Learning Outcomes – Bioinformatics Graduate Programs

Last Updated March 14, 2021

Bioinformatics at the University of Guelph

Bioinformatics refers to the development or application of innovative computational, statistical, or mathematical methods for the analysis of large biological datasets. Bioinformatics projects may address needs relating to study design; data acquisition and project management; systems for storing, searching, and accessing data; novel algorithm development; applying or combining sophisticated methods into data analysis pipelines; and/or data visualization and communication.

Reflecting the inter-disciplinary nature of bioinformatics, all graduate students are guided by a diverse Advisory Committee consisting of at least one life scientist and at least one specialist in the computational or mathematical sciences. Teaching teams for the bioinformatics programs are similarly diverse, such that students gain a range of perspectives. The curriculum features the analysis of data from molecular biology, while general and transferable data science skills are also stressed. Research projects span a wide range of topics, including environmental health, biodiversity and evolution, medical and veterinary science, agriculture including plant and animal breeding, image processing, machine learning, biomathematical methods development, and statistical bioinformatics.

The bioinformatics programs at the University of Guelph are particularly suited to students with a strong background in biology and genetics and an interest in data analysis. Coursework provides training in computer programming and statistics in the context of bioinformatics and data science, providing a background for thesis or major research project research. Research topics may be similar to those of other students in the home department of the primary advisor but have a stronger analytical focus. Career paths of alumni include: bioinformatician, data scientist in diverse sectors, software developer, research scientist, and molecular biologist.

Learning Outcomes for Three Graduate Programs in Bioinformatics at Guelph

The University of Guelph is committed to outcome-based pedagogical approaches and clear expectations for students. The below program-specific learning outcomes are arranged to reflect the university-level graduate learning outcomes, which span programs.

MSc in Bioinformatics Learning Outcomes

Through successfully completing the MSc in Bioinformatics program, students should be able to:

1. Critical and Creative Thinking

- *Contribute to the advancement of science, through formulating clear study goals or hypotheses and designing research to meet the goals*
- *Conduct data exploration and test hypotheses through well-reasoned methodological choices*
- *Program accurately and efficiently in two or more computer languages commonly used in bioinformatics*
- *Solve problems in novel and creative ways in a sub-area of specialization in bioinformatics*

Evidence of success in this area will involve integrating knowledge from two or more disciplines (such as biology and statistics or medicine and computer science) to solve problems in the student's area of research. Students will receive guidance towards these learning outcomes through advisorship by a diverse Advisory Committee. Originality in the application of knowledge is expected for the MSc level. Technical proficiency is also required of MSc in Bioinformatics students, and students must have sufficient depth and breadth of knowledge and skills to complete an original thesis that advances science. This may involve applying computational tools to address a biological hypothesis or developing a novel bioinformatics tool.

2. Literacy

- *Exhibit professional-level literacy, as demonstrated through reading and critically interpreting the scientific literature and assessing quantitative evidence*

Evidence of success in meeting this learning outcome will include a literature review that synthesizes current evidence in an area of bioinformatics specialization and identifies a gap either in biological knowledge that can be addressed through application of tools or a gap in available bioinformatics tools. A short literature review and thesis proposal will be presented by MSc students to their Advisory Committee by the end of semester 2. Final evidence of this learning outcome would be the introduction and interpretation sections of the thesis document.

3. Global Understanding

- *Recognize global challenges and be able to collaborate with individuals having diverse perspectives and varied cultural and academic backgrounds*

Bioinformatics is a highly collaborative and inter-disciplinary subject. Evidence of success in this area will include collaboration in group projects in coursework, with lab members, with Advisory Committee Members, outside collaborators, etc. Students should critically examine their research problem from two or more academic perspectives, such as biological and statistical. An inter-disciplinary perspective should be reflected in the thesis study design and interpretation. Students should be able to articulate

how their research area contributes to society more broadly, such as evidenced during the introductory section of the final thesis research oral presentation.

4. Communicating

- *Communicate ideas clearly and effectively to diverse audiences in visual, written, oral, and computational formats*

Evidence of success in this area will include presenting effective oral presentations in coursework and at thesis defence that are accessible to a diverse audience. The thesis document will be written in a clear style understandable to biologists and informatics specialists, which also increases student understanding. Visual communication will include presentations and preparation of graphics that convey complex data and ideas. Students will prepare correct, well-commented, reproducible computer code in pursuit of their research goals.

5. Professional and Ethical Behaviour

- *Model ethical professional behaviour, including transparency and honesty in analysis and reporting of results, ethical reasoning during study design, and engaging respectfully with others*

Evidence of success in this area will include transparency in analytics, including full accounting of methods in the thesis document as well as preparing reproducible analyses and code. Students are encouraged to make their code publicly available through online repositories, when suitable. Engaging respectfully with others will include contributing to group projects during coursework and working with a diverse Advisory Committee, lab members, and others to achieve success in the MSc program. Additionally, students should demonstrate an awareness of ethics relating to the societal impact of their work. The Advisory Committee will provide oversight of performance in this area.

Master of Bioinformatics Learning Outcomes

The Master of Bioinformatics (MBINF) is a coursework-based Masters program, which includes a major research project of 1-2 semesters. Some coursework is shared between the MBINF and MSc programs, and learning outcomes are similar. While originality and emerging independence as a scientist receive more focus in the MSc program, the MBINF program more strongly emphasizes technical skills and the application of knowledge. Differences from the MSc learning outcomes are marked in bold. Through successfully completing the Master of Bioinformatics program, students should be able to:

1. Critical and Creative Thinking

- *Contribute to the advancement of science, through formulating clear study goals or hypotheses and* ***contributing to the design of research*** *to meet the goals*
- *Conduct data exploration and test hypotheses through well-reasoned methodological choices*
- ***Program accurately*** *in two or more computer languages commonly used in bioinformatics*
- *Solve* ***analytical*** *problems in novel and creative ways*

Evidence of success in this area will involve integrating knowledge from two or more disciplines (such as biology and statistics or medicine and computer science) to solve problems **during coursework and the BINF*6999 research project**. Students will receive guidance towards these learning outcomes through **coursework and advisorship by two BINF*6999 project advisors with diverse expertise**. **Competent application of knowledge** is expected for the MBINF program, and students must have sufficient depth and breadth of knowledge and **technical** skills **to write original code to solve bioinformatics problems**. **BINF*6999 projects** may involve applying computational tools to address a biological hypothesis or developing a novel bioinformatics tool.

2. Literacy

- *Exhibit professional-level literacy, as demonstrated through reading and critically interpreting the scientific literature and assessing quantitative evidence*

Evidence of success in meeting this learning outcome will include **writing literature critiques during coursework as well as writing the introductory and discussion sections of the BINF*6999 report. The report will briefly** synthesize current evidence in an area of bioinformatics specialization and identify a gap either in biological knowledge that can be addressed through application of tools or a gap in available bioinformatics tools.

3. Global Understanding

- *Recognize global challenges and be able to collaborate with individuals having diverse perspectives and varied cultural and academic backgrounds*

Bioinformatics is a highly collaborative and inter-disciplinary subject. Evidence of success in this area will include collaboration in group projects in coursework, with lab members, with **project advisors**, outside collaborators, etc. Students should critically examine their research problem from two or more

academic perspectives, such as biological and statistical. An inter-disciplinary perspective should be reflected in the **BINF*6999 study** design and interpretation. Students should be able to articulate how their research area contributes to society more broadly, such as evidenced during the introductory and conclusion sections of the **final poster or oral presentation for BINF*6999**.

4. Communicating

- *Communicate ideas clearly and effectively to diverse audiences in visual, written, oral, and computational formats*

Evidence of success in this area will include writing well-commented, reproducible computer code **throughout their coursework and** in pursuit of their research goals. Students will also present effective oral presentations in **coursework and in lab meetings** that are accessible to a diverse audience. The **BINF*6999 project** document will be written in a clear style understandable to biologists and informatics specialists, which also increases student understanding. Visual communication will include **a poster or oral presentation for BINF*6999** and preparation of graphics **throughout coursework** that convey complex data and ideas.

5. Professional and Ethical Behaviour

- *Model ethical professional behaviour, including transparency and honesty in analysis and reporting of results, ethical reasoning during study design, and engaging respectfully with others*

Evidence of success in this area will include transparency in analytics, including full accounting of methods in the **coursework assignments and the BINF*6999 final project report** as well as preparing reproducible analyses and code. Students are encouraged to make their code publicly available through online repositories, when suitable. Engaging respectfully with others will include contributing to group projects during coursework and working with **diverse project advisors**, lab members, and others to achieve success in the MBINF program. Additionally, students should demonstrate an awareness of ethics relating to the societal impact of their work. The **project advisors** will provide oversight of performance in this area.

PhD in Bioinformatics Learning Outcomes

The PhD in Bioinformatics program involves undertaking a significant, original work of research. Graduates of the PhD program will become an expert in their area of specialization and will be well prepared to take on future roles as an independent and collaborative researcher. Differences from the MSc learning outcomes are marked in bold below. Through successfully completing the PhD in Bioinformatics program, students should be able to:

1. Critical and Creative Thinking

- *Contribute to the advancement of science, through formulating clear study goals or hypotheses and designing **and publishing original** research to meet the goals*
- *Conduct data exploration and test hypotheses through well-reasoned methodological choices, **recognizing the strengths and limitations of various approaches and demonstrating a thorough understanding of the state-of the-art in an area of specialization***
- *Program accurately and efficiently in two or more computer languages commonly used in bioinformatics*
- *Solve problems in novel and creative ways in a sub-area of specialization in bioinformatics **and make a scientific impact in the chosen sub-discipline***

Evidence of success in this area will involve integrating knowledge from two or more disciplines (such as biology and statistics or medicine and computer science) to solve **significant scientific** problems in the student's area of research. Students will receive guidance towards these learning outcomes through advisorship by a diverse Advisory Committee. Originality in the application of knowledge **and generation of new knowledge** is expected for the PhD level. Technical proficiency is also required of PhD in Bioinformatics students, and students must have sufficient depth and breadth of knowledge and skills to complete an original thesis that advances science. This may involve applying **sophisticated** computational tools to address a biological hypothesis or developing a **substantially novel** bioinformatics tool. **Doctoral-level research is expected to be publishable in a reputable, peer-reviewed scientific journal or conference proceedings.**

2. Literacy

- *Exhibit **expert**-level literacy, as demonstrated through reading and critically interpreting and **synthesizing** the scientific literature and assessing quantitative evidence*

Evidence of success in meeting this learning outcome will include a literature review that synthesizes current evidence in an area of bioinformatics specialization and identifies a gap either in biological knowledge that can be addressed through application of tools or a gap in available bioinformatics tools. A **substantial** literature review and **novel** thesis proposal will be presented by PhD students to their Advisory Committee by the end of semester 2. Final evidence of this learning outcome would be the introduction and interpretation sections of the thesis document and final oral presentation.

3. Global Understanding

- *Recognize global challenges and be able to collaborate with individuals having diverse perspectives and varied cultural and academic backgrounds*

Bioinformatics is a highly collaborative and inter-disciplinary subject. Evidence of success in this area will include collaboration **or cooperation** with lab members, with Advisory Committee Members, outside collaborators, etc. Students should critically examine their research problem **and integrate approaches or insights** from two or more academic perspectives, such as biological and statistical. An inter-disciplinary perspective should be reflected in the thesis study design and interpretation. **The doctoral thesis proposal should be placed in the context of the current scientific state-of-the art and society, with ideas expressed regarding a longer-term research program.** Students should be able to articulate **clearly to a diverse audience** how their research area contributes to society more broadly, such as evidenced during the introductory section of the final thesis research presentation.

4. Communicating

- *Communicate ideas clearly and effectively to diverse audiences in visual, written, oral, and computational formats*

Evidence of success in this area will include presenting effective oral presentations in **research group meetings** and at thesis defence that are accessible to a diverse audience. The thesis document will be written in a clear style understandable to biologists and informatics specialists, which also increases student understanding. Visual communication will include presentations and preparation of graphics that convey complex data and ideas. Students will prepare correct, well-commented, reproducible computer code in pursuit of their research goals.

5. Professional and Ethical Behaviour

- *Model ethical professional behaviour, including transparency and honesty in analysis and reporting of results, ethical reasoning during study design, engaging respectfully with others, and **taking a leadership role in designing their research***

Evidence of success in this area will include transparency in analytics, including full accounting of methods in the thesis document as well as preparing reproducible analyses and code. Students are encouraged to make their code publicly available through online repositories, when suitable. Engaging respectfully with others will include working with a diverse Advisory Committee, lab members, and others to achieve success in the PhD program. Additionally, students should demonstrate an awareness of ethics relating to the societal impact of their work. The Advisory Committee will provide oversight of performance in this area. **Doctoral students should progress towards professional independence throughout their program and take on a leadership role in developing their research. Upon graduation, students should be prepared to work in professional environments, can be relied upon to draw conclusions and recommendations supported by evidence, and can be trusted to communicate the levels of uncertainty involved in complex decisions. Graduates will be prepared to undertake independent as well as collaborative research.**

This document was written by members of the 2019-20 and 2020-21 Bioinformatics Graduate Curriculum Committees: Sarah Adamowicz, Karl Cottenie, Alicia Halhed, Lewis Lukens, Elizabeth Mandeville, Khurram Nadeem, Jessmyn Niergarth, Monica Wong.