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Excerpt
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Asking Questions about Primates

All observation must be for or against some view, if it is to be of any service
Charles Darwin[1]

Like all science, studying primates is about asking the right questions in the right way. Most studies of primates fall within the life sciences, so I focus on the scientific method in this book.[2]

In this chapter I first introduce how science works, then look at what it takes to be a primatologist. Finally, I outline the contents of the rest of the book.

1.1 HOW SCIENCE WORKS

All cultures produce and accumulate knowledge to understand and explain the natural world. Science is one such knowledge system.

Science is an attempt to explain observations of natural phenomena such that we can predict future observations. We begin with observations, either our own or those reported in the literature. We look for patterns in those observations and propose explanations for the patterns we identify (**hypotheses**). We then use those hypotheses to derive **predictions** about what will happen under specific circumstances, and collect, analyse and interpret new observations (**empirical data**) to test whether our predictions are upheld. New data may support a hypothesis, help to refine it, help to refute it or inspire us to suggest a new hypothesis. We retain or refine hypotheses that successfully predict observations, but we cannot prove them (Box 1.1). We reject hypotheses if they are not consistent with our observations.

[1] Darwin Correspondence Project, 'Letter no. 3257'. www.darwinproject.ac.uk/DCP-LETT-3257 [Accessed 8 April 2017].
[2] Studies of human relations with primates need a broader approach, including the social sciences.

Box 1.1: Common misconceptions about science

Science is often misrepresented in the media, leading to misunderstandings about how science works. Common misconceptions include the following points.

Science Is about Facts
Science is about the process of asking questions, not about facts. In other words, it is about what we don't know, not what we do know.

Scientists Prove Hypotheses
We retain or refine hypotheses that successfully predict observations; we do not (and cannot) prove them. All scientific knowledge is provisional, although some hypotheses are very strongly supported.

Scientists Seek Evidence That Supports an Explanation
Good scientists look for evidence that their ideas are wrong. We don't seek evidence that supports an explanation.

Science Is about Breakthroughs
Although media coverage often hypes breakthroughs (as well as bizarre and scary stories), science is usually incremental and major breakthroughs are rare.

We Can Achieve a Complete Understanding of a Question
We rarely provide a definitive or simple answer to a question, and usually end with more questions than we began with at the end of a study. We never achieve a complete understanding of a question because each new answer opens further questions.

Using Individual Cases to Counter General Models
Media coverage and non-scientists often highlight an individual case that forms an exception to criticise a study. However, scientific hypotheses are simplified models of complex real-world phenomena, and they do not explain every detail, every situation or every case, so an exception does not necessarily mean that the model is false.

There Is a Single Explanation for a Phenomenon
People also often confuse mechanistic (how things work) and functional (why they happen) explanations for a phenomenon, putting one forward as a counterargument to the other. However,

Box 1.1: (cont.)

the two explanations do not compete, and we need to understand both to understand a phenomenon.

Science Is Completely Objective
Scientists strive to be objective, but we are human, and subject to bias.

Confusing Statistical Significance with Real-World Importance
Scientists use the word *significant* to mean that results are statistically significant. This is often misinterpreted as *meaningful* in terms of the real world. However, statistical significance does not measure the size or importance of an effect. The size of the *difference* is more important. We'll look at this in more detail in Chapter 5.

FURTHER READING

Goldacre B. 2009. *Bad Science*. London: Fourth Estate. An entertaining review of how the media misunderstands and misrepresents health research.

A good scientific model explains as many observed patterns as possible. We use **Occam's razor** (also known as the law of **parsimony**) as a guide. Occam's razor holds that we should retain the simplest hypothesis – the one that makes the fewest assumptions. This guards against adding further explanations (***ad hoc* hypotheses**) to reinforce a favoured but unsupported model to explain patterns the original model failed to predict.

Models simplify reality and explain general patterns. They do not explain all individual observations. For example, if males are, in general, more aggressive than females, that doesn't mean that *all* males are more aggressive than *all* females. The variation among individuals is the raw material of evolution by natural selection. Similarly, a pattern found in one species does not necessarily apply (**generalise**) to other species. In other words, there is no *typical* primate, either within or across species.

Models explain natural phenomena at different levels of analysis, resulting in very different answers to the same question. A **proximate explanation** is an immediate cause of an observed phenomenon. Proximate explanations answer *how* questions. An **ultimate explanation** addresses how a trait contributes to an individual's ability to propagate its genes. Ultimate explanations answer *why* questions. These different levels of analysis are distinct and equally valid. They complement one another, rather than being competing alternatives, but are frequently confused. We need to address both to understand a phenomenon.

Often, we cannot observe or measure phenomena directly, so we infer an explanation based on **indirect evidence**. For example, we cannot measure an organism's mental state, so we might use observations of behaviour to infer it. Other phenomena are hard to observe because they are rare or cryptic, requiring creative solutions if we are to study them.

Over time, we accumulate and assess evidence and evaluate whether it supports or falsifies our models. A single study can't give a definitive answer to a question. Individual studies are often described as bricks in a wall – a useful if simplistic metaphor. We test findings to determine whether we can reproduce the original results using the same data (**reproduction**), and whether independent investigations (i.e. new data) will produce the same findings (**replication**).

Replication can be conducted at different levels, with a trade-off between establishing the validity of findings and their generality (Box 1.2). Repetition makes science self-correcting. If multiple lines of evidence support the same hypothesis, then we can be more confident in that explanation. Convergence of evidence from multiple approaches, each with different assumptions and sources of potential bias, is termed **triangulation** or **consilience**, and leads to robust conclusions. Breakthroughs, or **paradigm shifts**, occur when new observations, ideas, findings, or methods alter how we view a problem. The metaphorical wall falls down and is rebuilt in a different form.

Hypotheses that can be disproven (**falsified**) and tests that exclude alternative hypotheses (**strong inference**) were the dominant philosophies of twentieth-century science. However, many questions in primatology are better expressed in terms of the size of an effect, or the strength of a relationship, rather than a binary yes/no as to whether the effect or relationship exists.

1.2 What It Takes to Be a Primatologist

Primatologists study primates to understand them, conserve them and promote their welfare. We draw on diverse theory and methods from disciplines including anatomy, anthropology, biology, ecology, medicine, psychology, veterinary sciences and zoology. We work in laboratories, museums and libraries, and at animal sanctuaries, captive

Box 1.2: Types of replication

Replication is essential to scientific progress. It tells us whether the original results are reliable and meaningful.

An **exact replication** (or **direct replication**) aims to duplicate the methods of an earlier study completely. However, this is often impossible in primatology, where the exact conditions are unique to a study. **Partial replication** ranges from **close replication**, using the same methods to replicate the original study as far as possible, to **conceptual replication**, which evaluates the same hypothesis as the original study, but using different methods. Close replication is an excellent test of whether the results are repeatable and reliable, but not of whether they apply in other settings (**generality** or **generalisability**). In contrast, conceptual replication is a poor test of validity, but a better test of generality. **Quasi-replications** expand the scope of study to a new species or system. They are not effective at testing validity but are useful to assess the generalisability of findings across species.

The terms *reproducible* and *replicable* are often used interchangeably but have distinct meanings in science. Reproducible means that if we use the same dataset and methods we will obtain the same statistical results as those reported. Replicable means that an independent test of the same hypothesis, using the same methods, will obtain the same findings.

FURTHER READING

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research facilities, zoological parks (zoos) and field sites. We develop theory, collate and analyse existing data, create computer models, study fossils, observe behaviour, conduct experiments and do laboratory analyses. These diverse areas all require a combination of deep familiarity with our study animals, a strong grasp of theory, an excellent understanding of study design and statistical analysis, careful thought and planning, and the ability to communicate our research to academics and the general public.

Deep familiarity with our study animals and sharply honed observation skills are essential to a project. We can't design a project and we can't interpret our findings without understanding how our study animals behave. Observing other species can also provide illuminating comparisons and lead us to pose new questions.

A strong grasp of current theory is essential to put our observations into context and recognise interesting research questions. Simple descriptive research provides important **natural history** information and is essential to generate new hypotheses, but it is impossible to identify interesting questions without a sound understanding of theory.

Careful thought about study design and how to analyse our data is crucial to the success of a project. It can be very tempting to jump straight into data collection, using familiar methods or copying other researchers, without stopping to think about how we intend to analyse our data to address a specific question. However, data can be useless if the methods were not designed to answer a question or the number of cases we study (the **sample size**) is inadequate to draw any general conclusions. Moreover, mining data we have already collected for patterns runs a serious risk of testing hypotheses suggested by the data (more on what's wrong with this in Chapter 2). These are common, but preventable, errors.

The ability to communicate our ideas to readers is an indispensable component of research. Some of us are native English speakers, but none of us are native scientific English speakers, so we all need to learn this. We must also learn the skills to communicate with a broader audience.

Developing these diverse skills takes practice. We must be prepared to accept and act on critical feedback to refine and improve our work, however hard this may be. Science can be daunting and it's normal to feel overwhelmed at times (Box 1.3). Many scientists suffer from the feeling that they don't belong or might be exposed as a fraud. Box 1.4 explores the sources of this **imposter syndrome**, and how to handle it.

Beyond this, being a primatologist requires passion, creativity, adaptive perfectionism, curiosity, tenacity, creativity, stamina, resilience, flexibility, patience, commitment, attention to detail, openness

Box 1.3: Coping when you're overwhelmed

Science can be hard. At times your to-do list can seem unending. It's normal to feel like you're making a mess of things at times, and for tasks to take much longer than you had planned. Moreover, health, financial, and personal issues often intervene in a project. It can seem as though students and researchers are expected to have no other concerns in life and to devote all their time to research. However, this isn't realistic. Researchers are human, with responsibilities, financial concerns, caring responsibilities, families, hobbies and so on.

When you feel overwhelmed, take a step back and look at the bigger picture. Don't just dive into the first task you have to hand. Instead, list your goals and break them into tasks. Break tasks into sub-tasks until you reach small, manageable tasks. Prioritise among those tasks and put them into a timeline. Distinguish between urgent and important tasks and ensure what you're doing moves you towards your goals. Remember that you don't have to do everything, just something. Monitor your progress and readjust your timeline based on your experience. Reward yourself for achieving goals and be kind to yourself if you don't. Figure out what works best for you (e.g. where and what time of day you work best).

Take breaks. You can work flat-out for a while, but you can't sustain that for any length of time without negative effects on you and on your work. Sleep, eat regularly and well, exercise and take breaks from work. Spending time with people who are not researchers is a good way to take a break.

Scientific writing groups, either in person or online, can help with support, and strategies to combat **procrastination** (postponing tasks that you need to accomplish), or make it productive.

If something knocks you off course, remember that that is normal. Assess what happened. Many students and researchers experience anxiety and depression. If you do, you may feel alone, but you are not. Tell someone you trust, so that they can help. Seek professional help. If you're attached to an institution, find out what support measures are available. Awareness of mental health issues among postgraduate students and academics is improving, but attitudes to mental health vary and you may be treated unfairly if you disclose ill health. Many supervisors, advisors and mentors are

Box 1.3: (cont.)

supportive, but some are not. Know your rights and document any bias you experience. Online networks for students and researchers with mental health concerns are a good source of support.

If you need to take a break from your research due to ill health, you may not be able to jump back into work at 100%. Chronic health conditions may mean that you need to manage your work carefully. Be honest with yourself and with your co-workers about how much you can achieve. Again, you may face discrimination.

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Sohn E. 2018. How to handle the dark days of depression. *Nature* 557: 267–269. https://doi.org/10.1038/d41586–018-05088-y. Stories and advice about mental health from researchers.

to experience and the ability to recognise what we don't know. It also requires an ability to set goals and to be thorough, methodical and rigorous. The demands can be extreme, ranging from remote fieldwork to challenging statistical analysis, and no single primatologist can be expert in all areas, making it essential to work together with other researchers.

1.3 THIS BOOK

I begin this book with several topics that are relevant throughout the scientific process: ethics (Chapter 2), research integrity (Chapter 3),

Box 1.4: Imposter syndrome (feeling like a fraud)

Imposter syndrome is the feeling that you don't deserve your success, that you're not as good as other people in the same position, that you're not good enough and that you might be exposed as a fraud, or disappoint your supporters. It is common in research, in which we receive critical feedback on work that is often very important to us.

Imposter syndrome can affect anyone, but is particularly prevalent in women, people of colour, and first-generation students. It may partly explain the under-representation of these groups in higher positions in science. Imposter syndrome affects those marginalised by society because it is difficult to believe in your own abilities when society assumes you are inferior and where there are few role models. Search for images of *professor* on the Internet, and you'll see what I mean (professors are overwhelmingly older white men). Imposter syndrome also affects those who feel that they are expected to do very well due to their background or circumstances.

Imposter syndrome skews your perspective on your own achievements and leads you to discount your own accomplishments, attributing them to luck, while you attribute other people's success to ability. If you score 98% on a test, imposter syndrome makes you focus on the 2% you didn't get right, rather than the extraordinarily high mark. It makes you ignore any positive comments on your work and focus on those that confirm your own feelings of inadequacy.

The harsh self-criticism associated with imposter syndrome reduces your confidence in your work and can be paralysing. It can cause you to delay seeking feedback, because you want your work to be perfect before you show it to anyone (**perfectionism**).

If this sounds like you, then these tips may help:

1. Realise that you're not alone. Many of the researchers you most admire suffer from imposter syndrome, too. Labelling and describing your experience helps.
2. Talk about it. This can be difficult but talking to other people helps a great deal. Online forums can help, too.
3. Recognise the difference between feeling and fact. Just because you feel incompetent doesn't mean you are incompetent. Take a step back and be fair to yourself. How would others see you? Are your expectations realistic?

Box 1.4: (cont.)

4. Remember that it's normal to feel daunted by a complex task. It doesn't mean you can't do it. Break it down into smaller, achievable sub-tasks (Box 1.3).
5. Don't compare yourself with other people (you will always find someone doing better than you).
6. Save positive feedback and read it again. (I keep it in a separate folder.)
7. Allow yourself to make mistakes. That's how we learn.
8. Remind yourself that negative comments on a piece of work aren't about you as a person, and they're not about all of your work (at least, they shouldn't be if the reviewer has done his or her job properly).
9. Learn to sort out useful constructive criticism from destructive criticism. Evaluate negative feedback carefully. Ask yourself whether all aspects of the criticism are true, and what you can do to address those aspects. If the criticism is personal (in other words, *ad hominem* attacks, directed at you, not your work) or nasty, consider the motivations of the person giving it.
10. Recognise that while we're constantly aware of our own failings, we see only what others choose to share with us. In other words, maybe everyone else is faking it, too. Success is the visible tip of an iceberg. You don't see what lies below the water. Perfection is impossible, and failure is not a catastrophe, even if it feels that way at the time.
11. Be generous with yourself, and with others. Researchers can be highly critical of one another and our working environment can be extremely competitive, but it doesn't need to be that way. Seek out collaborative and supportive colleagues.
12. Take care of your physical and mental health. Protect your life outside your research and take breaks. Take advantage of counselling if it's available to you.

This type of advice is easy to give, but hard to put into practice. Much of it puts the responsibility on the person with imposter syndrome. However, the negative ideas that we have about ourselves are internalisations of the power dynamics around us. Empower yourself by understanding the ways in which your struggles are not