker, Columbia, Md.

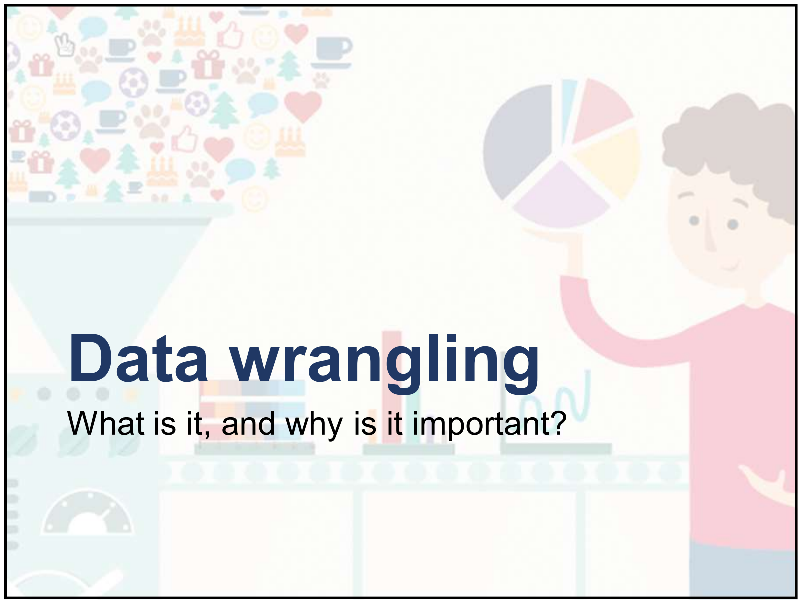
## Simulating in R



```r
n.iter <- 100000

Switch <- noSwitch <- numeric(length = n.iter)
for(i in seq_along(Switch)){

  # cup with ball will always be cup #1
  # Win = 1, Lose = 0

  ## switch. If you guess #1, you lose. Win otherwise.
  Switch[i] <- ifelse(sample(1:3, size = 1) == 1, 0, 1)

  ## don't switch. If you guess #1, you win. Lose otherwise.
  noSwitch[i] <- ifelse(sample(1:3, size = 1) == 1, 1, 0)
}

mean(Switch) # 0.66982
mean(noSwitch) # 0.33648
```

## Lecture outline

1. Data wrangling
   - What is it, and why is it important?
2. General rules for data organization in spreadsheets
   - Emphasize the intimate connection with R
3. Data structures



# Data wrangling

What is it, and why is it important?

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## What is data wrangling?

- Cleaning and organizing raw data to suit your research questions and analyses
- Important because data are rarely in a form ready to be analyzed *according to your goals*
- Incredibly marketable skill! Some data scientists only wrangle data

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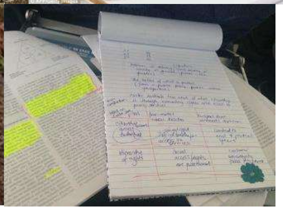
## The data pipeline

Collect raw data



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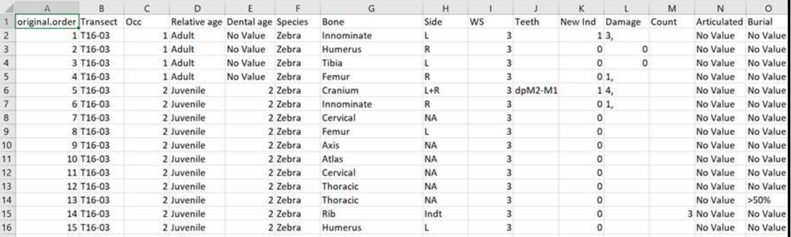
## The data pipeline

Collect raw data → Enter data into computer spreadsheet



| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | original.order | Transect | Occ | Relative age | Dental age | Species | Bone | Side | WS | Teeth | New Ind | Damage | Count | Articulated | Burial |
| 2 | 1 | T16-03 | 1 | Adult | No Value | Zebra | Innominate | L | 3 | | 1 | 3, | | No Value | No Value |
| 3 | 2 | T16-03 | 1 | Adult | No Value | Zebra | Humerus | R | 3 | | 0 | 0 | | No Value | No Value |
| 4 | 3 | T16-03 | 1 | Adult | No Value | Zebra | Tibia | L | 3 | | 0 | 0 | | No Value | No Value |
| 5 | 4 | T16-03 | 1 | Adult | No Value | Zebra | Femur | R | 3 | | 0 | 1, | | No Value | No Value |
| 6 | 5 | T16-03 | 2 | Juvenile | 2 | Zebra | Cranium | L+R | 3 | dpM2-M1 | 1 | 4, | | No Value | No Value |
| 7 | 6 | T16-03 | 2 | Juvenile | 2 | Zebra | Innominate | R | 3 | | 0 | 1, | | No Value | No Value |
| 8 | 7 | T16-03 | 2 | Juvenile | 2 | Zebra | Cervical | NA | 3 | | 0 | | | No Value | No Value |
| 9 | 8 | T16-03 | 2 | Juvenile | 2 | Zebra | Femur | L | 3 | | 0 | | | No Value | No Value |
| 10 | 9 | T16-03 | 2 | Juvenile | 2 | Zebra | Axis | NA | 3 | | 0 | | | No Value | No Value |
| 11 | 10 | T16-03 | 2 | Juvenile | 2 | Zebra | Atlas | NA | 3 | | 0 | | | No Value | No Value |
| 12 | 11 | T16-03 | 2 | Juvenile | 2 | Zebra | Cervical | NA | 3 | | 0 | | | No Value | No Value |
| 13 | 12 | T16-03 | 2 | Juvenile | 2 | Zebra | Thoracic | NA | 3 | | 0 | | | No Value | No Value |
| 14 | 13 | T16-03 | 2 | Juvenile | 2 | Zebra | Thoracic | NA | 3 | | 0 | | | No Value | >50% |
| 15 | 14 | T16-03 | 2 | Juvenile | 2 | Zebra | Rib | Indt | 3 | | 0 | | 3 | No Value | No Value |
| 16 | 15 | T16-03 | 2 | Juvenile | 2 | Zebra | Humerus | L | 3 | | 0 | | | No Value | No Value |

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## The data pipeline

Collect raw data

Enter data into computer spreadsheet

- Also enter **metadata** – "data about data"
- For example:
  - Name of data collector
  - GPS coordinates
  - When data was collected
  - Funding support
  - Methods used to collect data
  - Units of measurement
  - Description of abbreviations
  - What the variables are

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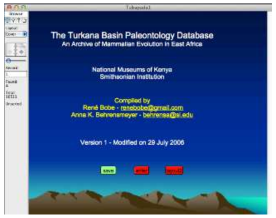
## The data pipeline

Collect raw data

Enter data into computer spreadsheet

Published datasets/ databases



The Turkana Basin Paleontology Database

An Archive of Mammalian Evolution in East Africa

National Museums of Kenya

Smithsonian Institution

Compiled by

René Bobe - renebobe@gmail.com

Anna K. Behrensmeyer - behrensa@si.edu

Version 1 - Modified on 29 July 2006

CODI

www.olduvai-paleo.org

The Comprehensive Olduvai Database Initiative, or CODI, is a free online inventory of all paleontological specimens collected from Olduvai Gorge in Tanzania. This database provides a research tool for scientists interested in studying this assemblage as well as a curatorial aid for the Tanzanian government.

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## Where issues arise

Collect raw data

Enter data into computer spreadsheet

Published datasets/ databases

- Missing data
- Erroneous measurements (e.g., broken or miscalibrated instruments)

| Subject number | Human height (inches) |
|---|---|
| 1 | 64 |
| 2 | 70 |
| 3 | |
| 4 | 58 |
| 5 | 110 |
| 6 | 124 |
| 7 | 118 |

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## Where issues arise

Collect raw data

Enter data into computer spreadsheet

Published datasets/ databases

- Missing data
- Transcription errors
- Inconsistent data formats
- Combine data in one cell

| Subject number | Human height (inches) | Sex | Date of birth |
|---|---|---|---|
| 1 | 64 | M | 1970-02-24 |
| 22 | 70 | m | 1992-09-12 |
| 3 | | F | 1977-07-11 |
| 4 | 58 | F | 1965-03-20 |
| 5 | 6 | Fem | 1982-05-25 |
| 6 | 73 | M | 06-10-1987 |
| 7; 8 | 68; 62 | M; M | 2000-12-13 |

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## Where issues arise

Collect
ra

Enter data

- Missing data
- Transcription errors
- Inconsistent data

in one cell

Published
datasets/
databases

In 13 audits of real-world spreadsheets, an average of 88% contain errors (Panko 2008)

| number | (inches) | | ate of birth |
|---|---|---|---|
| 1 | 64 | M | 1970-02-24 |
| 22 | 70 | m | 1992-09-12 |
| 3 | | F | 1977-07-11 |
| 4 | 58 | F | 1965-03-20 |
| 5 | 6 | Fem | 1982-05-25 |
| 6 | 73 | M | 06-10-1987 |
| 7; 8 | 68; 62 | M; M | 2000-12-13 |

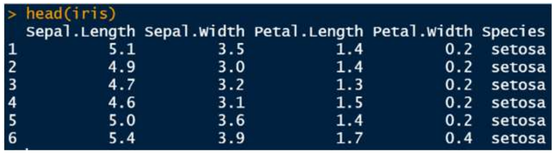
## Where issues arise

Collect
raw data

Enter data
into computer
spreadsheet

- Ideally 100% clean, but often not
- Missing data
- Inconsistent data formats
- Extra variables
- Extra data

Published
datasets/
databases



```
> head(iris)
  Sepal.Length Sepal.Width Petal.Length Petal.Width Species
1          5.1         3.5          1.4         0.2  setosa
2          4.9         3.0          1.4         0.2  setosa
3          4.7         3.2          1.3         0.2  setosa
4          4.6         3.1          1.5         0.2  setosa
5          5.0         3.6          1.4         0.2  setosa
6          5.4         3.9          1.7         0.4  setosa
```

- What if I’m interested only in petal lengths of individuals from *Iris virginica* species?

## How to wrangle?

- Once research question & general analytical methodology is defined, it’s clear how data should be collected and organized
- **ALWAYS** keep the raw “dirty” data file! Save cleaned data to new file
- **ALWAYS** back up your data (e.g., external hard drive, the cloud)!

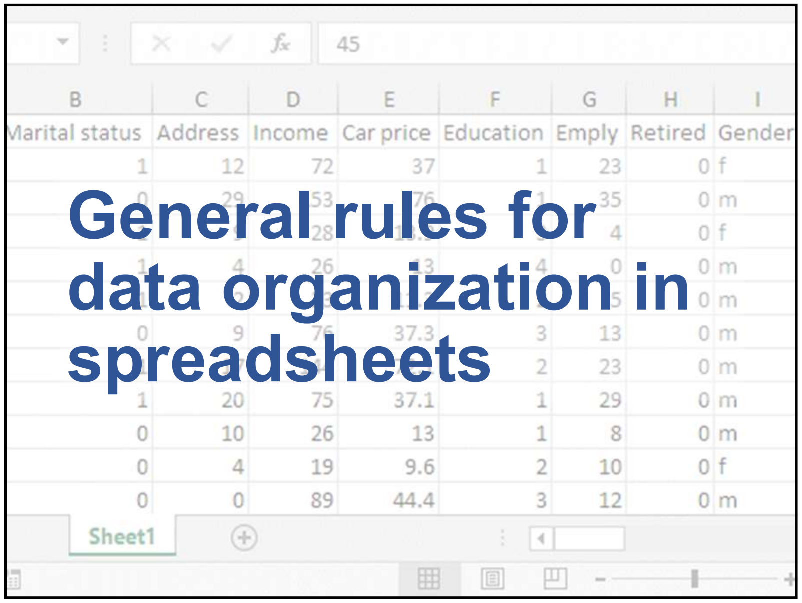
## Important not only for analyses

- Need to (should) publish raw data these days
  - Data collection supported by public funds *legally must* be published (granting agency technically owns the data)
  - Increases collegiality and rate of scientific progress (e.g., large-scale analyses)
  - Transparency & replicability of analyses
  - Clean data → increase your citation count!
- Be courteous & publish data in clean, analyzable format!

## R makes wrangling (relatively) easy!

- Don’t need to fix *every single* data entry by hand
- Leaves a record of what you did (your R script)

## Questions?

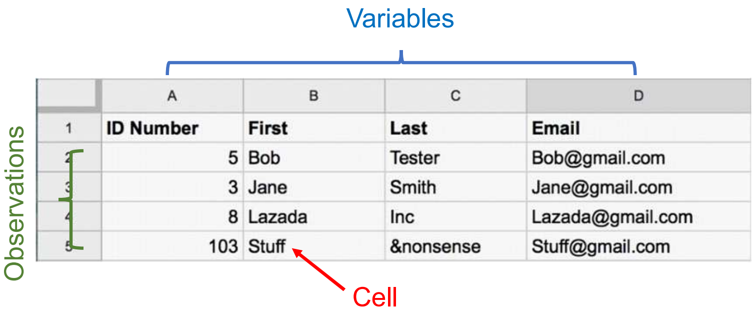


| B | C | D | E | F | G | H | I |
|---|---|---|---|---|---|---|---|
| Marital status | Address | Income | Car price | Education | Emply | Retired | Gender |
| 1 | 12 | 72 | 37 | 1 | 23 | 0 | f |
| 0 | 29 | 53 | 76 | 1 | 35 | 0 | m |
| [illegible] | [illegible] | 28 | [illegible] | [illegible] | 4 | 0 | f |
| 1 | 4 | 26 | 13 | 4 | 0 | 0 | m |
| 1 | [illegible] | [illegible] | [illegible] | [illegible] | 5 | 0 | m |
| 0 | 9 | 76 | 37.3 | 3 | 13 | 0 | m |
| 1 | [illegible] | [illegible] | [illegible] | 2 | 23 | 0 | m |
| 1 | 20 | 75 | 37.1 | 1 | 29 | 0 | m |
| 0 | 10 | 26 | 13 | 1 | 8 | 0 | m |
| 0 | 4 | 19 | 9.6 | 2 | 10 | 0 | f |
| 0 | 0 | 89 | 44.4 | 3 | 12 | 0 | m |

# General rules for data organization in spreadsheets

## What is a spreadsheet?

- An electronic page in which each row represents a single observation (i.e., unit of study), and each column represents a variable



Variables

Observations

Cell

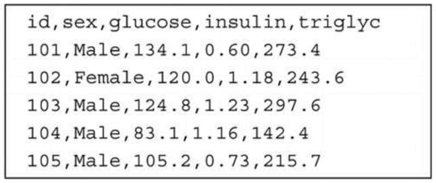
|  | A | B | C | D |
|---|---|---|---|---|
| 1 | ID Number | First | Last | Email |
| 2 | 5 | Bob | Tester | Bob@gmail.com |
| 3 | 3 | Jane | Smith | Jane@gmail.com |
| 4 | 8 | Lazada | Inc | Lazada@gmail.com |
| 5 | 103 | Stuff | &nonsense | Stuff@gmail.com |

## What is a spreadsheet?

- An electronic page in which each row represents a single observation (i.e., unit of study), and each column represents a variable
- Used for entering, storing, analyzing (not anymore), and visualizing data (not anymore)
  - Analyzing & visualizing data in R ensures original dataset remains unchanged
- Most commonly used program is Microsoft Excel (it's what I use)
- For R, use comma-separated values (.csv) files (not proprietary & works in Excel)

## CSV format

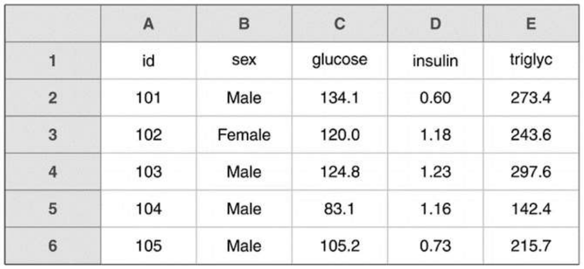
Plain text format



```
id,sex,glucose,insulin,triglyc
101,Male,134.1,0.60,273.4
102,Female,120.0,1.18,243.6
103,Male,124.8,1.23,297.6
104,Male,83.1,1.16,142.4
105,Male,105.2,0.73,215.7
```

- What it looks like in Excel

- Only **one** Excel sheet can be saved to **one** CSV file!



| | A | B | C | D | E |
|---|---|---|---|---|---|
| 1 | id | sex | glucose | insulin | triglyc |
| 2 | 101 | Male | 134.1 | 0.60 | 273.4 |
| 3 | 102 | Female | 120.0 | 1.18 | 243.6 |
| 4 | 103 | Male | 124.8 | 1.23 | 297.6 |
| 5 | 104 | Male | 83.1 | 1.16 | 142.4 |
| 6 | 105 | Male | 105.2 | 0.73 | 215.7 |

## Rules for data organization

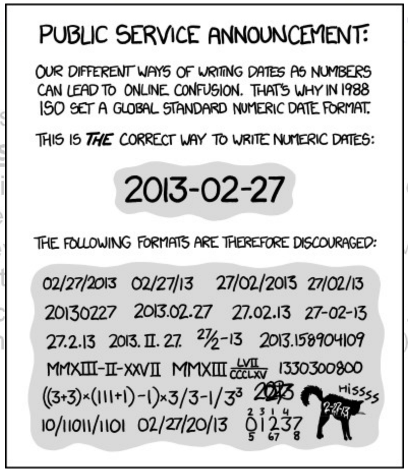
- In general, how R handles names, numbers, etc. is how data should be structured
- In fact, cleaning a dataset in R for analyses → dataset is publishable!
- Becoming proficient in R makes you better at organizing data!

## Rules for data organization

1. Make sure your names are always ***consistent***
   1. R will treat "`M`", "`male`", and "`Male`" as completely different. Stick to one!
   2. Likewise, be careful of extra spaces! "`Male`" is treated differently than "`Male `"
   3. Be consistent with your formatting (e.g., don't use both `2020-08-29` and `08-29-2020`)

## Rules tion

1. Make s consis
   1. R wi completely diffe
   2. Like Male" is treat
   3. Be c ., don't use both )



PUBLIC SERVICE ANNOUNCEMENT:

OUR DIFFERENT WAYS OF WRITING DATES AS NUMBERS CAN LEAD TO ONLINE CONFUSION. THAT'S WHY IN 1988 ISO SET A GLOBAL STANDARD NUMERIC DATE FORMAT.

THIS IS ***THE*** CORRECT WAY TO WRITE NUMERIC DATES:

2013-02-27

THE FOLLOWING FORMATS ARE THEREFORE DISCOURAGED:

## Rules for data organization

1. Make sure your names are always ***<u>consistent</u>***
2. Use NA to represent missing data
   1. Best to not leave spreadsheet cell blank (even though R will automatically replace it w/ NA)
   2. R is great at dealing with NAs, so don't use other symbols (e.g., "`.`", "`-`")
   3. Can add notes about missing data in another column

## Rules for data organization

1. Make sure your names are always ***consistent***
2. Use NA to represent missing data
3. Avoid spaces. Use underscores ("snake case"), periods, or camel case instead
   - `human_height`, `human.height`, `humanHeight`

## Rules for data organization

1. Make sure your names are always ***consistent***
2. Use NA to represent missing data
3. Avoid spaces. Use underscores ("snake case"), periods, or camel case instead
4. Avoid special characters (e.g., $, @, %, !, #, &, *)
5. Use short, informative variable names (e.g., `HumanHeight_in`)

## Why are these bad names?

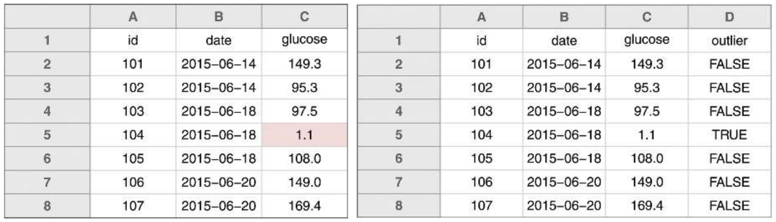
| good name | good alternative | avoid |
|---|---|---|
| `Max_temp_C` | `MaxTemp` | `Maximum Temp (°C)` |
| `Precipitation_mm` | `Precipitation` | `precmm` |
| `Mean_year_growth` | `MeanYearGrowth` | `Mean growth/year` |
| `sex` | `sex` | `M/F` |
| `weight` | `weight` | `w.` |
| `cell_type` | `CellType` | `Cell type` |
| `Observation_01` | `first_observation` | `1st Obs.` |

## Rules for data organization

6. Put only one piece of data in each cell
   1. E.g., don't input:
      1. `11,40` for lat/long
      2. `75kg` for mass
      3. `-10?` (uncertain measurement)
   2. When in doubt, put data in separate columns

## Rules for data organization

6. Put only one piece of data in each cell
7. Do not use font color or highlighting
   1. R cannot interpret font colors/highlighting
   2. Won't be saved in a CSV file anyway

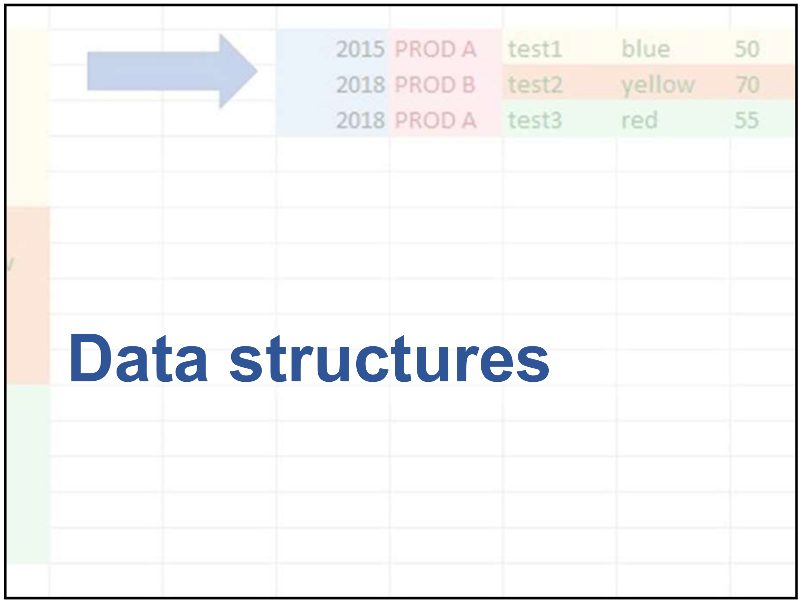


| | A | B | C |
|---|---|---|---|
| 1 | id | date | glucose |
| 2 | 101 | 2015-06-14 | 149.3 |
| 3 | 102 | 2015-06-14 | 95.3 |
| 4 | 103 | 2015-06-18 | 97.5 |
| 5 | 104 | 2015-06-18 | 1.1 |
| 6 | 105 | 2015-06-18 | 108.0 |
| 7 | 106 | 2015-06-20 | 149.0 |
| 8 | 107 | 2015-06-20 | 169.4 |

| | A | B | C | D |
|---|---|---|---|---|
| 1 | id | date | glucose | outlier |
| 2 | 101 | 2015-06-14 | 149.3 | FALSE |
| 3 | 102 | 2015-06-14 | 95.3 | FALSE |
| 4 | 103 | 2015-06-18 | 97.5 | FALSE |
| 5 | 104 | 2015-06-18 | 1.1 | TRUE |
| 6 | 105 | 2015-06-18 | 108.0 | FALSE |
| 7 | 106 | 2015-06-20 | 149.0 | FALSE |
| 8 | 107 | 2015-06-20 | 169.4 | FALSE |

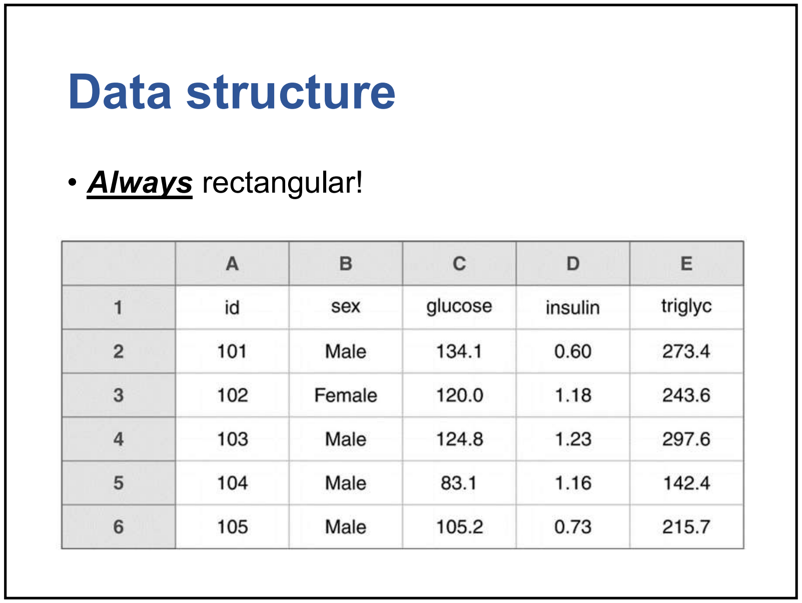
Broman & Woo 2018

## Questions?



| | | | | |
|---|---|---|---|---|
| 2015 | PROD A | test1 | blue | 50 |
| 2018 | PROD B | test2 | yellow | 70 |
| 2018 | PROD A | test3 | red | 55 |

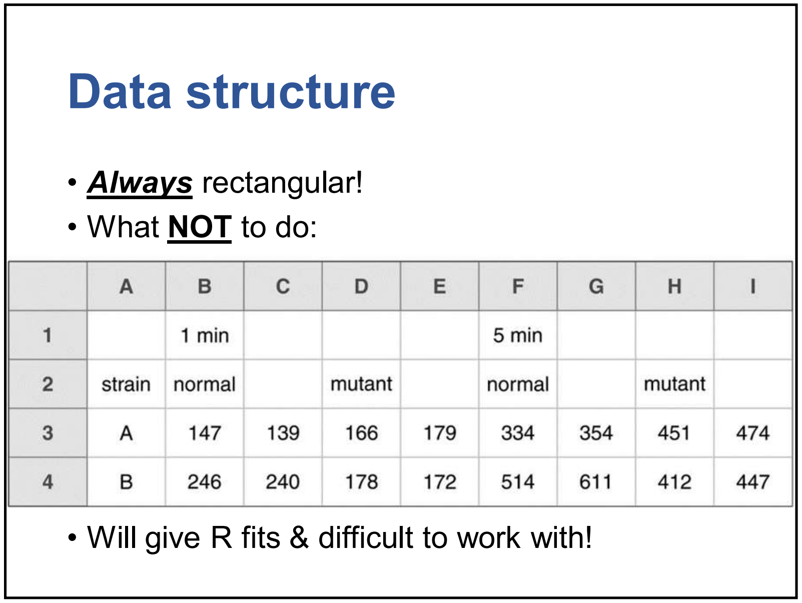
# Data structures



## Data structure

- ***Always*** rectangular!

| | A | B | C | D | E |
|---|---|---|---|---|---|
| 1 | id | sex | glucose | insulin | triglyc |
| 2 | 101 | Male | 134.1 | 0.60 | 273.4 |
| 3 | 102 | Female | 120.0 | 1.18 | 243.6 |
| 4 | 103 | Male | 124.8 | 1.23 | 297.6 |
| 5 | 104 | Male | 83.1 | 1.16 | 142.4 |
| 6 | 105 | Male | 105.2 | 0.73 | 215.7 |

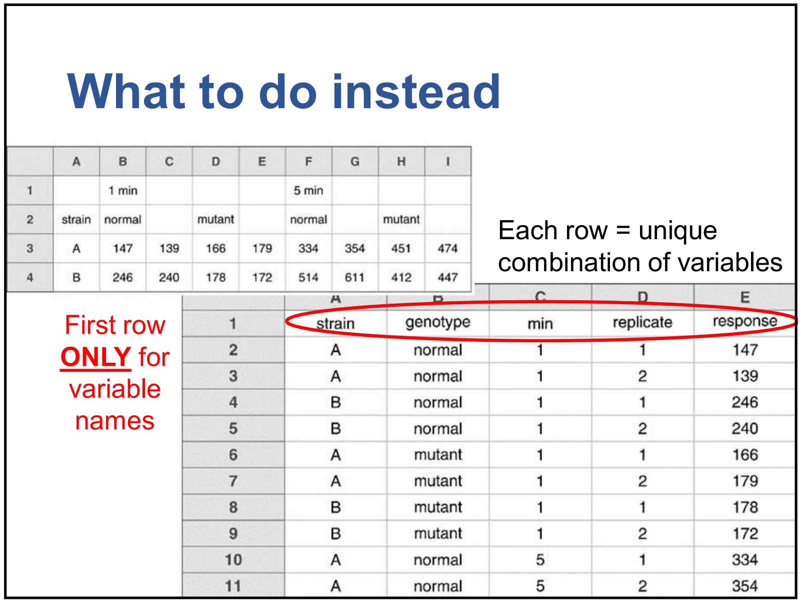


## Data structure

- ***Always*** rectangular!
- What **NOT** to do:

| | A | B | C | D | E | F | G | H | I |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | 1 min | | | | 5 min | | | |
| 2 | strain | normal | | mutant | | normal | | mutant | |
| 3 | A | 147 | 139 | 166 | 179 | 334 | 354 | 451 | 474 |
| 4 | B | 246 | 240 | 178 | 172 | 514 | 611 | 412 | 447 |

- Will give R fits & difficult to work with!



## What to do instead

| | A | B | C | D | E | F | G | H | I |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | 1 min | | | | 5 min | | | |
| 2 | strain | normal | | mutant | | normal | | mutant | |
| 3 | A | 147 | 139 | 166 | 179 | 334 | 354 | 451 | 474 |
| 4 | B | 246 | 240 | 178 | 172 | 514 | 611 | 412 | 447 |

Each row = unique combination of variables

First row **ONLY** for variable names

| | A | B | C | D | E |
|---|---|---|---|---|---|
| 1 | strain | genotype | min | replicate | response |
| 2 | A | normal | 1 | 1 | 147 |
| 3 | A | normal | 1 | 2 | 139 |
| 4 | B | normal | 1 | 1 | 246 |
| 5 | B | normal | 1 | 2 | 240 |
| 6 | A | mutant | 1 | 1 | 166 |
| 7 | A | mutant | 1 | 2 | 179 |
| 8 | B | mutant | 1 | 1 | 178 |
| 9 | B | mutant | 1 | 2 | 172 |
| 10 | A | normal | 5 | 1 | 334 |
| 11 | A | normal | 5 | 2 | 354 |

## Relating different spreadsheets

- To keep spreadsheets rectangular, may need to keep different rectangles in different files
- Relate rectangles to each other using consistent variable names
  - e.g., don't use `HumanHeight` in one and `Human_Height` in another

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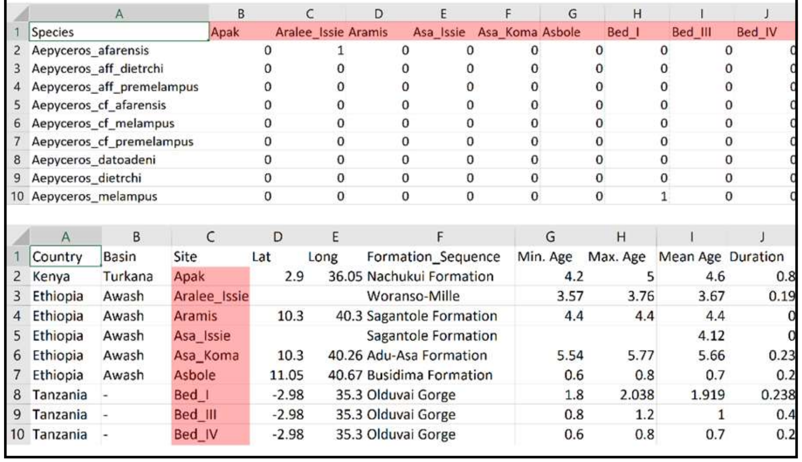
## Relating different spreadsheets



| | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Species | Apak | Aralee_Issie | Aramis | Asa_Issie | Asa_Koma | Asbole | Bed_I | Bed_III | Bed_IV |
| 2 | Aepyceros_afarensis | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | Aepyceros_aff_dietrchi | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | Aepyceros_aff_premelampus | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | Aepyceros_cf_afarensis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | Aepyceros_cf_melampus | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | Aepyceros_cf_premelampus | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | Aepyceros_datoadeni | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | Aepyceros_dietrchi | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | Aepyceros_melampus | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |

| | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Country | Basin | Site | Lat | Long | Formation_Sequence | Min. Age | Max. Age | Mean Age | Duration |
| 2 | Kenya | Turkana | Apak | 2.9 | 36.05 | Nachukui Formation | 4.2 | 5 | 4.6 | 0.8 |
| 3 | Ethiopia | Awash | Aralee_Issie | | | Woranso-Mille | 3.57 | 3.76 | 3.67 | 0.19 |
| 4 | Ethiopia | Awash | Aramis | 10.3 | 40.3 | Sagantole Formation | 4.4 | 4.4 | 4.4 | 0 |
| 5 | Ethiopia | Awash | Asa_Issie | | | Sagantole Formation | | | 4.12 | 0 |
| 6 | Ethiopia | Awash | Asa_Koma | 10.3 | 40.26 | Adu-Asa Formation | 5.54 | 5.77 | 5.66 | 0.23 |
| 7 | Ethiopia | Awash | Asbole | 11.05 | 40.67 | Busidima Formation | 0.6 | 0.8 | 0.7 | 0.2 |
| 8 | Tanzania | - | Bed_I | -2.98 | 35.3 | Olduvai Gorge | 1.8 | 2.038 | 1.919 | 0.238 |
| 9 | Tanzania | - | Bed_III | -2.98 | 35.3 | Olduvai Gorge | 0.8 | 1.2 | 1 | 0.4 |
| 10 | Tanzania | - | Bed_IV | -2.98 | 35.3 | Olduvai Gorge | 0.6 | 0.8 | 0.7 | 0.2 |

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## Questions?

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## Summary

- The importance of data wrangling
- Rules for data in spreadsheets
  - Keep names consistent
  - Use NA to represent missing data
  - Avoid spaces & special characters
  - Use short, informative names
  - One piece of data per cell
  - Don't use highlighting or font coloring
- Keep spreadsheets rectangular!
  - Use different spreadsheets if necessary
- When in doubt, refer to Broman & Woo, 2018
- If you follow these rules when entering data, the less wrangling you will need to do later

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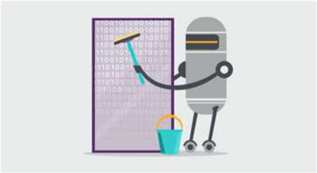
## But how to clean data?

- Thus far, you learned what good data practices are
- But what to do if you are dealing with bad, dirty data (***very*** common)?
- This week’s R tutorial will teach you how to fix these data issues using R



## Show data & code

- Show published data structure
- Show published R code structure
- Clarify distinction between console, R script, & R Markdown