Information, Computation, and Communication

Introduction to Part Theory

Instructor: Barbara Jobstmann

Agenda for Today

- **Motivation**
- Content of the course
- Organization
- Topic 1: Representation of Information

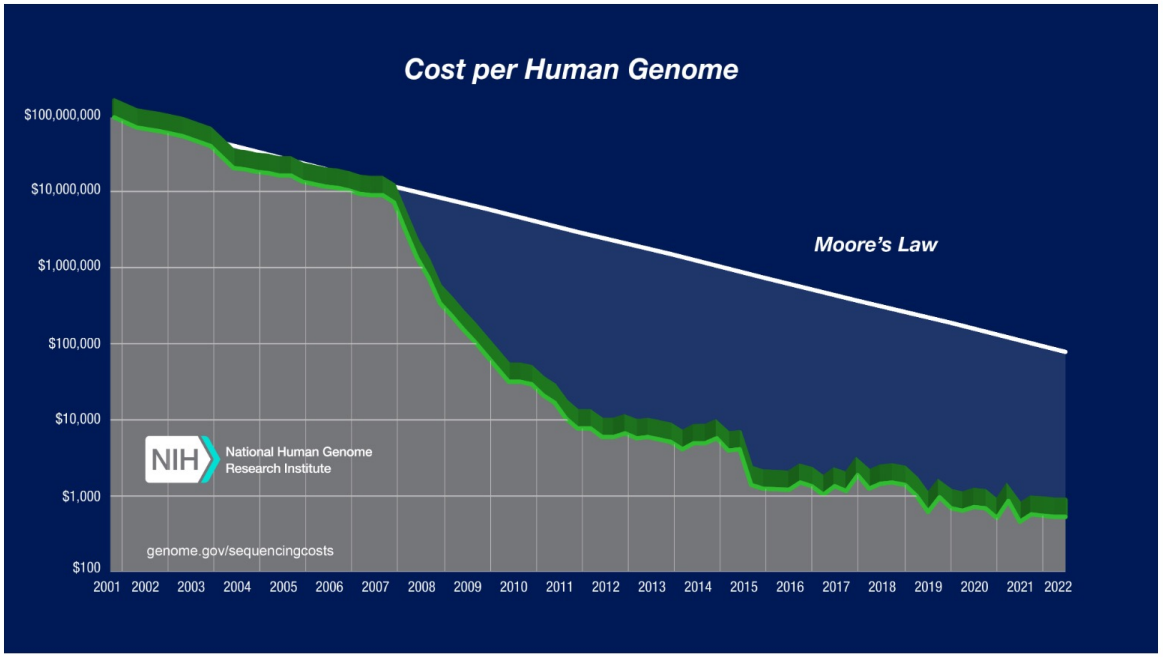
Objectives of ICC Theory

- Introduce computer and communication sciences
- Present fundamental principles
- Explain basics of how the "digital world" works, so you can **understand, influence, and transform** this world.

Motivation

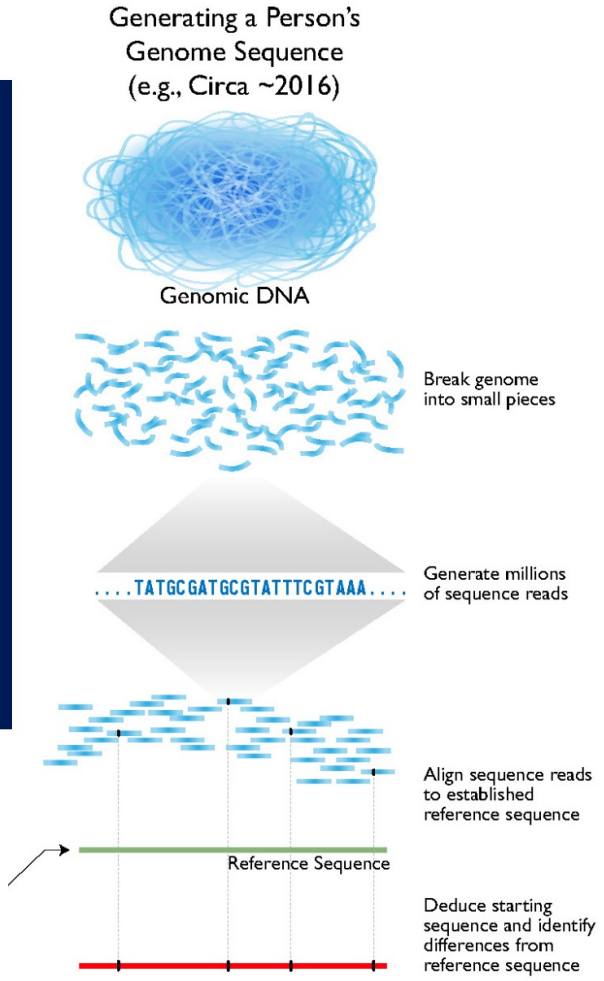
- Examples of computation in Life Sciences
  - Genomics
  - Drug Design and Discovery
  - Medical Imaging
  - Assistive Technology

The Cost of Sequencing a Human Genome



Cost per genome data - 2022

https://www.genome.gov/about-genomics/fact-sheets/Sequencing-Human-Genome-cost



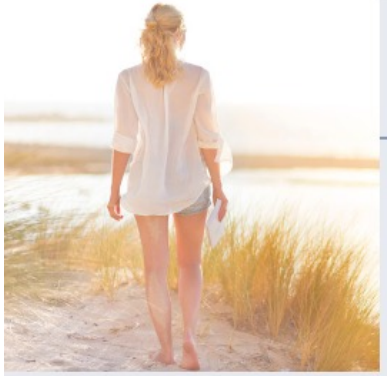
Genomics and Genetics

Prendia
Non-invasive prenatal screening

en | fr | de

Prendia: Informations for expectant mothers

Procedure, duration, price



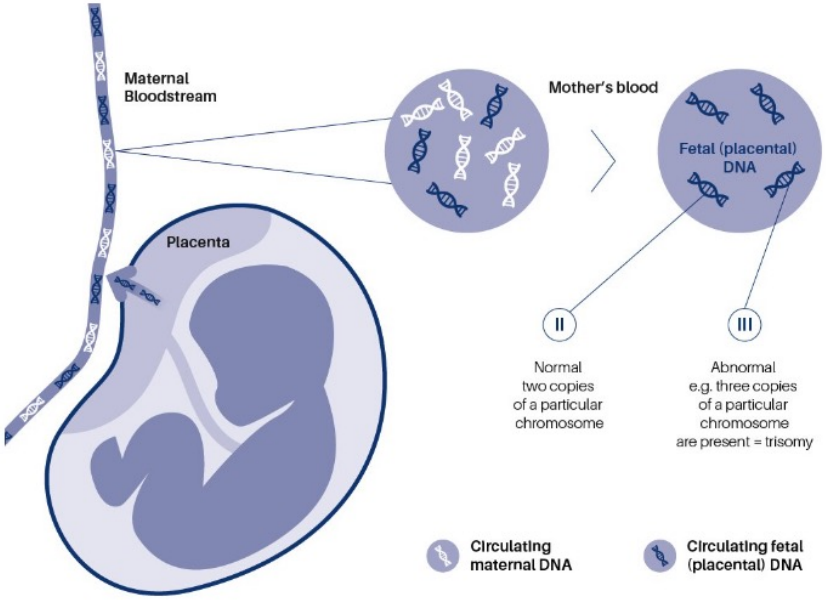
Prendia, non-invasive prenatal screening
to determine possible chromosomal abnormalities in the foetus

- No danger for the foetus
- 100% made in Switzerland
- Reimbursed by health insurance (under certain circumstances)

The analysis of fetal DNA circulating in maternal blood

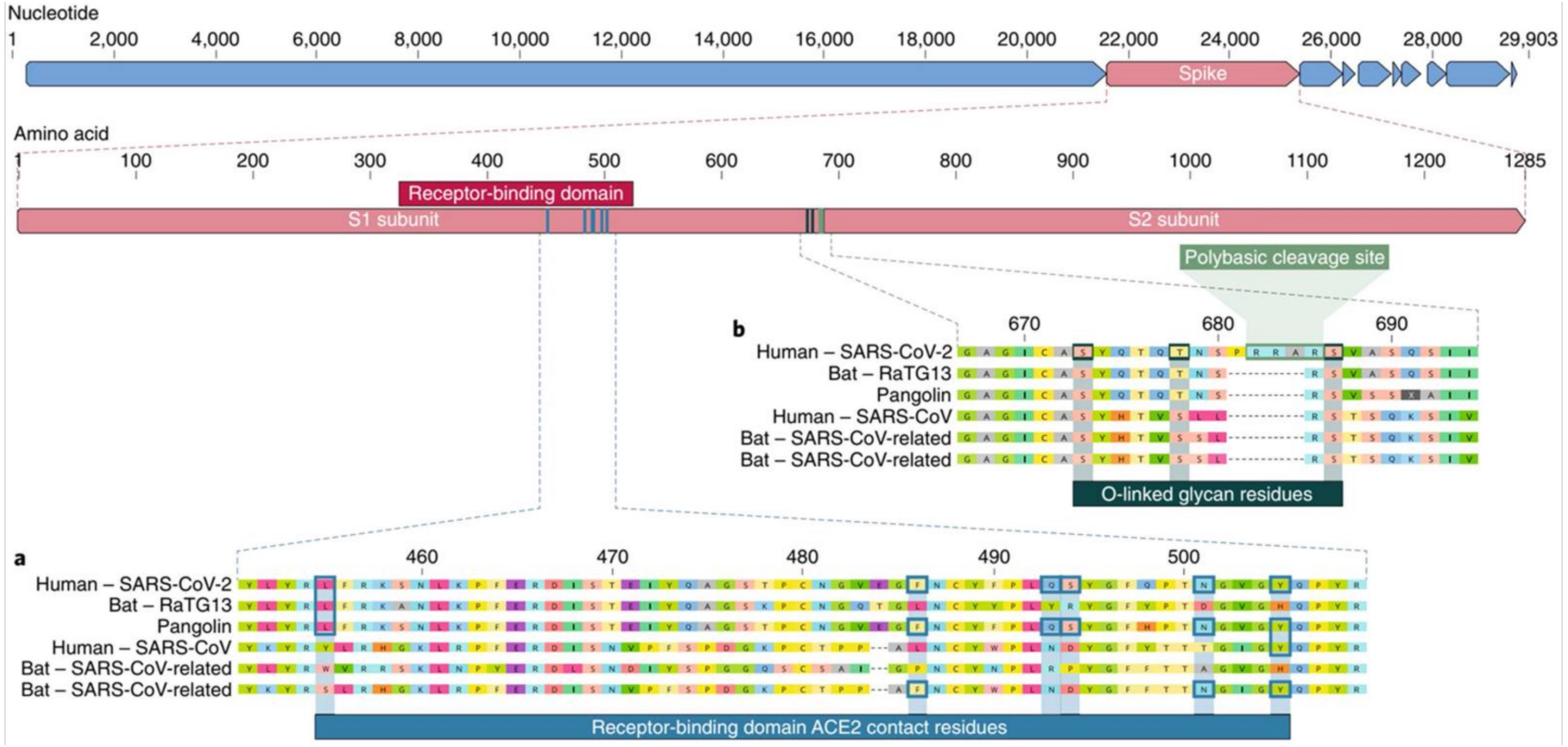
The Prendia method uses small amounts of the fetal DNA which is contained in the maternal blood coming from the placenta.

Thanks to molecular genetics and bioinformatics it is possible to determine whether the fetal DNA contains a complete double set of chromosomes.



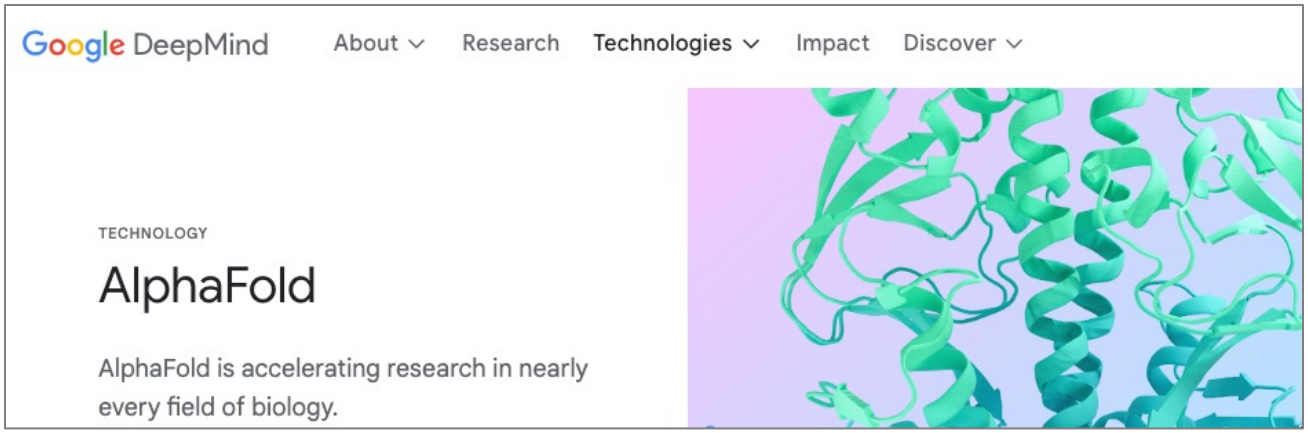
Genomics and Genetics

- SARS-CoV-2 genome is composed of a single strand of RNA with 29’903 base pairs.
- Its spike protein is encoded by 3’831 base pairs of the SARS-CoV-2 RNA.



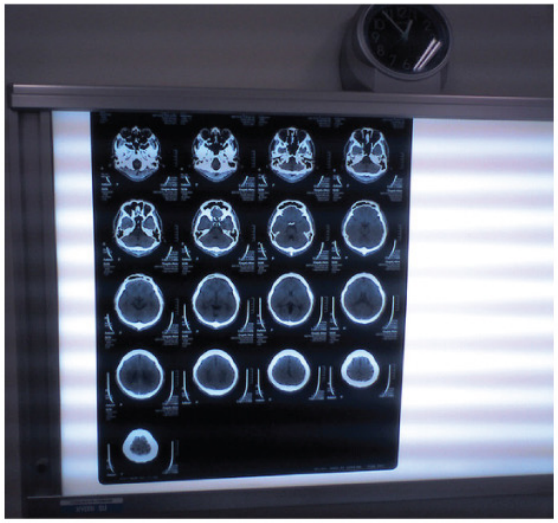
AI-driven Drug Discovery

- The integration of AI/ML in drug discovery has accelerated the identification of new drug candidates, reducing the time and cost of developing new treatments.
- AlphaFold predicts the 3D structures of proteins from their amino acid sequences with remarkable accuracy.



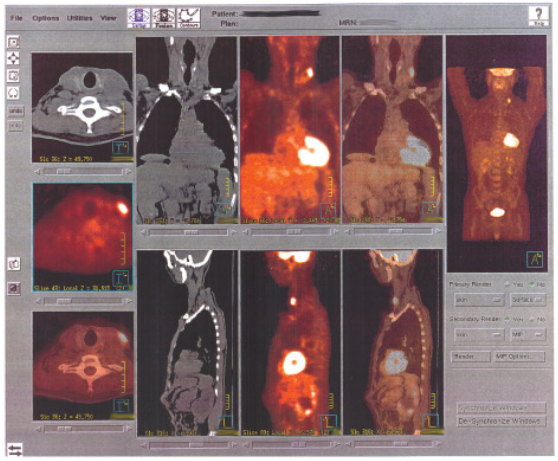
Medical Imaging

- Process of creating a picture of the inside of a human or animal body (e.g., MRI scanner)
- How does CS help?
  - Image Quality
  - Diagnoses
  - Patient comfort



(a)

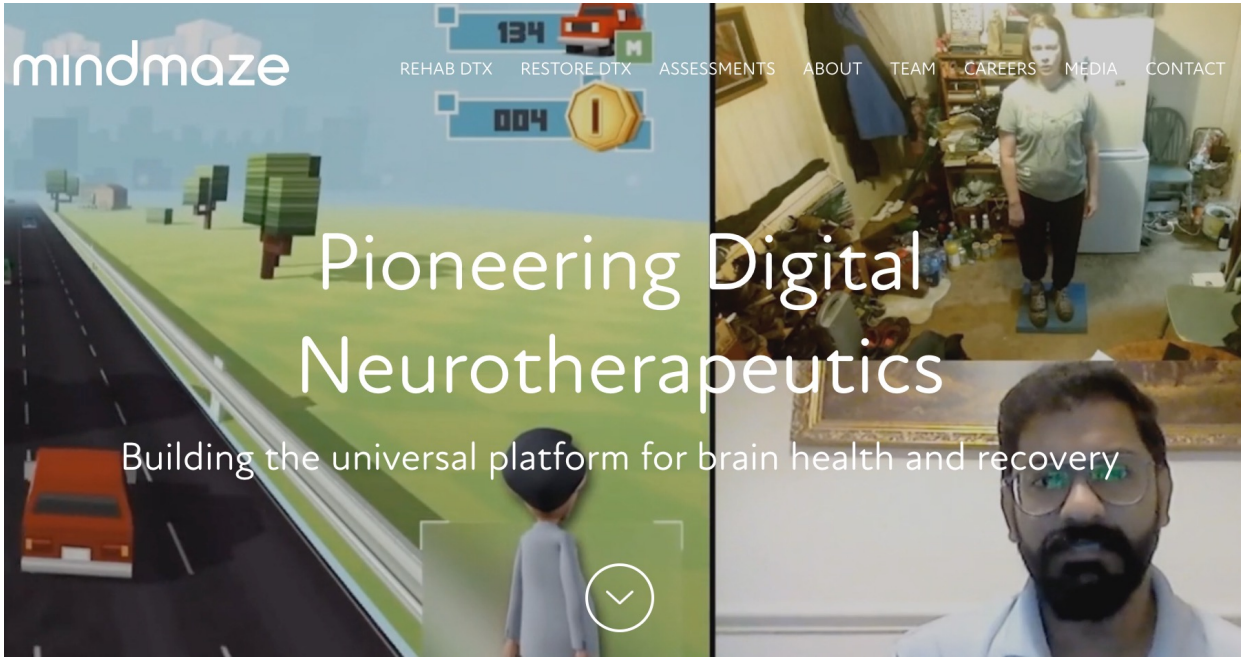
(b)



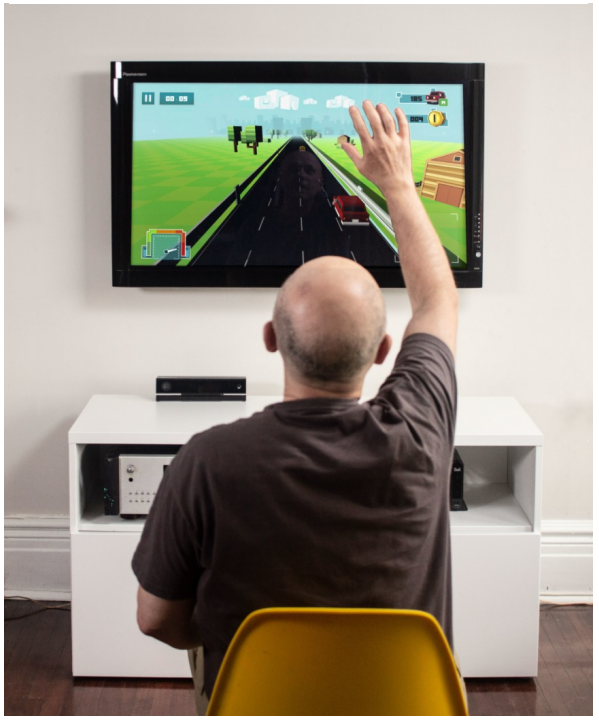
(c)

(d)

Assistive Technology



MindMotion™ GO for home use



MindPod Dolphin for Alzheimer's, Ageing & neurodegenerative conditions

With research indicating that exercise, particularly complex sports, is an effective way of engaging and training cognitive function through movement, MindPod Dolphin is ideally suited as an intervention for neurological diseases requiring the training of residual cognitive function. A location-based trial in an assisted-living facility for patients at risk of Alzheimer's Disease and Dementia was just completed. The US Department of Defence has also funded a trial to use MindPod Dolphin to prevent the onset of dementia in war veterans with TBI.

Importance of Computation in General

2024

This list is up to date as of 30 June 2024.

Rank	First quarter	Second quarter
1	Microsoft ▲3,126,000[32]	Microsoft ▲3,322,000[32]
2	Apple ▼2,648,000[33]	Apple ▲3,230,000[33]
3	Nvidia ▲2,259,000[34]	Nvidia ▲3,182,000[34]
4	Alphabet ▲1,893,000[35]	Alphabet ▲2,267,000[35]
5	Amazon ▲1,874,000[36]	Amazon ▲2,011,000[36]
6	Meta ▲1,238,000[37]	Meta ▲1,279,000[37]

Creates hardware to run LLM (Large Language Models) like GPT4 efficiently.

Owns Google

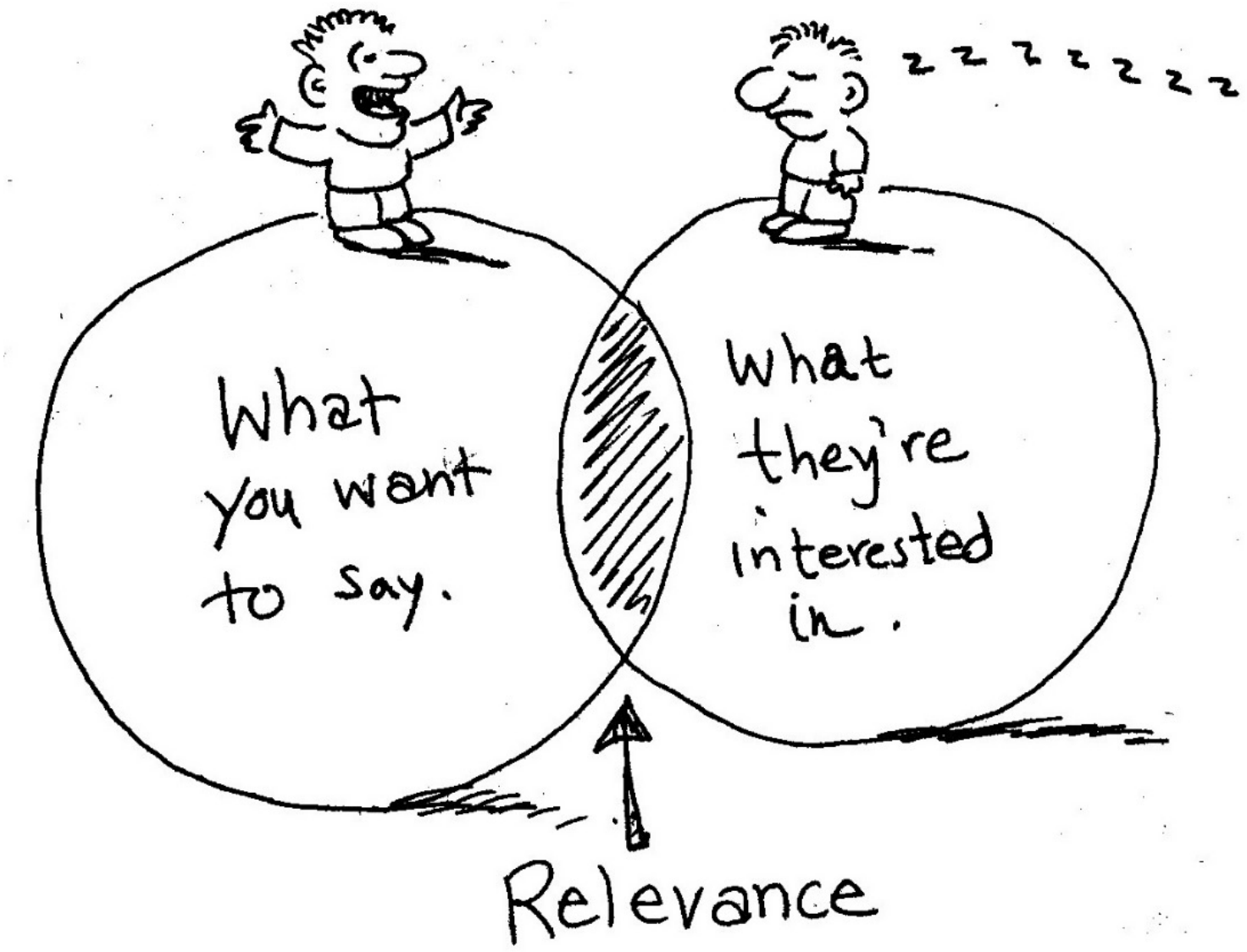
Owns Facebook

[https://en.wikipedia.org/wiki/List_of_public_corporations_by_market_capitalization]

Agenda for Today

- Motivation
- **Content of the course**
- Organization
- Topic 1: Representation of Information

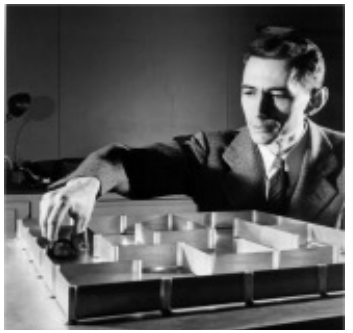
Content of ICC Theory Part



Content of Theory Part

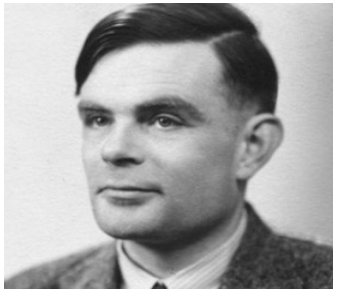
- **Foundations of Information and Communication**
  - Representation of Information
  - Sampling, reconstruction, compression
- **Foundations of Computation**
  - Algorithms, Complexity, Computability
- **Foundations of Systems**
  - Computer architecture, Memory Hierarchies,
    Storage and Network

Add Lovelace

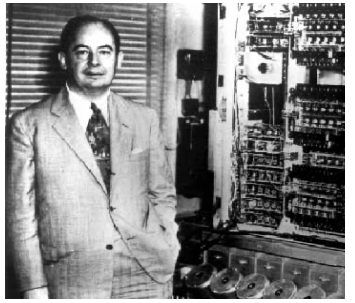


Claude Shannon

Grace Hopper



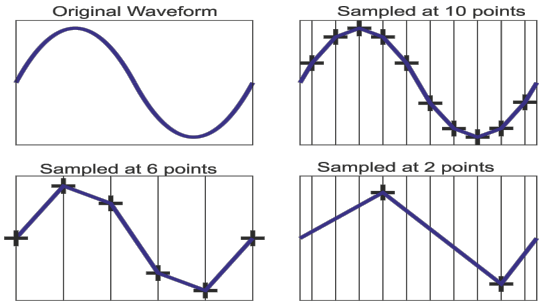
Alan Turing



John von Neumann

Foundations of Information and Communications

- Representation of information
  - System to represent information
  - Natural Numbers, Integers, reals (fix point and floating point)
- Sampling
  - Analog/Digital conversion
- Reconstruction
  - D/A conversion



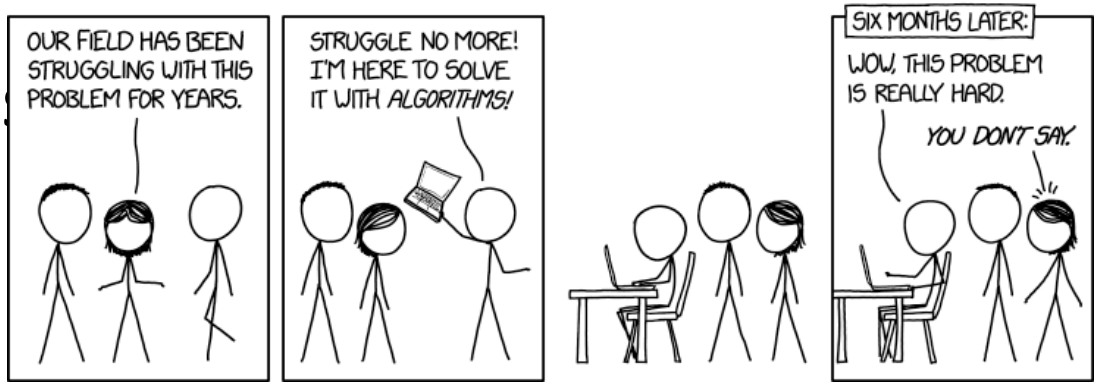
- Entropy (Shannon)
  - Entropy as a measure of the complexity of information
- Compression
  - Bit saving with or without loss of information to save transmission time or storage space

Link with the Programming Part

- In the programming part, you will learn about **types**, which determine how a computing device interprets a sequence of 0s and 1s. We will learn different interpretation methods used by computers.
- Computers work with digital signals. Most signals in the real world are analog. We will see how to transfer an analog signal into a digital signal and vice versa.
- We produce a lot of data. We will see how to compress this data to use less space.

Foundation of Computation

- Algorithms
  - Basic elements
  - Complexity (approx.)
- Computation strategies
  - Iteration, recursion, top-down/bottom-up, divide & conquer, etc.
- Theory of computation
  - The possible and the impossible



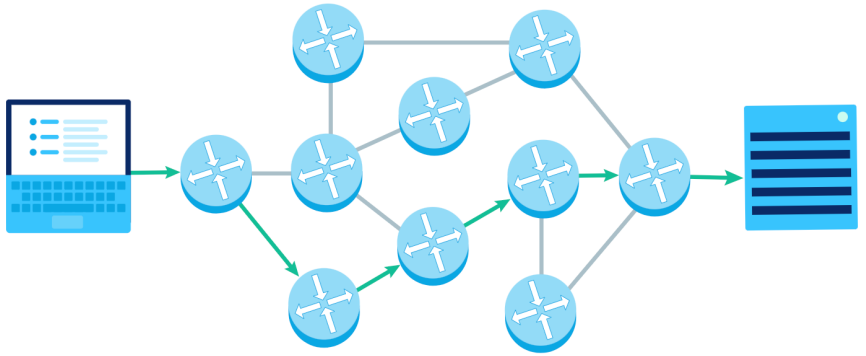
Here to Help
[https://xkcd.com/1831//]

Link with the Programming Part

- In both parts (theory and programming) you will train yourself in writing **algorithms**. In the programming part you will write them in C++, in the theory part we will use **pseudo-code,** which is a simplified version of a **programming language** like C++.
- We use pseudo-code because it is simple to write and for the theory part, the code does not need to compile.
- To pass from the pseudo-code to a code that a computer understands, it is necessary to master a programming language, in our case C++.
- In the theory part, we will focus on the correctness and **efficiency** of an algorithm. We will learn how to measure efficiency and we will discuss for which problems one can create algorithms.

Fundamentals of Systems

- Architecture
  - Program to executable code
  - Processor (CPU)
- Hierarchical memories
  - Cache
- Network
  - Types and architecture of networks (Internet)
  - IP protocol: how does a computer know where to send a message?



[https://www.khanacademy.org/]

Link with the Programming Part

- In the programming part you will use a **compiler** to translate your program so that the **processor** of your computer (e.g., Intel, ARM, AMD,…) understands it.
- In the theory part, you will learn about the core parts of such a processor.
- We will discuss how a program (that you write in the programming part) is executed by a computer.
- We will also see how the speed of computation can be influenced by the architecture.

Summary

- This course aims to explain key concepts of the "digital world", so you can **understand, influence, and transform** this world.
- With the help of computing **Life Sciences** will shaping the future like no under discipline.

Agenda for Today

- Motivation
- Content of the course
- **Organization**
- Topic 1: Representation of Information

Organization

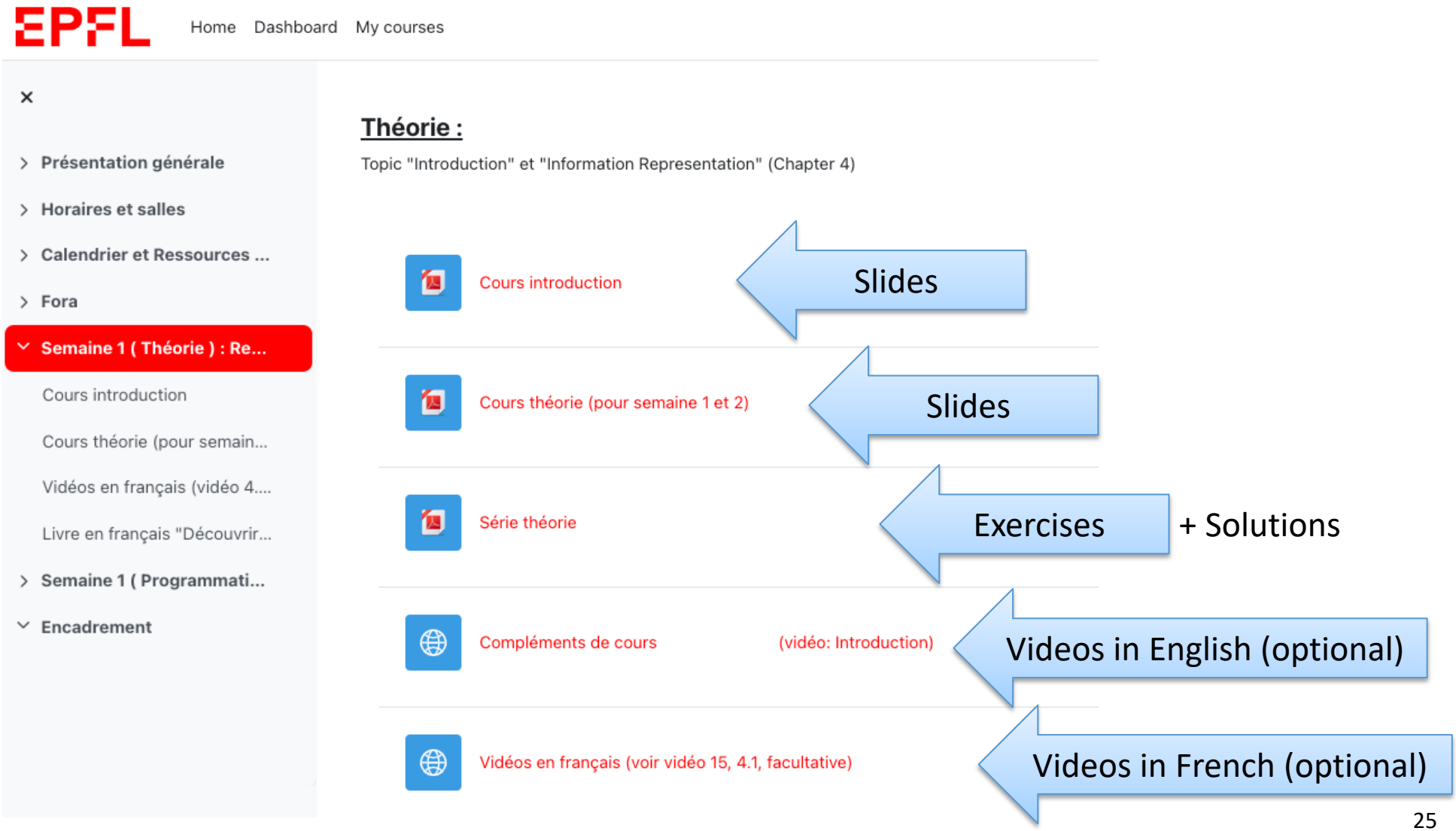
Information and Material

You will find all the information and material on Moodle (either directly or as links).

Moodle CS-119(g)

https://moodle.epfl.ch/course/view.php?id=15751

Moodle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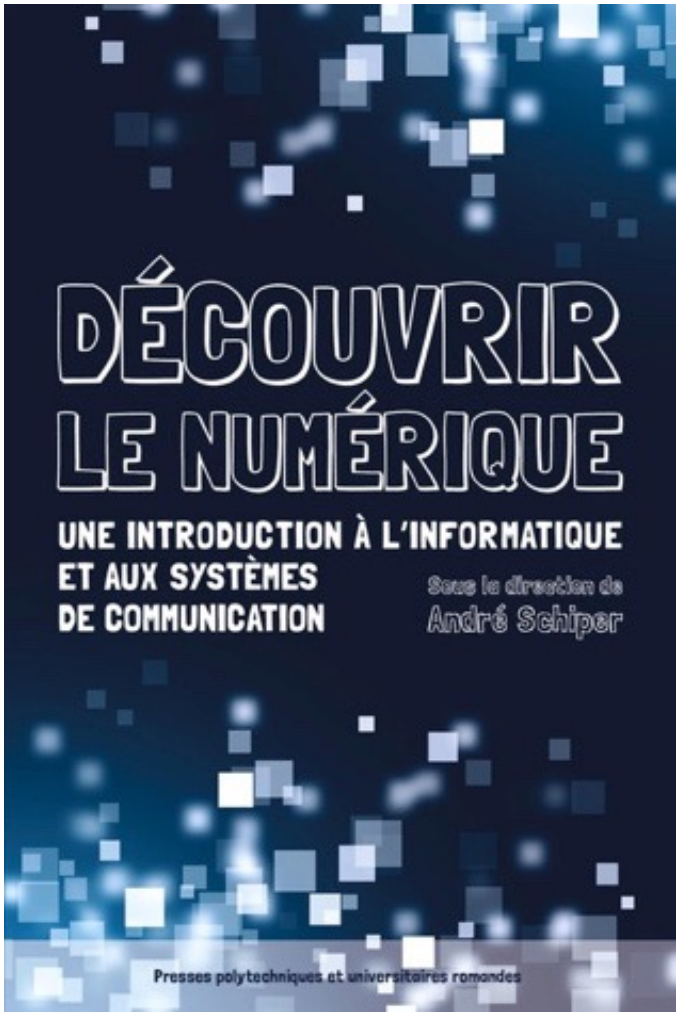
Calendrier et Ressources ...
Fora
Semaine 1 (Théorie) : Re...
Cours introduction
Cours théorie (pour semain...
Vidéos en français (vidéo 4....
Livre en français "Découvrir...
Semaine 1 (Programmati...
Encadrement
Théorie :
Topic "Introduction" et "Information Representation" (Chapter 4)
Cours introduction
Slides
Cours théorie (pour semaine 1 et 2)
Slides
Série théorie
Exercises
+ Solutions
Compléments de cours
(vidéo: Introduction)
Videos in English (optional)
Vidéos en français (voir vidéo 15, 4.1, facultative)
Videos in French (optional)

Material



Lectures:

- Slides will be published on Moodle

Videos:

- See links on Moodle

Book:

- "Découvrir le numérique" – Une introduction à l'informatique et aux systèmes de communication edited by A. Schiper, PPUR, 2016

Team

- Instructors:
  - Dr. Jamila Sam (Part Programming)
  - Dr. Barbara Jobstmann (Part Theory)
- Teaching Assistants (PhD students):
  - Miguel Crespo Castaño (programming)
  - Martin Everaert (programming)
  - Ekaterina Kutsenok (administration)
  - Haoqi Wang (theory)
- Student Assistants (Bac/MSc students)
  - 16 assistants for exercise sessions (**13 for theory**, 15 for programming)

Schedule

	Monday	Tuesday	Friday
8h-10h		Programming (4 rooms)	
9h-11h			Theory (Rolex*)
12h-13h	Programming (CO1)		
15h-16h			Theory (5 rooms)

***Exams will be in different rooms! Check Moodle!**

Extra sessions ("**appui**") **Mondays 18h-19h** and **Thursdays 17h30-19h** (starting Sep 25) in **CO 020**.

Theory Exercises: Friday, 15h-16h

- Multiple classrooms
  1. INR219 (79 places): family name starting with A to D
  2. INM201 (36 places): E to G
  3. INM10 (62 places): H to M
  4. INM11 (42 places): N to Rh
  5. INF119 (54 places): Ri to Z
- Ed Discussions: https://edstem.org/eu/courses/647/discussion/

Theory Exercises

- Available in Moodle (we will not print them for you!)

- You are expected to **start** them **before** the exercise session and **finish them at home.**
- Make use of the assistants! Ask for help!
- Theory exam questions will be similar to the exercises

Agenda (Theory)

* Different room(s)

Week	Date	Topics
1	Sep 13	Introduction + Representation of Information
2	Sep 20	Representation of Information
3	Sep 27	Sampling of signals I
4	Oct 4	Sampling of signals II
5	Oct 11	Data compression I
6	Oct 18	Data compression II
7	**Oct 25**	**Fall break (no lecture and exercises)**
8	Nov 1 **Sat, Nov 2***	Q&A session **Theory Mid-term Exam**
9	Nov 8	Computation and Algorithms I (control structures, imperative)
10	Nov 15	Computation and Algorithm II (recursive algorithms)
11	Nov 22	Theory of computation (computability)
12	Nov 29	Computer Architecture
13	Dec 6	Memory Hierarchies (+ Network)
14	**Dec 13***	**Final Exam (Programming + Theory)**
15	Wed, Dec 18 Fri, Dec 20	**Submission of mini-project** **No lecture and exercises**

Questions?