

Bioinformatics III

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Exercise Sheet 1

Due: April 22, 2021 before 12:00

Submit your solutions via email to markus-hollander@bioinformatik.uni-saarland.de before the deadline, as described below under 'Submission Process and Rules'.

Introduction to Python and Network Properties

The first part of the lecture is about networks and their properties. To keep complexity down for this assignment, we focus on random networks and provide several hints and code stubs to ease you into building and analysing networks.

Since the first assignments are based on each other, it is recommended that you visit the tutorials if there are any problems early on. Otherwise you are likely to encounter difficulties when working on the following assignment sheets.

Submission Process and Rules

- (a) **Groups:** You are advised to work in groups of **two** people. If necessary, we will suggest teammates after the first assignment has been submitted.
- (b) **Language:** You may submit your solutions in English or German.
- (c) **Format:** Your submissions should be in **PDF format**. It should be readable and contain your names and matriculation numbers. If you include images, make sure that they are of sufficient quality to be readable as well. In addition to your answers to questions asked in the assignment, the PDF document should **also** include your properly formatted source code. We will **not** layout your source code and merge it into the PDF for you.

You can use the \LaTeX -template provided in the supplementary material to format your submission. If you are new to \LaTeX , you can get started with [overleaf.com](https://www.overleaf.com). It provides free tutorials, online storage, a PDF autocompiler, and simultaneous editing by multiple people.
- (d) **Source Code:** Make sure that your code runs properly. Use meaningful variable names and add comments that describe the gist of what you are trying to do with a certain function, line, or section of code. Other people, especially the tutor, have to be able to understand your code.
- (e) **Submission:** Submit your solutions via email to the current tutor as **two** attachments:
 - A1_Lastname1_Lastname2.zip: The ZIP file should contain all your source code files, potential result files and whatever else is needed to generate your solution.
 - A1_Lastname1_Lastname2.pdf: The PDF file should contain your answers **and** your properly formatted source code as described above under '**Format**'.

Submissions as Word- or simple text files will **not** be considered.

- (f) **Deadline:** The deadline for submission is given on each assignment sheet. Late submissions will **not** be considered.

- (g) **Tutors:** Please note that later sheets need to be sent to different teaching assistants. The respective email address will be given at the top of the exercise sheet below the due date. If you have questions, you can also use that email address to ask the current tutor.
- (h) **Plagiarism:** Solutions and code should be written by you in your own words. Parts that were copied from other groups, the internet or submissions of previous years will be marked with 0 points.
- (i) **First tutorial:** Discussion of this exercise will take place on Thursday, April 22 at 12:15 in Microsoft Teams.

Python

The programming language Python (version 3.x) is used for the programming tasks of the first couple of assignments. The goal of this assignment is to learn basic Python concepts and to get familiar with network properties. Current Python 3 versions can be obtained from python.org or be installed via macOS and Linux package management systems.

Note that line indentation is crucial in Python! All code templates you are given use 4 spaces as tabs, so adjust your editor or IDE accordingly to avoid problems. An example of a good, free Python IDE is [PyCharm](https://www.jetbrains.com/pycharm/).

Furthermore, you need to install the popular plotting library “matplotlib”. Linux users are advised to install the library using their package management system, .e.g for Ubuntu:

```
sudo apt-get install python3-matplotlib
```

macOS users can install it as follows on the command line:

```
pip3 install matplotlib
```

Windows users might want to take a look at [this guide](#).

Exercise 1.1: Network Construction (50 Points)

We start by building a simple data structure that represents a general network. Therefore we first implement a **Node**-class that represents a single node in the network and stores edges to its neighbouring nodes. Then, we define an abstract super-class that provides basic network functionality and which can later be used to derive our different network types. Finally, we implement a sub-class that actually builds a random network.

We provide templates for **all** classes that you need to implement in the supplementary material. Most method implementations are very short. Feel free to extend your interface to suit your needs.

- (a) Implement the missing methods of the **Node**-class in **node.py**.
- (b) We need a network class that stores all nodes of a network. Use a Python dictionary to store all nodes in a **key** → **node** fashion within a class variable called **self.nodes**. Implement all functions of the **AbstractNetwork**-class in **abstract_network.py**.

Hint: An example of using Python dictionaries:

```
# initialise a dictionary called nodes
nodes = {}

# create a node with id 0
node = Node(0)

# add entry to dictionary
nodes[node.id] = node
```

- (c) Next, we want to build random networks. Our **RandomNetwork**-class inherits basic network functionality from the **AbstractNetwork**-class. All that is left to do is implement the initialisation method of **RandomNetwork** in **random_network.py**.

Exercise 1.2: Degree Distribution of Random Networks (50 Points)

- (a) Implement the **DegreeDistribution**-class in **degree_distribution.py** that determines the normalised degree distribution of a given network.

- (1) First, determine the largest degree occurring in the network and initialise a list of that size with zeros, which represents the degree histogram. An example of doing this for 10 entries is:

```
histogram = [0] * 10
```

This array then holds the degree distribution.

- (2) Next, count how often each degree occurs in the network by looping over the nodes in the network and increment the histogram cells indexed with the corresponding node degree.
 - (3) Finally, normalise the histogram with the number of nodes in the network to obtain a valid probability distribution.
- (b) To visually assess if the degree distribution of a random network obeys the Poisson distribution $P(k)$ with a mean value of λ , you need to implement a few methods in **tools.py**:
- (1) Implement the method **poisson**(k, λ), which returns $P(k)$ for given λ :

$$P(k) = \frac{\lambda^k}{k!} e^{-\lambda}.$$

Hint: In case you encounter numerical problems calculating the factorial, consider an iterative or recursive solution, e.g.

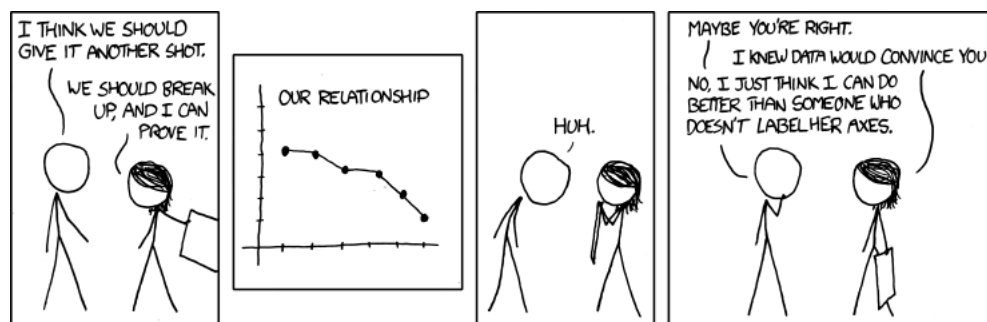
$$P(0) = e^{-\lambda} \text{ and } P(k) = \frac{\lambda}{k} \cdot P(k-1).$$

- (2) In **poisson_histogram**(n, m, max) you first determine λ from the numbers of nodes n and number of edges m :

$$\lambda = \frac{2m}{n},$$

and then compute the Poisson distribution for all $k \in \{0, \dots, max\}$. The structure of the output should match the output of (a).

- (3) The file also contains the simple function **plot_distribution_comparison** that plots several distributions at once for comparison. To get visually pleasing plots, ensure that all distributions that are plotted together have the same length. This can be done by appropriately extending the shorter ones. Furthermore, two important annotations are still missing there, fill the two empty strings correctly.



Question: Why are some distributions shorter than others and how do you need to “fill” the shorter distributions?

- (c) Run the provided script **main.py**, which sets up the following networks and plots the Poisson distributions together with the degree distributions of the random networks. Save the plots and attach them to your solution.

number of nodes / edges				
Plot 1:	50/100	500/1,000	5,000/10,000	50,000/100,000
Plot 2:	20,000/5,000	20,000/17,000	20,000/40,000	20,000/70,000

Describe both plots and **explain** the difference (or the trend) between the different parameter sets.

Have fun!