

OpenScience

March 26, 2019

1 Open Science: Theory and Practice

1.1 Overview and Objectives

“Open Science” is something of an umbrella term encompassing everything related to reproducible, transparent science.

There have been some complaints that Open Science is amorphous and ambiguous, that its prescription for reproducibility is not, in itself, reproducible.

However, Open Science is broadly defined and meant to appeal to every area of science, from life sciences to computational sciences to theoretical sciences. What Open Science looks like is field-specific, but there are general principles that cut across all fields of science.

By the end of this lecture, you should be able to

- Define “open science” and its importance to scientific inquiry
- Recall the core strategies for reproducing and replicating results
- Package and release your Python code via distribution channels

1.2 Part 1: What is “Open Science”?

Simply put, Open Science is the **movement to make all scientific data, methods, and materials accessible to all levels of society.**

Why is this a good thing?



openscience

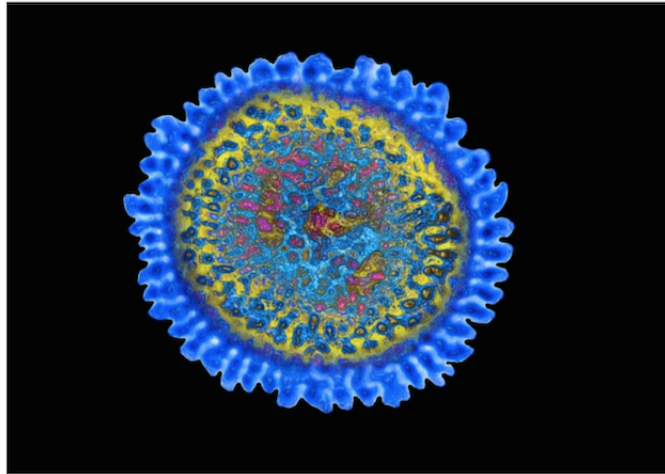
Work resumes on lethal flu strains

Study of lab-made viruses a 'public-health responsibility'.

Declan Butler

23 January 2013

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JAMES CAVALLINI/SPL

A moratorium on research that modifies the potential virulence of avian influenza virus has now been lifted.

An international group of scientists this week ended a year-long moratorium on controversial work to engineer potentially deadly strains of the H5N1 avian flu virus in the lab.

flu

- The vast majority of research is publicly funded; it would seem logical that the public have access to it!
- Open and transparent research makes peer review and replication much easier.
- There is some convincing evidence that Open Science gives projects more downstream impact in the scientific community

Nonetheless, there are some downsides to making everything openly available.

- The deluge of science will overwhelm already heavily-burdened researchers.
- The tools could be used for more nefarious purposes (influenza strain, GPT-2 language model).

My opinion—as you’ve probably guessed by the title of the lecture—is that the benefits of good Open Science practices outweigh the drawbacks, for the following reason:

I learn best when I can dig in and get my hands dirty.

Reading a paper or even a blog post that vaguely describes a method is one thing. Actually seeing the code, changing it, and re-running it to observe the results is something else entirely and, so I believe, is vastly superior in educational terms.

The scientific deluge is legitimate, though this was already happening even without the addition of open data, open access, and open source. And it would seem that, while we do absolutely need to exercise caution in our research and not pursue the ends by any means necessary, sci-

SYSTEM PROMPT (HUMAN-WRITTEN)	<i>In a shocking finding, scientist discovered a herd of unicorns living in a remote, previously unexplored valley, in the Andes Mountains. Even more surprising to the researchers was the fact that the unicorns spoke perfect English.</i>
MODEL COMPLETION (MACHINE- WRITTEN, 10 TRIES)	<p>The scientist named the population, after their distinctive horn, Ovid's Unicorn. These four-horned, silver-white unicorns were previously unknown to science.</p> <p>Now, after almost two centuries, the mystery of what sparked this odd phenomenon is finally solved.</p> <p>Dr. Jorge Pérez, an evolutionary biologist from the University of La Paz, and several companions, were exploring the Andes Mountains when they found a small valley, with no other animals or humans. Pérez noticed that the valley had what appeared to be a natural fountain, surrounded by two peaks of rock and silver snow.</p> <p>Pérez and the others then ventured further into the valley. "By the time we reached the top of one peak, the water looked blue, with some crystals on top," said Pérez.</p> <p>Pérez and his friends were astonished to see the unicorn herd. These creatures could be seen from the air without having to move too much to see them - they were so close they could touch their horns.</p> <p>While examining these bizarre creatures the scientists discovered that the creatures also spoke some fairly regular English. Pérez stated, "We can see, for example, that they have a common 'language,' something like a dialect or dialectic."</p>

gpt2



opendata

ence is the pursuit of knowledge for its own sake and that should also be respected to the highest degree.

To that end, there are **six** main themes that comprise the Open Science guidelines.

1. Open data: all data used in the project should be made available.
2. Open source: all code written in the project should be publicly available.
3. Open methods: the exact procedure of the project is publicly documented.
4. Open review: correspondence between reviewers and authors is public.
5. Open access: resulting publications are publicly available.
6. Open education: all education materials are publicly available.

1.2.1 1: Open Data

If you had to pick the “core” of Open Science, this would probably be it. All of the data used in your study and experiments are published online.

This is definitely a shift from prior precedent; most raw data from scientific experiments remain cloistered.

The situation is further complicated by Terms of Service agreements that prohibit the sharing of data collected. - For example: if you hooked up a Python client to listen to and capture public Twitter posts, you are forbidden from sharing the Twitter data publicly. - Which seems odd, given that the data are public anyway, but there you go.

Repositories and online data banks have sprung up around this idea. Many research institutions host their own open data repositories, as do some large tech companies.

- CERN, the organization behind the Large Hadron Collider, has posted its data online: <http://opendata.cern.ch/about/CMS>
- Amazon has released its own set of large public datasets: <https://aws.amazon.com/public-data-sets/>

opendata
CERN

Search

Dataset x Collision x
CMS x

Filter by type

- ☒ Dataset 878
- ☒ Collision 86
- ☐ Derived 111
- ☐ Simulated 661
- ☒ Documentation 38
 - ☐ About 3
 - ☐ Activities 13
 - ☐ Authors 3
 - ☐ Guide 12
 - ☐ Help 2
 - ☐ Policy 2
 - ☐ Report 1
- ☒ Environment 13
 - ☐ Condition 5
 - ☐ VM 5
 - ☐ Validation 3
 - ☐ News 5
- ☒ Software 20
 - ☐ Analysis 10
 - ☐ Framework 3
 - ☐ Tool 7
 - ☐ Validation 5

Sort by: Best match | asc. |

Display: detailed | 20 results |

Found 86 results.

/MuOniaParked/Run2012B-22Jan2013-v1/AOD
MuOniaParked primary dataset in AOD format from RunB of 2012. Run period from run number 193833 to 196531...

[Dataset](#) [Collisions](#) [CMS](#)

/HT/Run2011A-12Oct2013-v1/AOD
HT primary dataset in AOD format from RunA of 2011. Run period from run number 160404 to 173692...

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/SingleMu/Run2011A-12Oct2013-v1/AOD
SingleMu primary dataset in AOD format from RunA of 2011. Run period from run number 160404 to 173692...

[Dataset](#) [Collisions](#) [CMS](#)

cerndata

Registry of Open Data on AWS

aws

About

This registry exists to help people discover and share datasets that are available via AWS resources. Learn more about sharing data on AWS.

See all usage examples for datasets listed in this registry.

Search datasets (currently 84 matching datasets)

Search datasets

Add to this registry

If you want to add a dataset or example of how to use a dataset to this registry, please follow the instructions on the [Registry of Open Data on AWS GitHub repository](#).

Unless specifically stated in the applicable dataset documentation, datasets available through the Registry of Open Data on AWS are not provided and maintained by AWS. Datasets are provided and maintained by a variety of third parties under a variety of licenses. Please check dataset licenses and related documentation to determine if a dataset may be used for your application.

Sentinel-2

[earth observation](#) [satellite imagery](#) [gis](#) [natural resource](#) [sustainability](#) [disaster response](#)

The Sentinel-2 mission is a land monitoring constellation of two satellites that provide high resolution optical imagery and provide continuity for the current SPOT and Landsat missions. The mission provides a global coverage of the Earth's land surface every 5 days, making the data of great use in on-going studies. L1C data are available from June 2015 globally. L2A data are available from April 2017 over wider Europe region, planned to be expanded globally in July 2018.

Details →

Usage examples

- FME Landsat-8/Sentinel-2 File Selector by Safe Software
- Sentinel-2 Cloudless Atlas by EOX
- Integrate imagery from the Sentinel-2 archive into your own apps, maps, and analysis with the Sentinel-2 image service by Esri
- Sterling Geo Using Sentinel-2 on Amazon Web Services to Create NDVI by Sterling Geo
- Satellite Search by Remote Pixel by Remote Pixel

See 16 usage examples →

Landsat 8

[earth observation](#) [satellite imagery](#) [gis](#) [natural resource](#) [sustainability](#) [disaster response](#)

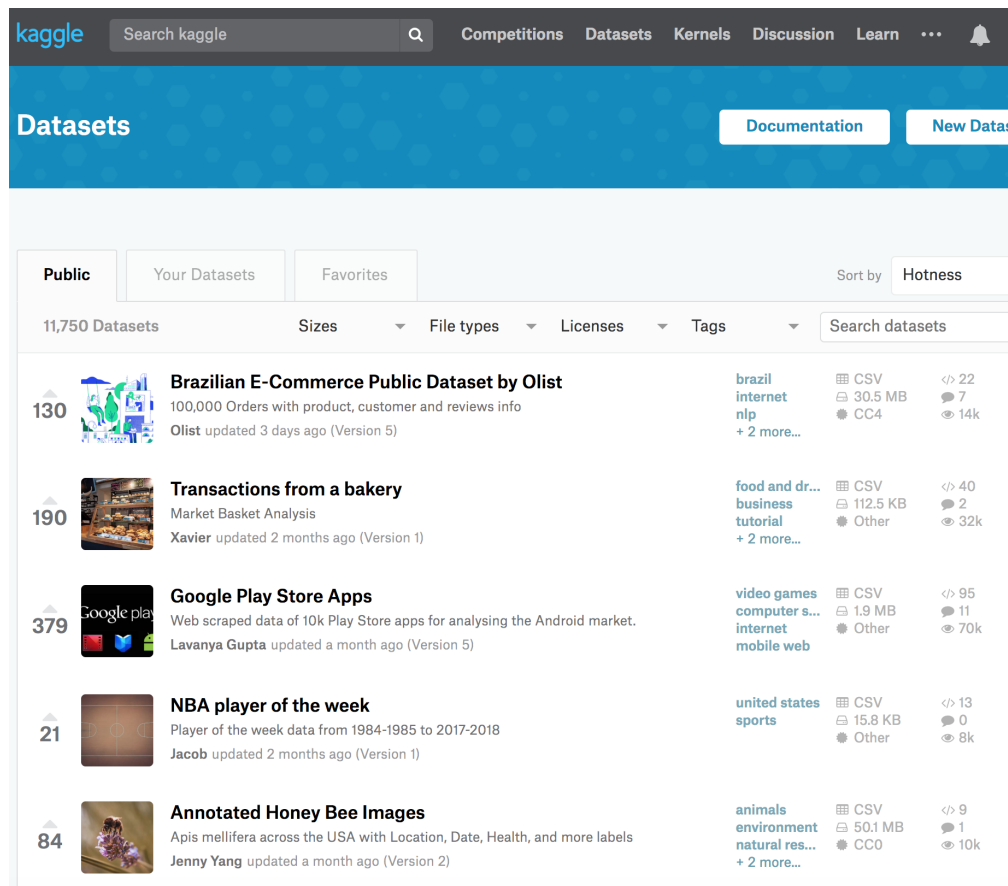
An ongoing collection of satellite imagery of all land on Earth produced by the Landsat 8 satellite.

Details →

Usage examples

- Exploring the Chile wildfires with Landsat and Sentinel-2 imagery by Timothy

awsdata



kaggldata

- Kaggle also has some pretty fantastic open datasets from its competitions:
<https://www.kaggle.com/datasets>
- DataHub is a general-purpose repository for anyone to submit their own datasets.
<https://datahub.io/en/dataset>

I encourage you to google “open datasets” in your area of interest! Go check them out!

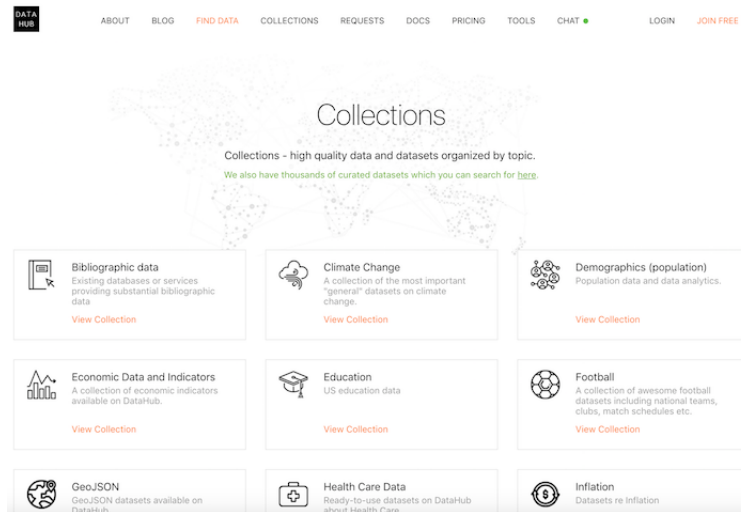
1.2.2 2: Open Source

This is probably the part you’re most familiar with. Any (and *all*) code that’s used in your project is published somewhere publicly for download.

There are certainly conditions where code can’t be fully sourced—proprietary corporate secrets, pending patents, etc—but to fully adhere to Open Science, the code has to be made completely available for anyone.

Like with open data, there are numerous **repositories** across the web that specialize in providing publicly-available versioning systems for both maintaining and publishing your code.

- GitHub is easily the most popular, and is where the materials for this lecture are published!
<https://github.com/>



datahub



github



- BitBucket is another option that also uses git to manage team codebases
<https://bitbucket.org/>
- SourceForge is one of the oldest and most well-known online repositories
<https://sourceforge.net/>

If you're looking for the actual source code, it's pretty likely to be on one of these sites.

1.2.3 3: Open Methods


This is probably the trickiest item. How does one make *methods* reproducible?


Open source code is part of it, but even more important is the effort put into making the methods in the code understandable. This takes several forms:

- Documentation, both as accompanying doc files (e.g. JavaDoc) as well as in-code comments
- Proofs of the methods devised if they're novel, or references to their original sources
- Pre-packaged examples that will run with little or no prior configuration on the user's part
- Pre-registered methods *before* any work is conducted
- Self-contained virtual container scripts that satisfy all the prerequisites

We'll get into more detail about how one can make their methods "open" in a bit!

Submission: LAS: an integrated language analysis tool for multiple languages #35

 **Open** whedon opened this issue 26 days ago · 8 comments



whedon commented 26 days ago • edited

Submitting author: @jiemakel (Eetu Mäkelä)

Repository: <https://github.com/jiemakel/las>

Version: v1.4.8

Status

JOSS Under Review

Status badge code:

```
HTML: <a href="http://joss.theoj.org/papers/87f0093e30a01b1078d8dea41476a08a">, which collates the papers you

OpenReview.net
Search ICLR 2019 Conference

## ICLR 2019

### International Conference on Learning Representations

New Orleans, Louisiana, United States
May 6 - May 9, 2019
<https://iclr.cc/Conferences/2019>

#### Important Information

- Note to Authors and Reviewers: Please update your OpenReview profile to have all your recent emails.
- ICLR 2019 Conference submissions are now closed.
- For more details refer to the ICLR 2019 - Call for Papers.

#### Questions or Concerns

Please contact the OpenReview support team at [info@openreview.net](mailto:info@openreview.net) with any questions or concerns about the OpenReview platform.

Please contact the ICLR 2019 Program Chairs at [iclr2019programchairs@googlegroups.com](mailto:iclr2019programchairs@googlegroups.com) with any questions or concerns about conference administration.

Submission Deadline: 6:00 pm EDT, September 27, 2018

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#### Efficient Exploration through Bayesian Deep Q-Networks

Anonymous

27 Sep 2018 ICLR 2019 Conference Blind Submission Readers: Everyone 3 Replies

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#### Learning to Separate Domains in Generalized Zero-Shot and Open Set Learning: a probabilistic perspective

Anonymous

27 Sep 2018 ICLR 2019 Conference Blind Submission Readers: Everyone 4 Replies

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Open access to 1,169,533 e-prints in Physics, Mathematics, Computer Science, Quantitative Biology, Quantitative Finance and Statistics

arxiv

## Preprint servers are appearing in many disciplines



preprints

want to read and helps filter out all the others.

Preprints have become *so* popular, that versions of arXiv have popped up for almost every area!

If you're already posting your papers on your own personal website, give arXiv a try! Some of them even have automated journal submission buttons baked into the site!

### 1.2.6 6: Open Education

This and Open Methods are closely related. In this sense, any course materials that come from research that is done are made available for others.

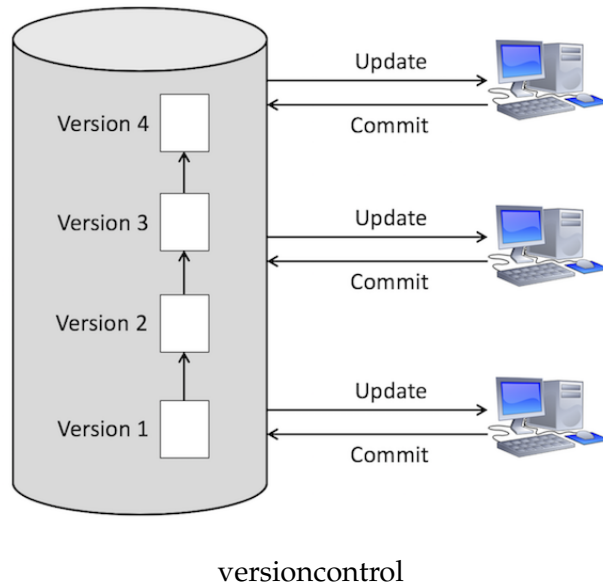
**MIT OpenCourseWare** is probably the best example of open education at work, but these types of sites are proliferating.

- Many courses are making their materials freely available on GitHub ([this lecture is also freely available!](#)).
- Tech companies such as GitHub (aptly named: [GitHub Classroom](#)) are developing educational tools specifically aimed at student classrooms. Amazon Web Services [provides a similar platform](#) for course materials, often bundled with its cloud compute services.

**Note:** This does not by default include MOOCs. If MOOCs make their materials freely available online, then and only then would it fall under this section.

So that's all great! But...

**What can I do? Where do I start?**



## 1.3 Part 2: Open Science Best Practices

In the previous section we went over the absolute essentials for an Open Science project or research endeavor. It included some examples of real-world services and tools to help expedite the process.

Here, we'll go into a bit more detail as to exactly how you should tweak your projects to be truly Open Science. It's not really something you can just "tack on" at the end; rather, you'll need to design your projects from the onset to be part of the Open Science initiative.

When you invent the next [TensorFlow](#), we'll all be thanking you for following these best practices!

### 1.3.1 Version control

This is a good starting point for any project.

Version control keeps track of changes within your code base.

It's a lot like Google docs, but for code.

You all know Dropbox? Has it ever saved your life? If so, the next time you start a coding project, use some form of *version control*.

There are several different version control systems out there for code, depending on what you like.

I personally prefer `git`, but I've used all of these before.

A lot of these have graphical interfaces you can use if you really want to avoid the command line!

### 1.3.2 Anatomy of an open source project

There are some common files and folder hierarchies to implement at the very start of a new project. The [shablona](#) GitHub repository has all this documented very well, but here are the highlights:

- Your `src` folder, containing all your source code. Surprise!
- A directory of tests for your code. Always always always *always* write tests!



vcsystems

- A README file of some kind. This is your introduction that summarizes your project, gives a basic overview of how to use it, what the prerequisites are, links to further (more detailed) documentation, and any problems that are known.
- A doc folder containing *detailed* documentation about every aspect of your project, including any examples.
- A build script of some sort: a script you can run which automates the majority of the install process.
- Continuous integration (CI). This is bit more advanced, but the idea of continuous integration is to have your code exported out to an auto-compiler every time you update the code, so that you know *immediately* whether or not it builds successfully.
- A LICENSE file. This is often overlooked (like clicking through a EULA), but in the age of open source and Open Science it is *absolutely essential* to have a license of some sort.

### 1.3.3 Document, document, document

This is drilled into computer science students from day 1, and yet one constant across every software project is that the *documentation is terrible*. To meet basic adequacy standards, documentation should include

- **The code itself.** This is the [radical notion](#) that code should be easy to understand, especially if read by someone who did NOT write it. Save [code golf](#) for the competitions!
- **Comments in the code.** Invariably there will be some logic in the code that doesn't make sense at first glance. This should be explained with clear comments. Not comments like `# loop through the array`, but useful comments like `# Because the array is already sorted, we only loop through parts of it to search for the value we want.`

```

shablona/
|- README.md
|- shablona/
 |- __init__.py
 |- shablona.py
 |- due.py
 |- data/
 |- ...
 |- tests/
 |- ...
|- doc/
 |- Makefile
 |- conf.py
 |- sphinxext/
 |- ...
 |- _static/
 |- ...
|- setup.py
|- .travis.yml
|- .mailmap
|- appveyor.yml
|- LICENSE
|- Makefile
|- ipynb/
 |- ...

```

shablona

What does this code do?

```

In [1]: def do(a, b):
 c = a + " " + b
 return c

```

What if I'd written it this way:

```

In [2]: def full_name(first_name, last_name):
 name = first_name + " " + last_name
 return name

```

Or even this way:

```

In [3]: def full_name(first_name, last_name):
 """
 Helper function, to concatenate the
 first name and the last name
 into a single full name.
 """

 # Concatenates the two names with a space in between.
 name = first_name + " " + last_name

 # Return the full name.
 return name

```



## Welcome

Sphinx is a tool that makes it easy to create intelligent and beautiful documentation, written by Georg Brandl and licensed under the BSD license.

It was originally created for [the Python documentation](#), and it has excellent facilities for the documentation of software projects in a range of languages. Of course, this site is also created from reStructuredText sources using Sphinx!

sphinx

Python (and *any other* programming language) will have a “style” of documenting the code whereby other utilities can take those comments and turn them into documentation.

Java pioneered this approach in the 1990s with “Javadocs” and every language since has emulated that in some way.

Python’s version is “Sphinx” <http://www.sphinx-doc.org/en/master/>

- **README.** This is usually the user’s first introduction to a new software package (GitHub makes this file the default landing page of a repository!). It should clearly state the purpose of the software, how to install and run it, and some basic usage examples before pointing the user to where they can go to learn more.

### 1.3.4 Examples and tests

Right after the README, this is the next place the user will go: examples for how to run the code. Is it command line? What options are there? What kind of data can I run through it? What should I expect for output? These sorts of questions can be addressed with

- **Quickstart.** This is file that is dedicated to getting the user up and running with the software as quickly as possible with an example. The goal is to put the user in the driver’s seat as quickly as possible, and let them ask questions later.
- **Examples.** This usually takes the form of a bash script, written to invoke the code and have it run on a sample dataset that’s provided. Alternatively, you can give a step-by-step guide of what commands to run, what inputs to give, and what the expected output should be.
- **Unit tests.** You’ll learn more about this as you take higher-level software engineering courses, but the main idea is you want to write code that *tests* your main code. The user can also go here to get a feel for how the code should be used.
- **Containers.** This is a very advanced topic that we won’t cover in this course, but the “wave of the future” is to build your software inside *containers* (e.g. [Docker](#)). Think of containers as super-lightweight virtual machines that anyone can build from a simple script. Using containers, you can package your software in such a way that you don’t have to worry about operating systems or clashing software dependencies.

```
(py27) Apollo:OpenScience squinn$ ipython
Python 2.7.15 |Anaconda custom (64-bit)| (default, May 1 2018, 18:37:05)
Type "copyright", "credits" or "license" for more information.

IPython 5.6.0 -- An enhanced Interactive Python.
? -> Introduction and overview of IPython's features.
%quickref -> Quick reference.
help -> Python's own help system.
object? -> Details about 'object', use 'object??' for extra details.

In [1]: division = 5 / 2

In [2]: print division
2

In [3]:
```

python2

### 1.3.5 Containers

**WARNING: This is super-advanced.**

Has anyone ever - tried to run code that is 6+ months old? - tried to install an old(er) video game on a new computer? - tried to install a new app on an old smartphone OS?

Did it run?

Here's a great example: Python 2 versus Python 3.

Python 2 was the *de facto* Python version for over a decade (it's kind of the Windows XP of Python). When Python 3 was introduced in the late 2000s, nobody upgraded.

What should this code output?

```
In [4]: division = 5 / 2
```

```
In [5]: print(division)
```

2.5

This notebook is running Python 3. Let's run it in Python 2, shall we?

Containers, such as **Docker**, allow you to create bash-script-like *recipes* that build the precise environment you want.

This has *huge* implications in reproducibility: you can provide others with an exact set of instructions—even a pre-built image!—of the environment in which you conducted your work.

### 1.3.6 Scientific Notebooks

If you're an R or Python user, you've probably heard of "scientific notebooks".

They're interactive, usually web-based applications that blur the lines between - written documents - code modules - figures and tables

by interleaving all three within the same medium.

**\*\*These very slides were built entirely in Jupyter, a multi-language scientific notebook platform!**

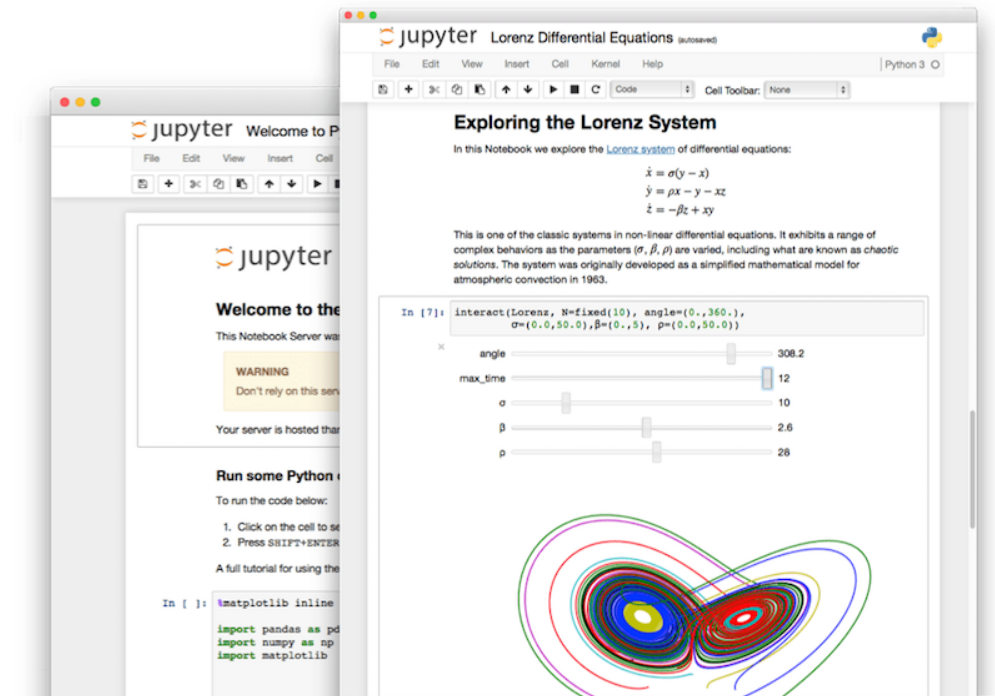
While these slides were built in Jupyter, they were exported into HTML and PDF, so the code isn't technically live anymore.

However, through platforms like mybinder, you can turn any GitHub repository into a collection of active notebooks! You can do this yourself with these slides—all you need is a web browser!





docker



jupyterpreview



Turn a Git repo into a collection of interactive notebooks

mybinder



pypi

### 1.3.7 Python Package Index (pypi) is your friend

PyPI is the [Python Package Index](https://pypi.org/), and is where the *vast* majority of external Python packages are hosted (over 85,000 as of this lecture!). In addition to publishing your code on GitHub, you can also package your code to be automatically installed via a package manager like `pip` or `easy_install`.

Provided you're already adhering to the anatomy of an open source project, there are only a few other steps needed to get your code ready for publishing on PyPI: in particular, writing the `setup.py` script that will tell the package managers of people who want to install your package exactly *how* to install your package.

Then you just upload the code to PyPI! <http://peterdowns.com/posts/first-time-with-pypi.html>

### 1.3.8 Study pre-registration

Pre-registration means *publishing your methods publicly BEFORE any work has been done*.

Why is this important?

Sites like Protocols.io <https://www.protocols.io/> and OSF <https://osf.io/prereg/> have pre-registration modules, sometimes linked with certain journals who agree to publish the results of the methods, regardless of whether they're positive or negative.

This makes sense for wet lab / life sciences or even theory-driven statistics, but what about empirical or computational studies like applied machine learning?

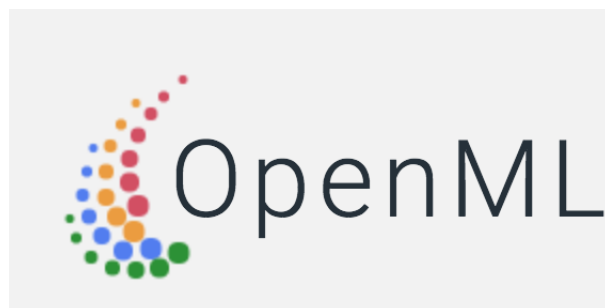
Turns out, there are a number of pre-registration sites for those too, including OpenML.



protocols



osf



openml

### 1.3.9 Licensing

Yes, this is super boring, I agree. Fortunately, the wonderful folks at GitHub have created an awesome resource for you to use.

**Choose a License:** It provides a handy choose-your-adventure flowchart for picking the perfect open software license for your project. I highly recommend it.

However, if you're just looking for a **tl;dr version** and want the basic lay of the land, GitHub's default licenses for new projects include

- MIT License (pretty much the “no warranty whatsoever, use at your own risk” license)
- Apache 2.0 License (almost exactly like the MIT, but allows for patents and trademarks)
- GPLv3 License (requires anyone who modifies your code to publish those modifications under GPLv3 too)

## 1.4 Final Thoughts

In my view, Open Science and its practices will only become more important. - Replicating previous results - Providing hands-on tools to the upcoming generation of scientists - Making cutting-edge resources accessible to broad audiences

Six major areas of Open Science - These have to be addressed from the beginning, not tacked on after the fact

Already lots of great open source tools and repositories to encourage Open Science practices - data repositories - tools for method replication and testing - standards for code structure, results presentation, and method preregistration

## 2 Questions?

### 2.1 Additional Resources

**These slides!** <https://github.com/quinnngroup/openscience-intro-march2019>

1. GitHub template for open source Python projects <https://github.com/uwescience/shablona>
2. Mozilla Open Science Lab <https://science.mozilla.org/>
3. Open Science Framework (OSF) for all phases of the scientific pipeline <https://osf.io/>
4. The Center for Open Science (COS), which supports OSF <https://cos.io/>
5. Docker <https://www.docker.com/>



questions