1

- Will it rain tomorrow?
  (a deterministic question)
- What is the probability that it will rain tomorrow?
  (a question framed in terms of uncertainty)

How do these two questions differ, and which one is more in line with a statistical question?

2

Key concepts underlying statistics and statistical thinking

- Decision (e.g., based on probability of raining).
- Uncertainty (unpredictability).
- Risk of being wrong (error).
- Variability - Answer (estimates of the probability of raining) may change with more data (preferably towards more accurate answers, i.e., probabilities).
- Accuracy (close to reality, i.e., yes/no rain; models predicts correctly).
- Knowledge (accumulation of evidence, i.e., that the model that we used to predict rain becomes more and more accurate).

3

Welcome to BIOL 422 & 680
(cross-listed)

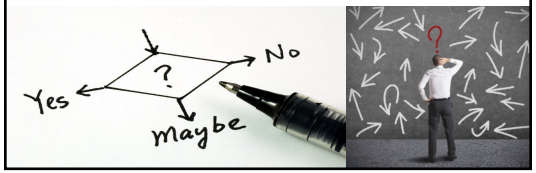
Advanced Statistics for Biological Sciences

Pedro Peres-Neto, PhD

Professor, Department of Biology,
Concordia University
& Canada Research Chair & Editor-in-Chief of Oikos

4

Welcome to the science of aiding decision-making with incomplete information
(or without complete knowledge)



5

Statistics is key!

"Statistical thinking will one day be as necessary for efficient citizenship as the ability to read and write"

- Herbert George Wells

6

Statistics is key!

"Mathematics may rule the universe, but statistics rule societies"

- Pedro in a very inspired moment during a BIOL322 lecture in 2018 ☺

7

Statistics is key!

Biostatistics is arguably the most general and widely applicable course you will take during a biology degree.

Biostatistics doesn't just help you analyze data - it changes how you think about evidence.

It is critical to every discipline, biological OR NOT.

Biology is now a data-driven science - from genomics to ecology, every field relies on statistical inference.

Biostatistics teaches you how to separate patterns from noise rather than trusting intuition or anecdotes.

You learn how to design better experiments - saving time, money, samples, and effort.

It makes you a critical consumer of research - you can spot weak claims, flawed methods, or overinterpretation.

Employers and graduate programs value it - quantitative and analytical skills consistently rank as top hiring criteria.

8

some initial thoughts

Learning is not a spectator sport. We don't learn much just sitting in classes listening to teachers, memorizing pre-packaged assignments, and spitting out answers.

We must talk about what we are learning, write about it, relate it to past experiences, and apply it to our daily lives. We must make what we learn part of ourselves.

- Chickering and Gamson

9

some initial thoughts about teaching philosophy

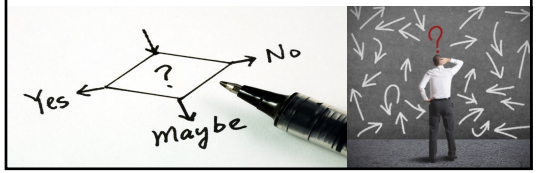
10

some initial thoughts

Learning is not a spectator sport.

11

Statistics is key in decision-making processes because most decisions are made without complete knowledge (i.e., decisions always carry some level of uncertainty).



12

What is the difference between the two definitions?

"Statistics is the study of the collection, analysis, interpretation, presentation, and organization of data." Wikipedia

"Statistics is the science of learning from data, and of measuring, controlling and **communicating uncertainty**." ASA

ASA includes critical thinking!

13

"Statistics" as defined by the American Statistical Association (ASA) "is the science of learning from data, and of measuring, controlling and **communicating uncertainty**."

"The statements of science are not of what is true and what is not true, but statements of what is known with different degrees of certainty." (Richard Feynman)

14

What is a statistical question?

- ✓ What is the average size of Canadians?
- ✓ Is 10 a number?

What is the difference between these two questions?

15

What is a statistical question?

✓ What is the average size of Canadians?

✓ Is 10 a number?

More information (data) changes (hopefully improving) the answer; i.e., one requires statistics and the other doesn't.

16

Do we need statistics to calculate the number of female candidates?

17

Do we need statistics to calculate the number of female candidates?

NO! This question would be answered by simply counting the number of female candidates over the total number of candidates. This question is not answered by collecting more data that may change the results.

18

NO! This question would be answered by simply counting the number of female candidates over the total number of candidates. This question is not answered by collecting more data that may **change the results**.

⬇

We should become comfortable with the idea that the most interesting and useful results may change if new information (data) is gathered

⬇

Statistics: "the science of assisting in decision making with incomplete knowledge"

19

What is statistics?

"Statistics is a science, not a branch of mathematics, but uses mathematical models as essential tools."

- John Tukey

20

Statistical Thinking *versus* Mathematical Thinking

Mathematics is, by and large, a deterministic way of thinking and the way mathematics is taught in schools entrenches students into a deterministic way of viewing the quantitative world around them - What is the size of our planet?

Statistics is, by and large, a probabilistic or stochastic way of thinking (i.e., it considers uncertainty) - What is the probability that it will rain tomorrow?

21

Statistical Thinking *versus* Mathematical Thinking

Statistics is a separate discipline with its own unique ways of thinking and its own tools for approaching problems.

- J. Michael Shaughnessy, "Research on Students' Understanding of Some Big Concepts in Statistics" (2006)

22

Statistics *versus* Data Science
(demystifying a trend)

"For statisticians, the entire data science trend seems a bit patronizing. No matter what your exact definition of data science is, it's going to sound pretty similar to the work that statisticians have been doing for decades."

- Nate Silver

23

Let's take a small break – 1 minute

24

Roles of statistics

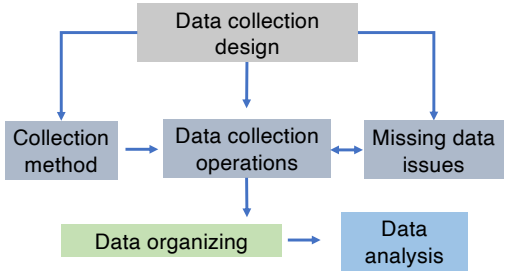
Statistics is a discipline that aims at:

1) Designing data collection protocols (observational and experimental).
2) Summarizing information to aid understanding.
3) Drawing conclusions from data.
4) Estimating the present or predict the future.
5) Communicate uncertainty.

- adapted from: http://www.scc.ms.unimelb.edu.au/whatisstatistics/

25

Roles of statistics (1) - Design data collection and protocols (experimental and observational)



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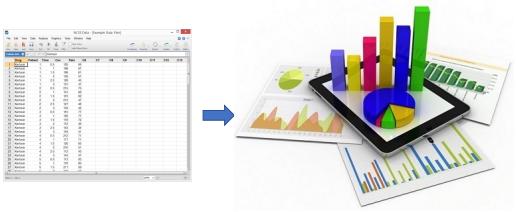
Roles of statistics (2) – Summarize information to aid understanding



From raw (primary) data……to summaries…. to information

27

Roles of statistics (3) – Produce estimates and draw conclusions from data based on samples

"There is a probability of 32% that a particular biological population will go extinct. The margin of error is 5%."

What does that mean?

28

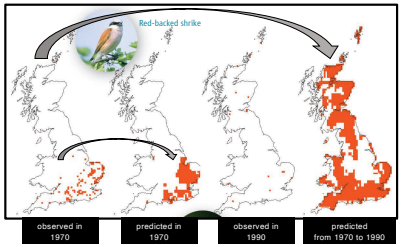
Roles of statistics (3) – Produce estimates and draw conclusions from data based on samples

"There is a probability of 32% that a particular biological population will go extinct. The margin of error is 5%."

What does that mean? ("we're pretty confident that the true probability is between 32 ± 5% or somewhere between 27% and 37%")

29

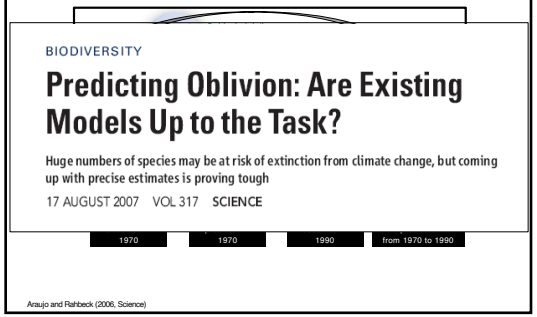
Roles of statistics (4) - Predict the present or predict the future



Araujo and Rahbeck (2006, Science)

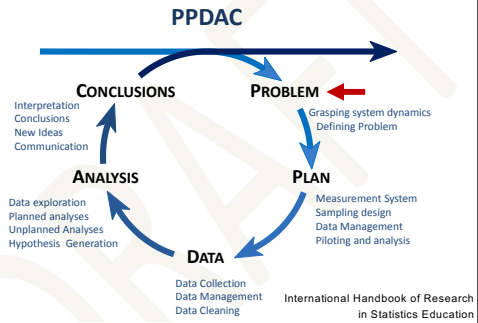
30

Roles of statistics (4) - Predict the present or predict the future



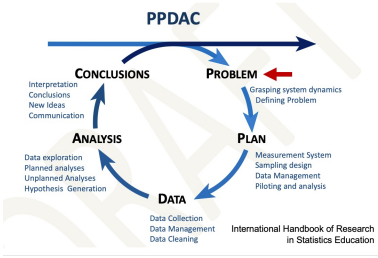
31

The statistical inquiry cycle



32

"To consult statisticians after an experiment is finished is often merely to ask them to conduct a *post mortem* examination. They can perhaps say what the experiment died of." (paraphrased from Fisher, 1938).



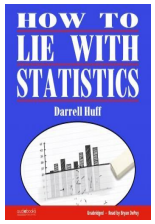
33

We need to develop our ability to think critically and make decisions by estimating parameters and assessing probabilities.

Understanding and embracing uncertainty is crucial in accurately estimating these values.

34

What is the role of statistics? **Convince you and others!**



HOW TO LIE WITH STATISTICS
(Huff, D. 1954)

There are three kinds of lies: lies, damned lies, and statistics.
—Disraeli

Statistical thinking will one day be as necessary for efficient citizenship as the ability to read and write.
—H. G. Wells

It ain't so much the things we don't know that get us in trouble. It's the things we know that ain't so.
—Artemus Ward

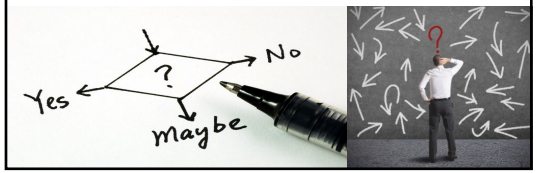
Round numbers are always false. —Samuel Johnson

I have a great subject [statistics] to write upon, but feel keenly my literary incapacity to make it easily intelligible without sacrificing accuracy and thoroughness.
—Sir Francis Galton

35

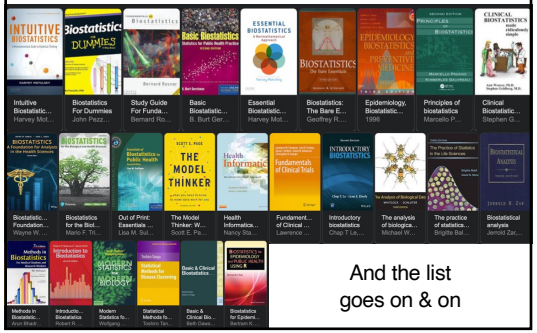
What is the role of statistics? **Convince you and others & make decisions!**

Statistics is part of a decision-making processes because most decisions are made without complete knowledge (i.e., they are based on samples and as such have some level of uncertainty).



36

There is a lot of BioStatistics out there



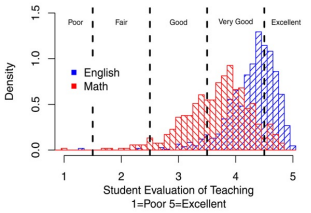
And the list goes on & on

37

The “fear” of BioStatistics

38

The fear of statistics



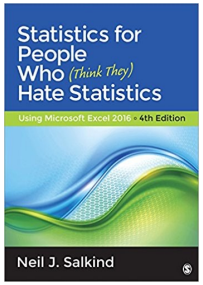
Source:https://www.insidehighered.com/news/2017/05/10/study-student-ratings-instructors-dependent-discipline-quantitative-fields-are-most

39

The fear of statistics

40

The fear of statistics



Bottom line:

There is fear of statistics…but *there is no need to!*

41

How to become interested in statistics?

Statistical concepts can promote interest, ability and intuition towards quantitative thinking & numeracy.

With time and experience, you will be able to choose or adapt available tools to particular needs….and perhaps even generate your own.

42

Let's take a break – 1 minute

43

The challenges in understanding statistics

A word on intuition – two meanings:

1) Easy to use and understand (goal here).

2) "Instinctive" – act on what one feels to be true even without reason (ultimate goal of experience).

44

The challenges in understanding statistics

Let me describe my goal & teaching philosophy with a problem: "Here is a new number system that you will need to learn"

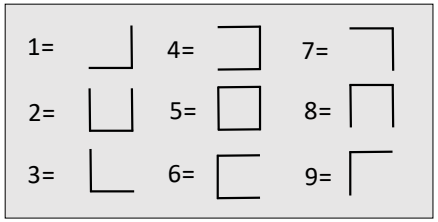


Image by P. Newbury

45

The challenges in understanding statistics

Let me describe my goal & teaching philosophy with a problem: "Here is a new number system that you will need to learn"

What is this number?

Image by P. Newbury

46

Teaching styles

Transmissionist	Constructivist
1= 4= 7= 2= 5= 8= 3= 6= 9=	1 2 3 4 5 6 7 8 9
Unsupported content	Built on familiar content

47

The challenges in understanding statistics

Let me describe my goal & teaching philosophy with a problem: "Here is a new number system that you will need to learn"

What is this number?

Image by P. Newbury

48

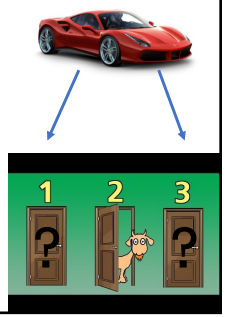
We are witnessing a pedagogical movement in statistics education aimed at shifting the focus of *instruction away from theory and recipes* toward *statistics thinking, genuine data, conceptual understanding, and active learning*.

Chance and Garfield, 2001

49

The challenges in understanding statistics - many problems are not intuitive at first

The Monty Hall Problem (from "Let's make a deal"): In search of a new car, you pick a door, say 1. The game host then opens one of the other doors, say 2, to reveal a goat and offers to let you pick door 3 instead of door 1 if you want to. ***Would you switch or keep the same door?***



50

Is it okay to learn statistics without memorizing the mathematical derivation of the formulas?
I like Peter Flom's answer!

Peter Flom, Independent statistical consultant for researchers in behavioral, social and medical sciences

Answered May 2, 2016

Yes, it's OK.

I've been a data analyst for 20+ years and I've never needed to know the derivation or proof of anything. In fact, you can mostly forget the formulas because they are easy to look up and, in any case, the computer does the calculating.

BUT: You do need to know a lot more than just the formulas. You need to know the assumptions, the things that can go wrong, the reasons to use or avoid a particular statistic, the alternatives that are available and so on.

51

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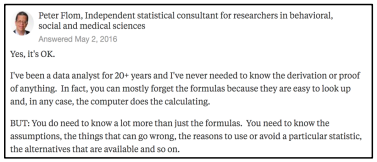

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BUT: You do need to know a lot more than just the formulas. You need to know the assumptions, the things that can go wrong, the reasons to use or avoid a particular statistic, the alternatives that are available and so on.

Of course, if you want to be a theoretical statistician and derive new statistics and stuff like that, forget all the above - you'll need to know a LOT of math.

52

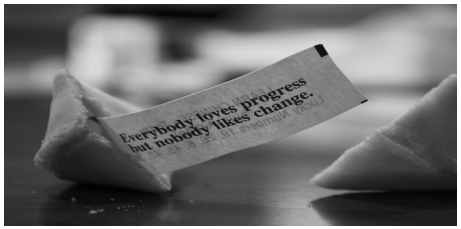
You may be able to use a car very well (or an environmental probe) even though you likely don't know how it really works!

Statistical inference and statistical hypothesis testing (not to be confused with hypothesis testing) are key statistical components that are general and can be understood without excruciating details. Understand the assumptions and limitations of methods are also analogous to driving without understanding the car's engine.

53

The challenges in understanding statistics

Imagination is our job

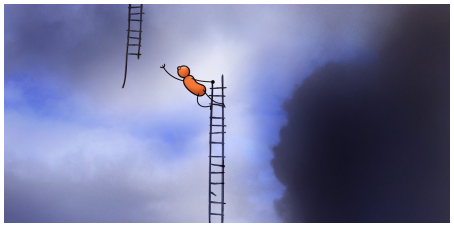


Let's connect ideas and concepts

54

The challenges in understanding statistics

Let's connect ideas and concepts



This is the role of tutorials & reports

55

Let's take a break – 1 minute

56

Our WebBook in a glance

Access through moodle or direct link:

https://mypage.concordia.ca/faculty/pperesne/BIOL_422_680_2026/

57

Moodle will be used for sending announcement, Forums and posting assignments

moodle

Please use our Moodle FORUM: the answer to your question can help everyone!

58

How to Say Hello (It Matters!)

Instructors enjoy being greeted cordially; for example:

Hello Pedro (I'm very informal)
Hello Dr. Peres-Neto; or Hello Professor Peres-Neto
Hello could be replaced by Hi or Dear depending on the occasion.

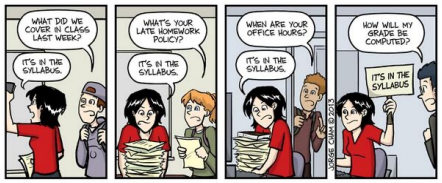
Perhaps avoid being impersonal:

Hello,
Hi,
Hello sir "If you forgot your instructor's name, please look over their course syllabus." I know is a sign of respect, but I do prefer to be referred by my name.

Thank you ☺ - I may send a reminder about this from time to time!

59

Read the Syllabus



IT'S IN THE SYLLABUS

This message brought to you by every instructor that ever lived.
WWW.PHDCOMICS.COM

But if it's not there…let me know

60

Academic Integrity

Sharing any assignment (e.g., exams, quizzes, reports, etc) and course material/content in public sites and with other students from Concordia or other institutions goes against academic integrity and can lead to sanctions and infraction. Please visit the Concordia website on academic integrity and contact me if you have any questions: https://www.concordia.ca/conduct/academic-integrity

PLEASE RESPECT THE WORK OF YOUR INSTRUCTORS

Sharing course material and assignements also demonstrates a lack of respect for the work of your instructors that put a lot of their time into your education.

WHAT YOU CAN and CAN'T DO in ASSIGNMENTS and EXAMS?

PLAGIARISM

The most common offense under the Academic Code of Conduct is plagiarism which the Code defines as "the presentation of the work of another person as one's own or without proper acknowledgement." This could be material copied word for word from books, journals, internet sites, professor's course notes, etc. It could be material that is paraphrased but closely resembles the original source. It could be the work of a fellow student, for example, an answer on a quiz, data for a lab report, a paper or assignment completed by another student. It might be a paper purchased through one of the many available sources. Plagiarism does not refer to words alone - it can also refer to copying images, graphs, tables, and ideas. "Presentation" is not limited to written work. It also includes oral presentations, computer assignments and artistic works. Finally, if you translate the work of another person into French or English and do not cite the source, this is also plagiarism.

In simple words: DO NOT COPY, PARAPHRASE OR TRANSLATE ANYTHING FROM ANYWHERE WITHOUT SAYING FROM WHERE YOU OBTAINED IT! Source: https://www.concordia.ca/students/academic-integrity.html

61

Academic Integrity

Sharing any assignment (e.g., exams, quizzes, reports, etc) and course material/content in public sites and with other students from Concordia or other institutions goes against academic integrity and can lead to sanctions and infraction. It also demonstrates a complete lack of respect for the work of professors and instructors.

We faculty put 100s of hours every semester for each course and many of these hours are taken away from our personal time, including time we don't spend with our families. Please respect us and the time we dedicate to your training.

Sharing any material is a high academic infraction that can have consequences to your records even if found out after your graduation.

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62

The use of ChatGPT and other AI systems for natural and computer languages

The use of ChatGPT and other AI systems is prohibited unless clearly stated in the assignment instructions.

Any submission that is found to have used ChatGPT or other AI systems without explicit permission will be considered a violation of the academic integrity policy. It is the responsibility of the student to ensure that all work submitted is their own original creation, and to seek clarification from the instructor if there is any doubt about the use of ChatGPT and other AI systems. We will have open discussions about these tools and the ethical implications of these to learning and assessment.

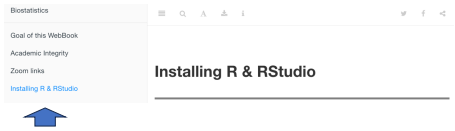
63

Subjects covered in the course

- Biological problems and associated data.
- R for statistical computing.
- Data structure and types of statistical variables.
- Field versus laboratory studies, experimental versus observational studies.
- The concepts of probability, parameters and maximum likelihood; revisiting inferential statistics and statistical hypothesis testing.
- Revisiting Analysis of Variance (ANOVA) – parametric and non-parametric.
- Advanced Multiple testing and post-hoc analysis.
- Multifactorial Analysis of Variance.
- Analysis of Covariance (ANCOVA).
- Fixed versus random factors: mixed model ANOVA.
- Multiple regression and variation partitioning.
- Generalized Linear Models (GLMs); spatial and phylogenetic autocorrelation: generalized least square solutions.
- Multivariate analyses: introduction and the concept of latent variables and processes.
- Multivariate inference: Multivariate Analysis of Variance (MANOVA) and Discriminant Function Analysis (DFA).
- Multivariate analyses: Principal Component Analysis (PCA), Principal Coordinate Analysis (PCoA) and Correspondence Analysis (CA).
- Multi -response multiple regression: Redundancy Analysis (RDA), relating species characteristics to their environments.
- Cluster Analysis, Machine learning, Classification and Regression Tree (CART), and K means.
- Advanced non-parametric inference: Monte Carlo testing and bootstrap.

64

This week!



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