

Immunoinformatics taught to middle and high school pupils in IMGT®

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Abstract

IMGT®, the international ImMunoGeneTics information system® (<http://www.imgt.org>) (Lefranc *et al.*, 2015), is the global reference in immunogenetics and immunoinformatics (Lefranc 2014). In 2019, for the first time, two pupils were welcomed within the team and introduced to immunoinformatics thank to the “Apprentis Chercheurs” program founded by the association l’Arbre des Connaissances. This article describes the method, and pedagogical approaches used, and demonstrates that immunoinformatics can be successfully taught to pupils of middle and high school.

Introduction

The association **l’Arbre des Connaissances**¹ founded by researchers to promote dialogue between scientists and the general public, set up since 2004 a program named “Apprentis Chercheurs” in Paris. This program allows middle and high school pupils to explore the different facets of research throughout the school year by immersion in research laboratories. The program was quickly replicated in other regions of the country. The local project coordinator is **Genopolys**². Once per month, the pupils work on their scientific project according to the thematic area of the laboratory. At the end of the school year, Genopolys organises a conference, where the pupils present their work in public (school director, rector of the academy, Arbre des connaissances, researchers, supervisors, teachers, family, *etc.*) and receive a certificate of research initiation.

For the 2019 program, IMGT®, for the first time, received Tessa (middle school pupil) and Jean-Baptiste (high school pupil) in the laboratory to introduce them to a relatively recent scientific field resulting from the fusion of two domains, namely informatics and immunology. To accomplish this goal, the IMGT® biocuration team established planning of the different sessions, topics and resources to be discussed (cf Table 1). This planning was divided into three parts, the first part covered the basics

of biology and immunology, the second was focused on bioinformatics, and the last part was an introduction to immunoinformatics. The purpose of these sessions was to introduce the pupils to the analysis of antibodies using bioinformatics tools.

Methods and pedagogical approaches

The delivered sessions had both a theoretical and a practical component. At the beginning of each session and before carrying out the project, it was essential to discuss with the pupils to make sure that they had understood what they were about to do, how they were supposed to do it and the importance of the task. Therefore, each topic started with a lecture or a video projection, which was a reportage or a documentary. After each projection, the content was addressed with many more details and the different questions of the pupils were discussed. Concerning the practical part of the sessions, the pupils’ project differed based on the topic. For example on the topic of animal and plant cells, the IMGT® curators had drawn down, separately, all the components of those cells and asked the pupils to put together all these pieces to build a 2D mock-up of an animal and a plant cell. For the immunology project, the pupils played an online game called **Leucowar**³ to understand better the immune response.

¹<http://arbre-des-connaissances-apsr.org/>

²<http://www.genopolys.fr>

³<http://philippe.cosentino.free.fr/productions/leucowar/>

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Table 1. Detailed program of the different topics discussed during the sessions as well as the projects carried out and resources.

Contents	Topics	Resources	Project applications
Biology and immunology	<ul style="list-style-type: none"> - Overview of the body systems - Immune system - Animal and plant cells - DNA/RNA structure - Protein synthesis - Genetics engineering 	https://www.youtube.com/watch?v=vAz_9_Jesbo https://www.youtube.com/watch?v=w_MsGXYMv3c https://www.youtube.com/watch?v=jSRMqO0e908 https://www.youtube.com/watch?v=to_62MXI8-o https://www.youtube.com/watch?v=tf3_k0-MQzc https://www.youtube.com/watch?v=iJE_FlrA0io	<ul style="list-style-type: none"> - Build a 2D mock-up of an animal and plant cells - Play an online game Leucowar - Quizzes on DNA/RNA, protein synthesis and genetic engineering
Bioinformatics	<ul style="list-style-type: none"> - Introduction to Bioinformatics - Function of Bioinformatics - Presentation of generalists databases - Common sequence analysis 	https://www.youtube.com/watch?v=CLV1nrzGyBA https://www.youtube.com/watch?v=xK9vOjvYoUM https://www.youtube.com/watch?v=0N3ize9CDwY	<ul style="list-style-type: none"> - Exploration of the databases NCBI and EBI - Blast analysis to compare sequences (Blast) - Multiple sequence alignment (ClustalOmega) - Phylogenetic tree (Phylogeny)
Immuno-informatics	<ul style="list-style-type: none"> - Introduction to Immuno-informatics - Presentation of specialised databases for Immunogenetics - Analyse of antibody genes 	http://www.imgt.org/IMGTIndex/factsbook.php http://www.imgt.org	<ul style="list-style-type: none"> - Exploration of IMGT/GENE-DB and IMGT/LIGM-DB specialised databases - Annotation of antibody genes (internal tool) - Analysis of rearranged antibody genes (IMGT/V-QUEST)

Quizzes to test the knowledge acquired by pupils were carried out, which helped us to know what topics were well understood by the pupils and which subjects needed to be revisited. At the end of each session, there was some time dedicated to collect and organise the information the pupils wanted for their end of year presentation. The last session was devoted to a rehearsal of the pupils' presentation in the IMGT® team.

Topics discussed

The first two sessions were used as a reminder of biology and immunology topics. We started with an overview of the different body systems, their functions, and how they interact with each other. We paid particular attention to the immune system and introduced some basics of immunology such as the different types of immune response, tolerance and system disorder. The different cells types, their structure, their component as well as their function were discussed in a session entitled cellular biology. Genetic engineering and what can be done with it as well as protein synthesis were addressed afterwards. The different types of antibody genes, their rearrangement process with an example, at the molecular level, of the synthesis of an antibody in humans, were presented in detail.

The huge amount of data accumulated from human and others species and the necessity to analyse them was an excellent topic to introduce the field of Bioinformatics, its use and the type of questions that can be answered with it. The pupils explored different publicly available databases and servers such as the **NCBI**⁴ and **EBI**⁵ resources.

⁴<https://www.ncbi.nlm.nih.gov/>

⁵<https://www.ebi.ac.uk/>

They extracted a gene sequence, which gave them a lot of satisfaction, and in parallel demystified the procedure of getting hold of gene sequences. Different available output files format were introduced such as fasta, genbank and embl, along with their features. Additionally, the pupils performed various analyses such as the pairwise sequence comparison and the extraction of similar sequences from these databases for functional assignment (Johnson *et al.*, 2008). The pupils carried out multiple sequence alignment using different online tools and reconstructed a phylogenetic tree to visualise the molecular relationships of species through their genes.

Immuno-informatics is a discipline which uses informatics to the study of molecules of the immune system (Tomar and De, 2014). Therefore, it is crucial to have various information on those molecules, which is the primary responsibility of the curators of IMGT® who analyse, interpret and integrate immunological information into databases and data repositories. For this part, as for the bioinformatics topic, the pupils explored two specialised databases, IMGT/LIGM-DB (Giudicelli *et al.*, 2006) and IMGT/GENE-DB (Giudicelli *et al.*, 2005). The pupils were shown how to identify and annotate different types of antibody genes on genomic sequences (Lane *et al.*, 2010) and analysed rearranged sequences (Giudicelli *et al.*, 2004).

Conclusion

Based on the pupils' final presentation, their involvement and engagement during the monthly sessions as well as the evaluation of the internship from both the pupils and their teachers, we feel confident that this undertaking was a successful first-time introduction of immuno-informatics to middle and high school pupils.

We are convinced that immunoinformatics can be successfully taught to this public and we presented this article in the hope that more people in the field will be encouraged to introduce pupils to this exciting, fast-moving and promising scientific field.

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