Faculty of Arts & Science
Major Modification to Program

<table>
<thead>
<tr>
<th>Program Title (POSt Code)</th>
<th>Specialist in Statistical Science: Theory and Methods (ASSPE2289)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit</td>
<td>Department of Statistical Sciences</td>
</tr>
<tr>
<td>Effective Date</td>
<td>March 1, 2020</td>
</tr>
</tbody>
</table>

Brief Description of the Proposed Changes

*Using bullet points, briefly summarize the main aspects of the changes (e.g. addition of required courses, restructuring higher-year course option, introduction of Streams, etc.). Specify changes to program description, requirements, and program learning outcomes.*

- Program learning outcomes have been redefined.
- We have re-named the program from Statistics to Statistical Science: Theory and Methods to better reflect the new learning outcomes and appropriately differentiate between our two specialist programs in statistics.
- To reflect the new program learning outcomes, we are making program changes in a staged implementation. In 2017-18, we introduced new courses (STA237H1, STA238H1, STA314H1) and made our first year course (STA130H1) required. In 2018-19 we are making some changes to how students can choose among our 3rd and 4th year course requirements. Future changes will be implemented as resources permit.

Program information

**Program Description**

New program name: Specialist in Statistical Science: Theory and Methods (was: Specialist in Statistics)

Statistical Science encompasses methods and tools for obtaining knowledge from data and for understanding the uncertainty associated with this knowledge. The purposes of the undergraduate programs are to: (1) equip students with a general framework for obtaining knowledge from data; (2) give students skills that they are able to flexibly apply to a variety of problems; and (3) to provide students with the ability to learn new methods as needs, data sources, and technology change.

The Specialist Program in Statistical Science: Theory and Methods emphasizes probability and the theory of statistical inference as underlying mathematical frameworks for statistical data analysis. Students in the program acquire advanced expertise in statistical theory and methods, as well as an understanding of the role of statistical science to solve problems in a variety of contexts. The successful student will also acquire skills in mathematical reasoning, computational thinking, and communication in the context of solving statistical problems.
**Enrolment Requirements**

*If a change in program type (e.g. Type 1 to Type 2) or a modification to existing enrolment restrictions is proposed, highlight changes to the previous requirements. Modifications to enrolment requirements will be reviewed in Committee on Admissions as well as Curriculum Committee.*

(The following enrolment requirements were approved in 2017-18 and will be in effect in the 2019 enrolment period.)

This is a limited enrolment program (Type 2L) that can only accommodate a certain number of students. Eligibility is based on the following criteria:

For students entering the program after first year:

1. Completion of at least 4.0 FCEs including:
   STA130H1, CSC108H1/CSC120H1/CSC121H1/CSC148H1, MAT223H1/MAT240H1, MAT137Y1 with a minimum grade of 65% or MAT157Y1 with a minimum grade of 65%
   AND
2. An average of the grades in STA130H1 and MAT137Y1/MAT157Y1 that meets the department's annual cut-off

For students entering the program after second year:

1. Completion of:
   CSC108H1/CSC120H1/CSC121H1/CSC148H1, MAT223H1/MAT240H1, MAT237Y1/MAT257Y1, STA257H1 with a minimum grade of 65% and STA261H1 with a minimum grade of 65%
   AND
2. An average of the grades in STA257H1 and STA261H1 and MAT237Y1/MAT257Y1 that meets the department’s annual cut-off

**Completion Requirements**

*State the completion requirements as they are to appear in the Calendar. Indicate in particular which courses are required in first year. Begin with the current calendar copy and use highlight or track changes to show the changes. The total FCEs, including specific courses required for enrolment, must be: Minors – 4.0 FCE, Majors – 6.0-8.0 FCE, Specialists – 10.0-14.0 (exceptions up to 16.0) FCE.*

(11.0 full courses or their equivalent)

First Year:
    STA130H1, CSC108H1/CSC120H1/CSC121H1/CSC148H1, MAT137Y1/MAT157Y1, MAT223H1/MAT240H1
Second Year:
    MAT224H1/MAT247H1, MAT237Y1/MAT257Y1; STA257H1, STA261H1
Higher Years:
1. STA302H1, STA303H1, STA347H1, STA355H1, STA410H1, STA442H1
2. 2 full year courses from the given list:
   (STA414H1/CSC411H1), STA422H1, STA437H1, STA447H1, STA452H1, STA453H1, STA457H1, STA465H1, STA480H1
3. 1.5 full year courses from: ACT451H1, ACT452H1, ACT460H1; APM412H1; MAT327H1, MAT334H1/MAT354H1, MAT337H1/MAT357H1, MAT301H1/MAT347Y1, CSC297H1, CSC310H1, CSC336H1/CSC436H1, STA300 + level courses (excluding STA310H5)
Proposal Questions – General

Answers to all questions in this section are required. Even a brief answer will assist in reviewing changes when they are heard in governance. These answers will be entered on CM under the same field titles.

Rationale

Explain why the changes have been proposed, providing any additional information that may be helpful for review, or of relevance for Curriculum Committees. This may include connections to the unit’s priorities, recent reviews or institutional planning, or alignment with other programs. Be sure to note student input and benefit.

In the fall of 2016, the Department of Statistical Sciences began a major curriculum renewal project, supported by a grant from the Learning and Education Advancement Fund, and with the guidance of Jessie Richards, Curriculum Development Specialist in the office of the Vice-Provost, Innovations in Undergraduate Education. The curriculum changes proposed here reflect most of the outcomes of this exercise.

The curriculum changes are being implemented in a staged process. In 2017-18, minor modifications to the Statistics Major and Specialist programs in Statistics and Applied Statistics were approved. Beginning in March 2019, the introductory course STA130H1 will now be required for all students, and a new cluster of second year courses, STA237H1 and STA238H1 were approved, which will become the core of the statistics major program and a suitable follow-up to STA130H1. In addition, a new course in machine learning, STA314H1, was added to our course offerings. The changes proposed in this document reflect the major re-organization of our 3rd and 4th year program requirements to incorporate the program changes.

Our revised program learning outcomes fall into five themes: Theory, Methods, Computational Thinking, Professional Practice, and Problem Solving. To map our students’ development of proficiency in each of these themes, our third year courses have been categorized as courses in statistical theory, courses in design and analysis (addressing the program learning outcomes in methods), and computationally intensive courses. The development of the professional practice and problem solving skills will be introduced and reinforced in various ways in all of these courses, for example, through exercises that require communication of results for non-technical audiences, problems that require the adaptation of methods learned, and assignments that require the discussion of the relative merits and limitations of statistical methods in the context of an authentic problem. A subset of our 4th year courses have been identified to include significant experiences in data analysis (often through a project), through which proficiency in many of the learning outcomes related to professional practice and problem solving will be
developed and assessed. (See the Statistics curriculum map for the development of our program learning outcomes through the program.)

The program modifications proposed in this document reflect the alignment of required upper year courses with these new learning outcomes and the corresponding curriculum map. In third year, students will take a course in each of design (STA304H1/STA305H1), analysis (STA302H1, STA303H1), computationally intensive methods (STA314H1/STA365H1), and theory (STA347H1, STA355H1). Students choose 1.0 FCE from among the fourth year courses that have been identified to include significant experiences in data analysis. To reflect the emphasis on probability and the theory of statistical inference as underlying mathematical frameworks for statistical data analysis in the Specialist program in Statistical Science: Theory and Methods, students complete at least one FCE in theory at the 3rd year level (STA347H1, STA355H1) and 0.5 FCE in 4th year (STA447H1/STA452H1/STA453H1). The 4th year capstone experience (one of STA492H1, STA496H1 / STA497H1 / STA498Y / STA499Y1 or an internship) gives students a high impact integrative inquiry-based learning experience, in either professional practice or research, at the level of sophistication expected of graduates of this Specialist program.

In future years, as resources permit, we plan to introduce a new course in statistical computation and re-organize our 3rd year methods course sequence (STA302H1, STA303H1, STA304H1, STA305H1) to fully implement the outcomes of our modified program. We will also be working with instructors in key courses to enhance the development of skills in communication and computation and to introduce experiential learning components in a scaffolded way throughout the program.

**Impact**

*Specify the impact the changes may have on students or other units/programs. If courses listed in the program are offered by other units, include a letter of support from the head of that unit, speaking to enrolment controls and priority enrolment, if applicable.*

Impact of changes introduced to the Specialist programs this year will only affect some statistics courses offerings, particularly how many sections of each course will need to be offered. In 2020-21 we will begin offering a new course STA492H1: Seminar in Statistics, designed as a capstone for students in this specialist program.

The modified requirements to our 3rd and 4th year program requirements of the Specialist in Statistical Science: Theory and Methods ensure students acquire a deep understanding of the underlying mathematical frameworks for statistical data analysis and have exposure to intermediate computationally intensive courses. The modified program gives students greater flexibility in 4th year offerings, depending on their interests, while ensuring depth of understanding in both statistical theory and methods.

**Consultation**

*Describe consultation that has already been done within the unit, with outside units and with students, in particular if other units are affected or if resources are necessary to mount the changes. Indicate date of sign-off from external units, dates of meetings with students, etc.*

The proposed program changes are the result of a two-year curriculum renewal exercise. This exercise began in September 2016 with a department workshop, surveys of students and alumni, followed by a departmental learning outcomes development workshop. The new learning outcomes and programs were developed in 2016-17 by the departmental curriculum renewal committee and discussed at a departmental meeting. The new programs were discussed by the department in meetings throughout 2017-18.
Students in Statistics programs of study have been extensively consulted throughout this curriculum renewal project (through a survey, a town hall, and through students serving on our curriculum committee). These changes have been approved by the Statistics undergraduate committee and by the department faculty at a department meeting.

The proposed program changes have been informed by our initial consultations. In subsequent consultations, the modified programs have been universally and enthusiastically supported. Faculty members have been particularly supportive of the increased emphasis on computation, beginning in first year. Students have been particularly enthusiastic about the greater emphasis on statistical computation, predictive models, and modern methods in machine learning and Bayesian analysis. These are in demand in the work force and will introduce students to some research areas that have recently emerged.

**Diversity**

*How does the proposed program or modification support diversity? E.g through curriculum design supporting different learners, accommodation, etc.*

Regarding the addition of STA130H1 as a program requirement: Key learning outcomes in STA130H1 include the development of oral and written communication skills, with activities developed in collaboration with the English Language Learning (ELL) and Writing Instruction for TAs (WIT) teams, recognizing the large percentage (approximately 60%) of international students in statistics programs of study.

In higher years, students can take additional advanced statistics courses, or broaden their statistical training with complementary courses in mathematics, actuarial science, or computer science, depending on their interests and strengths (see program requirement 4.).

**Resource Implications**

*Provide a statement of the resource requirements for the program, and an indication of whether you can meet these requirements through your existing resources, or have received additional resources.*

No additional resources beyond those required to meet the demands of our current enrolment. There will be some reorganization of existing resources among courses.

The Department of Statistical Sciences hired a staff internship coordinator in 2018 who is developing opportunities, resources, and supporting professional training for internships for undergraduate students in programs of study in the Department of Statistical Sciences.

**Academic Context**

*Outline the context that explains why the program is designed this way, e.g. relation of program to discipline, students’ interests, career paths, etc.*

The discipline of statistics is evolving rapidly with the recent emergence of “data science” and “big data”. Statistics is foundational to data science and statistical reasoning is essential to maximize the full potential of new sources of data.

Coupled with this external context, the Department of Statistical Sciences has seen astounding growth in our undergraduate programs in statistics. Enrolment in statistics major and specialist programs of study is currently 3500 students, an over 12-fold increase in 10 years. These students are attracted to our programs by the growing demand for experts who can think with data.
The proposed modifications in statistical sciences programs address the knowledge, skills, and habits of mind needed of statisticians in the era of data science, while building on the traditional strengths of our department. The program changes include greater focus on predictive modelling and data from a wide variety of sources. The new learning outcomes reflect greater emphasis on communication, computation, and problem solving in novel contexts.

Faculty and TA Support

*Indicate how the modifications will be supported with existing faculty and Teaching Assistant resources. If new resources are needed, give more detail here about approvals obtained.*

The new program changes will require only minor changes in how our current teaching resources are distributed as students are reshuffled among some courses.

Learning Outcomes

*Explain how the change affects, or does not affect, the program learning outcomes, including disciplinary goals, relevant methodologies and skills acquired upon program completion.*

The changes in the program are motivated by our new program learning outcomes. See the attached document.

Statistical Science encompasses methods and tools for obtaining knowledge from data and for understanding the uncertainty associated with this knowledge. The purposes of the undergraduate programs are to: (1) equip students with a general framework for obtaining knowledge from data; (2) give students skills that they are able to flexibly apply to a variety of problems; and (3) to provide students with the ability to learn new methods as needs, data sources, and technology change.

Students in the major and all specialist programs of study in statistics will acquire core learning outcomes in statistical methods, theory, computation, and communication. The Specialist Program in Statistical Science: Theory and Methods emphasizes probability and the theory of statistical inference as underlying mathematical frameworks for statistical data analysis. Students in the program acquire advanced expertise in statistical theory and methods, as well as an understanding of the role of statistical science to solve problems in a variety of contexts.

Depth of Knowledge

*The achievement of several of a set of learning outcomes that contribute to mastery of an area through intensive study. Explain how particular courses allow students to achieve depth of knowledge, relating to the proposed change.*

The new introductory course, STA130H1, introduces students to the broad range of competencies required by modern statisticians including statistical reasoning in a variety of contexts for a variety of purposes, computational facility, ethical reasoning, and oral and written communication skills. Required courses in mathematics, computer science, and statistical theory ensure that by the end of 2nd year, students will have acquired the essential mathematical and computing background and the fundamental ideas of probability and statistical reasoning that will provide the foundation for deeper study. The 300-level courses in statistics provide in-depth study of statistical methodology, approaches to statistical practice, greater development of computational and problem solving skills, and, in the theory courses, deeper development of foundational mathematical ideas that underpin statistical methods. Many of the 300-level courses are pre-requisites to the 400-level courses that cover advanced aspects of statistical methodology, computation, and theory. Important topics in statistical reasoning can be traced through courses in the program with increasing levels of sophistication each year (for example, the fundamental ideas in statistical reasoning and statistical models in 2nd year courses lead to the methods covered in the courses in linear models at the 300-level STA 302/303/305, with more complex and leading-edge models covered in 400-level courses such as STA
Competencies

For these five categories, describe how each competency is developed within the modified program to the degree relevant to the area/discipline. If the program does not address a particular competency, explain why that competency is not relevant to your area/discipline and how students in your program are expected to attain that competency within their overall degree program.

Critical and Creative Thinking

The purposeful and reflective examination of knowledge and ideas beyond memory and recall, whereby students can make informed judgments, synthesize what they have learned, and apply their ideas in novel ways.

Statistical scientists need to be able to read and evaluate the relevance of both the statistics literature and the relevant literature in their area of application, they need to assess and evaluate alternative statistical methods in the context of any project they are working on, and they need to develop novel approaches and adapt existing methodology (and sometimes develop new methodology) in the process of applying their quantitative reasoning skills to imperfect practical problems in order to get the most information from the available data.

The second year courses in statistics develop the foundations of statistical reasoning and, for the student, initiate the development of a logical thought that is later brought to bear on problems requiring critical reflection prior to the use of statistical methods. In more advanced courses, this development continues as the creative process required to tackle complex practical problems is demonstrated by faculty members and reinforced and further developed through assignments and projects. In the final year of the program students will be required to take a 4th year course with an emphasis on applying advanced statistical methodology to solving authentic problems.

In the new seminar in statistics, students will critically analyse the contributions of recent scholarly work in the discipline.

Communication

The ability to express ideas, arguments, and facts to convey an intended message in a manner that is cogent and effective.

The development of oral and written communication skills begins in STA130H1 which includes communication intensive tutorials, developed in collaboration with the ELL and WIT programs. Communication is further developed throughout the program, with increasing sophistication. In courses in probability and statistical theory, students are required to produce concise mathematical arguments. In courses in statistical methodology, students are required to express the importance of their findings in the context of the practical problem for which the data were collected. All of the courses in the program emphasize the sound, logical, clear and direct presentation of arguments in solutions to assignments and tests.

Information Literacy

The ability to effectively find, evaluate, create, use and present knowledge, data and critical analyses for scholarly and other purposes.
In many of the advanced courses in the program, students gain experience in combining various types of information into a coherent argument. Beginning in STA130H1 and throughout their programs, students become proficient in the use of statistical software. In doing so, they learn how to find sample code and documentation for the software they are using.

In the new seminar in statistics, students will critically analyse recent scholarly work in the discipline.

**Quantitative Reasoning**
The ability to reason with basic mathematical, numerical and statistical concepts in order to enhance understanding of an area of study and to help navigate a data-driven world.

The practice of statistics concerns how to extract information from data to make reasoned conclusions and decisions in the presence of uncertainty. All of the mathematics and statistics courses required in the program develop students’ abilities in quantitative reasoning.

**Social and Ethical Responsibility**
The ability to engage in critical reflection upon questions of responsibility to oneself and society and to develop values of academic and personal integrity.

Appropriate use of statistical methods is essential to virtually all aspects of society. Statisticians have the obligation to carry out their work with competence, diligence and integrity, without bias, and conscious of the need to protect the privacy of data.

An introduction to ethical statistical practice is a specific topic in STA130H1. All of the courses in statistical methodology emphasize the importance of basing conclusions and decisions only on valid statistical models, the role bias can play in data collection and analysis, and the limitations of the statistical methods in the context of the practical problem for which the data were collected. Courses that emphasize data collection include discussions of the importance of careful planning to protect the subjects of the study from unnecessary risks and the researchers from unnecessary expense.

**Integrative, Inquiry-based Activity**
Activity that involves substantial investigation, synthesis of knowledge, and communication of results of the inquiry.

As part of our curriculum renewal project, the 4th year courses that students can choose among will include authentic assessments, requiring students to integrate the knowledge and skills acquired throughout the program towards the solutions of real-world problems. The development of facility to do this begins in STA130H1, which culminates with a project in which students analyze data towards learning from a current data set, typically from a business, non-governmental organization, or government agency, with results presented in a poster sessions.

In the new seminar in statistics, students will critically analyze recent scholarly work in the discipline. Alternatively, students will have the opportunity to participate in a guided research for course credit or in our developing internship program.
Implementation of Change in 2019-20

Program modifications approved in the 2018-19 cycle will be published in the 2019-20 Calendar. To allow students time to plan their course and program choices for the 2019-20 year, program modifications will be in effect for students starting with the 2020 enrolment period. The Governance Unit and the Office of the Faculty Registrar can work with you to prepare for implementation and communicate the change to students.

Use this space to identify any planning concerns/considerations you may have that are associated with this change (for example, adding newly created courses to requirements, preparing for changes to enrolment requirements, messaging to students about the changes, etc).

We now have a departmental staff person working on identifying and creating an academic structure for internship opportunities for students in programs of study in statistical sciences. The structure of this opportunity will evolve with the infrastructure being created in the Faculty of Arts and Science.
Major Modification to Program

Program Title (POS Code)  Specialist in Statistical Science: Methods and Practice and new focus in Pharmacology and Biomedical Toxicology (ASSPE1540 / ASFOC1540Q)
Unit  Department of Statistical Sciences
Effective Date  March 1, 2020

Brief Description of the Proposed Changes

Using bullet points, briefly summarize the main aspects of the changes (e.g. addition of required courses, restructuring higher-year course option, introduction of Streams, etc.). Specify changes to program description, requirements, and program learning outcomes.

- Program learning outcomes have been redefined.
- The name of the specialist will change from Applied Statistics to Statistical Science: Methods and Practice. The modified program name reflects the modified program learning outcomes and better differentiates between our two specialist programs in statistics.
- To reflect the new program learning outcomes, we are making program changes in a staged implementation. In 2017-18, we introduced new courses (STA237H1, STA238H1, STA314H1) and made our first year course (STA130H1) required. In 2018-19 through this proposal, we are making some changes to how students can choose among our 3rd and 4th year course requirements. Future changes will be implemented as resources permit.
- The Applied Statistics Specialist program currently has focuses in Health Studies, Global Health, Health and Disease, Genes Genetics and Biotechnology, Neuroscience, Social Psychology, Cognitive Psychology, Sociolinguistics, Psycholinguistics, Astronomy & Astrophysics, Sociology, Ecology, Evolutionary Biology, and Economics. Seven of these focuses were added after the establishment of the program and our intent has been to continue to broaden the choice of focuses available to students. This proposed modification includes the addition of a new focus in Pharmacology and Biomedical Toxicology, created in collaboration with the relevant unit.

Program information

Program Description

New program name:  Specialist in Statistical Science: Methods and Practice (was:  Specialist in Applied Statistics)

Statistical Science encompasses methods and tools for obtaining knowledge from data and for understanding the uncertainty associated with this knowledge. The purposes of the undergraduate programs are to: (1) equip students with a general framework for obtaining knowledge from data; (2) give students skills that they are able to flexibly apply to a variety of problems; and (3) to provide students with the ability to learn new methods as needs, data sources, and technology change.

The Specialist Program in Statistical Science: Methods and Practice is distinguished from the specialist program in Statistical Science: Theory and Methods through its emphasis on collaborative statistical practice and advanced exposure to an allied discipline. The program includes fundamental concepts in probability and
statistical theory with mathematical prerequisites relevant to statistical practice. Students in the program acquire advanced expertise in statistical reasoning, methods, and computation, and complete a concentration in another discipline that permits students to become conversant in that discipline to the extent that they can effectively collaborate. Students will also acquire advanced skills in communication, consultation and collaboration and an understanding of the role of mathematical thinking to support the development and evaluate the properties of statistical methods.

Enrolment Requirements

If a change in program type (e.g. Type 1 to Type 2) or a modification to existing enrolment restrictions is proposed, highlight changes to the previous requirements. Modifications to enrolment requirements will be reviewed in Committee on Admissions as well as Curriculum Committee.

The following enrolment requirements were approved in 2017-18 and will be in effect in the 2019 enrolment period.

This is a limited enrolment program (Type 2L) that can only accommodate a certain number of students. Eligibility is based on the following criteria:

For students entering the program after first year:

1. Completion of at least 4.0 FCEs including:
   STA130H1, CSC108H1/ CSC120H1/ CSC121H1/ CSC148H1, MAT223H1/ MAT240H1, (MAT135H1, MAT136H1) with a minimum grade of 75% or MAT137Y1 with a minimum grade of 65% or MAT157Y1 with a minimum grade of 65%
   AND
2. An average of the grades in STA130H1 and (MAT135H1, MAT136H1)/ MAT137Y1/ MAT157Y1 that meets the department’s annual cutoff

For students entering the program after second year:

1. Completion of:
   CSC108H1/ CSC120H1/ CSC121H1/ CSC148H1, MAT223H1/ MAT240H1, 
   MAT235Y1/ MAT237Y1/ MAT257Y1, (STA237H1, STA238H1) with a minimum grade of 75% or (STA247H1, STA248H1) with a minimum grade of 75% or (STA257H1, STA261H1) with a minimum grade of 65%
   AND
2. An average of the grades in (STA237H1, STA238H1)/(STA257H1, STA261H1) and MAT235Y1/ MAT237Y1/ MAT257Y1 that meets the department’s annual cutoff

Completion Requirements

State the completion requirements as they are to appear in the Calendar. Indicate in particular which courses are required in first year. Begin with the current calendar copy and use highlight or track changes to show the changes. The total FCEs, including specific courses required for enrolment, must be: Minors – 4.0 FCE, Majors – 6.0-8.0 FCE, Specialists – 10.0-14.0 (exceptions up to 16.0) FCE.

Completion Requirements:

(10.0 or 10.5 FCEs plus a disciplinary focus requiring 2.0-3.5 FCEs)

First year:
1. STA130H1, CSC108H1/ CSC120H1/ CSC121H1/ CSC148H1, (MAT135H1, MAT136H1)/ MAT137Y1/ MAT157Y1, MAT223H1/ MAT240H1.
   (MAT137Y1/ MAT157Y1 recommended)
2. Recommended: introductory course in disciplinary focus.
MAT223H1/ MAT240H1 is also strongly recommended to be taken in first year and is required preparation for MAT237Y1.

Second year:
3. MAT235Y1/ MAT237Y1/ MAT257Y1, (STA237H1, STA238H1)/(STA247H1, STA248H1)/(STA257H1, STA261H1)
((STA257H1, STA261H1) recommended)

Upper years:
4. STA302H1, STA303H1, STA304H1/STA305H1, STA355H1, STA410H1, STA437H1, STA442H1, STA490Y1
5. 0.5 FCE from STA300+-level offerings (excluding STA310H5)
6. 1.0 FCE from the following list: MAT224H1, MAT247H1, MAT244H1, MAT267H1, APM236H1, APM346H1,
APM462H1, CSC148H1, CSC207H1

Upper years:
4. STA302H1, STA303H1, STA304H1/STA305H1, STA314H1/STA365H1, STA355H1, STA410H1, STA437H1,
STA442H1, STA490Y1
5. 1.5 FCE from the following list: STA414H1, STA437H1, STA442H1, STA457H1, STA465H1, STA480H1,
STA410H1, STA437H1, STA442H1, STA490Y1 or successful completion of an internship (see department of information about internships)
6. 1.0 FCE from the following list: MAT224H1/MAT247H1, MAT337H1/MAT357H1, MAT244H1, MAT267H1,
APM236H1, APM346H1, APM462H1, CSC148H1, CSC207H1, STA300+ level courses (excluding STA310H5)

Disciplinary Focuses
Students in the Applied Statistics Specialist program must complete at least one disciplinary focus.
To enrol in one or more focuses, students must first be enrolled in the Applied Statistics Specialist program. Enrolment instructions can be found on the Arts & Science Current Students program enrolment website. Focuses can be chosen on ACORN after admission to the program, which begins in July.

Health Studies: (2.0 FCE) HST209H1, HST211H1, HST373H1, HST330H1/HST411H1/HST464H1

Global Health: (2.5 FCE) BIO120H1, BIO130H1, HMB203H1, HMB323H1, HMB342H1/HMB433H1
(Recommended: HMB433H1)

Health and Disease: (3.0 FCE) BIO120H1, BIO130H1, HMB202H1, HMB265H1, HMB302H1, HMB321H1/HMB322H1/HMB422H1

Fundamental Genetics and its Applications: (3.0 FCE) BIO120H1, BIO130H1, HMB201H1, HMB265H1,
HMB301H1, HMB321H1/HMB421H1/HMB441H1 (Recommended: HMB421H1)

Neuroscience: (3.5 FCE) BIO120H1, BIO130H1, PSY100H1, HMB200H1/HMB220H1, HMB265H1, HMB300H1,
HMB420H1/HMB440H1 (Recommended: HMB420H1)

Social Psychology: (2.0 FCE) PSY100H1, PSY220H1, PSY322H1, PSY326H1/PSY321H1/PSY424H1/PSY426H1/
PSY405H1/PSY406H1

Cognitive Psychology: (2.0 FCE) PSY100H1, PSY270H1, PSY493H1, PSY372H1/PSY405H1/PSY406H1/
PSY475H1

Sociolinguistics: (3.0 FCE) LIN100Y1; 2 of LIN228H1, LIN229H1, LIN232H1 or LIN241H1; LIN351H1 and LIN456H1
Psycholinguistics: (3.0 FCE) LIN100Y1; 2 of LIN228H1, LIN229H1, LIN232H1 or LIN241H1; 2 of JLP374H1, JLP315H1 or JLP471H1

Astronomy & Astrophysics: (2.5 or 3.0 FCE) (PHY131H1, PHY132H1)/(PHY151H1, PHY152H1); AST221H1, AST222H1; (PHY252H1, AST320H1)/(AST325H1)/AST326Y1

Sociology: (2.5 FCE) SOC100H1+ SOC150H1 (minimum combined average grade of 65%); SOC204H1; 1.0 FCE from SOC303H1, SOC312H1, SOC336H1, SOC355H1, SOC363H1, SOC364H1.

Students interested in advanced study in Sociology should consider additional courses, in particular SOC201H1, SOC251H1, and SOC254H1

Ecology: (3.0 FCE) BIO120H1, BIO220H1; 2.0 FCE from (with at least 0.5 FCE at the 400 level) EEB319H1/EBB321H1/EBB328H1/EEB428H1/EEB433H1/EEB440H1 or ENV234H1/ENV334H1/ENV432H1

Evolutionary Biology: (3.5 FCE) BIO120H1, BIO130H1, BIO220H1; 1.5 FCE from HMB265H1/BIO260H1, EEB318H1, EEB323H1, EEB324H1, EEB325H1, EEB362H1, EHJ352H1; 0.5 FCE from EEB440H1, EEB455H1, EEB459H1, EEB460H1

Notes:

BIO260H1 requires BIO230H1 as a prerequisite. Students in the Applied Statistics specialist focus in Evolutionary Biology can request that HMB waive the co-requisite of BIO230H1 for HMB265H1 and that EEB waive the prerequisite of BIO230H1 for EEB460H1. These waivers will only be considered for students in the Applied Statistics specialist focus in Evolutionary Biology. All other pre- and co-requisites are required.

Economics: (3.5 FCE) (ECO101H1, ECO102H1), ECO200Y1/ECO206Y1, ECO202Y1/ECO208Y1, 0.5 FCE 300+ series ECO course with the exception of ECO374H1 and ECO375H1

Biochemistry: (3.0 FCE)
CHM135H1, CHM136H1, BCH210H1, BCH311H1, BCH370H1, BCH441H1

Physics: (2.5 FCE)
PHY131H1/PHY151H1, PHY132H1/PHY152H1, PHY224H1, PHY252H1/PHY254H1/PHY256H1, PHY324H1

Pharmacology and Biomedical Toxicology: (3.0 FCE)
BIO130H1 (minimum grade of 70%), PSL300H1, PSL301H1, PCL201H1, PCL302H1, PCL345H1/PCL362H1/PCL469H1/PCL470H1

Proposal Questions – General

Answers to all questions in this section are required. Even a brief answer will assist in reviewing changes when they are heard in governance. These answers will be entered on CM under the same field titles.

Rationale

*Explain why the changes have been proposed, providing any additional information that may be helpful for review, or of relevance for Curriculum Committees. This may include connections to the unit’s priorities, recent reviews or institutional planning, or alignment with other programs. Be sure to note student input and benefit.*
In the fall of 2016, the Department of Statistical Sciences began a major curriculum renewal project, supported by a grant from the Learning and Education Advancement Fund, and with the guidance of Jessie Richards, Curriculum Development Specialist in the office of the Vice-Provost, Innovations in Undergraduate Education. The curriculum changes proposed here reflect most of the outcomes of this exercise.

The curriculum changes are being implemented in a staged process. In 2017-18, minor modifications to the Statistics Major and Specialist programs were approved. Beginning in March 2019, the introductory course STA130H1 will now be required for all students, and a new cluster of second year courses, STA237H1 and STA238H1 were approved, which will become the core of the statistics Major program and a suitable follow-up to STA130H1. In addition, a new course in machine learning, STA314H1, was added to our course offerings. The changes proposed in this document reflect the major re-organization of our 3rd and 4th year program requirements to incorporate the program changes.

Our revised program learning outcomes fall into five themes: Theory, Methods, Computational Thinking, Professional Practice, and Problem Solving Skills in Context of Real Word Problems. To map our students’ development of proficiency in each of these themes, our third year courses have been categorized as courses in statistical theory, courses in design and analysis (addressing the program learning outcomes in methods), and computationally intensive courses. The development of the professional practice and problem solving skills will be introduced and reinforced in various ways in all of these courses, for example, through exercises that require communication of results for non-technical audiences, problems that require the adaptation of methods learned, and assignments that require the discussion of the relative merits and limitations of statistical methods in the context of an authentic problem. A subset of our 4th year courses have been identified to include significant experiences in data analysis (often through a project), through which proficiency in many of the learning outcomes related to professional practice and problem solving will be developed and assessed. (See the Statistics curriculum map for the development of our program learning outcomes through the program.)

The program modifications proposed in this document reflect the alignment of required upper year courses with these new learning outcomes and the corresponding curriculum map. In third year, students will take a course in each of design (STA304H1/STA305H1), analysis (STA302H1, STA303H1), computationally intensive methods (STA314H1/STA365H1), and theory (STA355H1). The fourth year course requirements reflect the emphasis on statistical practice in the specialist program in Statistical Science: Methods and Practice. Students choose 1.5 FCE from among the courses that have been identified to include significant experiences in data analysis. The 4th year capstone experience (STA490Y1 or an internship) ensures students in this program acquire the depth and level of sophistication in professional practice and real-world problem solving expected of a graduate of this specialist program.

In future years, as resources permit, we plan to introduce a new course in statistical computation and re-organize our 3rd year methods course sequence (STA302H1, STA303H1, STA304H1, STA305H1) to fully implement the outcomes of our modified program. We will also be working with instructors in key courses to enhance the development of skills in communication and computation and to introduce experiential learning components in a scaffolded way throughout the program.

Regarding the proposed new focus: The Applied Statistics Specialist program was established in 2012. Its creation was in direct response to the Department of Statistical Sciences’ academic plan, including the strengthening of our reputation in collaborative scientific activity and curriculum renewal focused on statistical communication, consultation, and collaboration. Since the creation of the program, our intent has been to continue to broaden the choice of focuses available to students. The creation of the proposed focus in Pharmacology and Biomedical Toxicology will create opportunities for interested students to develop an appreciation of the need for and application of statistical methods to important problems in this area and
greater choice for students interested in developing expertise in this area with a focus on quantitative methods.

**Impact**

*Specify the impact the changes may have on students or other units/programs. If courses listed in the program are offered by other units, include a letter of support from the head of that unit, speaking to enrolment controls and priority enrolment, if applicable.*

Impact of changes introduced this year will only affect some statistics courses offerings, particularly how many sections of each course will need to be offered.

Regarding the addition of (STA237H1, STA238H1) as an option for the sequence of courses that can be taken in 2nd year: This new course sequence is being proposed in part because analysis of student performance in a variety of third year courses in statistics has shown that students who completed the (STA220H1, STA255H1) sequence have performed, on average, several percentage points below students who completed the sequence (STA257H1, STA261H1) after controlling for their grade in the second year courses. We anticipate that (STA237H1, STA238H1) will help close that gap, particularly for courses in applied statistics. Many students struggle with the mathematical rigour in (STA257H1, STA261H1). The proposed sequence will give these students an option to drop down to the corresponding course in (STA237H1, STA238H1).

Regarding the revisions to required courses in 3rd year: A course in statistical methods (STA302H1) has always been a core, required 3rd year course. In the new program, students must complement that course with a course in statistical theory (one of STA347H1 or STA355H1) or a course in computationally intensive methods (STA314H1 or STA365H1); they will have the choice between the theoretical or computationally intensive course.

Regarding the addition of the new focus: We expect that the number of students in the new focus will be 5 or fewer per year. This focus has been developed collaboratively with PCL.

**Consultation**

*Describe consultation that has already been done within the unit, with outside units and with students, in particular if other units are affected or if resources are necessary to mount the changes. Indicate date of sign-off from external units, dates of meetings with students, etc.*

The proposed program changes are the result of a two-year curriculum renewal exercise. This exercise began in September 2016 with a department workshop, surveys of students and alumni, followed by a departmental learning outcomes development workshop. The new learning outcomes and programs were developed in 2016-17 by the departmental curriculum renewal committee and discussed at a departmental meeting. The new programs were discussed by the department in meetings throughout 2017-18.

Students in Statistics programs of study have been extensively consulted throughout this curriculum renewal project (through a survey, a town hall, and through students serving on our curriculum committee).

The proposed program changes have been informed by our initial consultations. In subsequent consultations, the modified programs have been universally and enthusiastically supported. Faculty members have been particularly supportive of the new sequence of second year courses and increased emphasis on computation, beginning in first year. They anticipate students will have much better preparation for advanced courses. Students have been particularly enthusiastic about the greater emphasis on statistical computation, predictive models, and modern methods in machine learning and Bayesian analysis. These are in demand in the work force and will introduce students to some research areas that have recently emerged.
The proposed new focus has been developed collaboratively with Pharmacology and Toxicology.

Diversity

*How does the proposed program or modification support diversity? E.g. through curriculum design supporting different learners, accommodation, etc.*

Regarding the addition of STA130H1 as a program requirement: Key learning outcomes in STA130H1 include the development of oral and written communication skills, with activities developed in collaboration with the English Language Learning (ELL) and Writing Instruction for TAs (WIT) teams, recognizing the large percentage (approximately 60%) of international students in statistics programs of study.

The final program requirement (requirement 7.) allows students to take additional advanced statistics courses, or to broaden their statistical training with complementary courses in mathematics or computer science, depending on their interests and strengths.

Resource Implications

*Provide a statement of the resource requirements for the program, and an indication of whether you can meet these requirements through your existing resources, or have received additional resources.*

No additional resources beyond those required to meet the demands of our current enrolment. There will be some reorganization of existing resources among courses.

The Department of Statistical Sciences hired a staff internship coordinator in 2018 who is developing opportunities, resources, and supporting professional training for internships for undergraduate students in programs of study in the Department of Statistical Sciences.

The development of the new focus was initiated by Pharmacology and Toxicology. We expect that there will be 5 or fewer students per year enrolled in this focus. These students will be accommodated in existing courses. There are no new resource requirements.

Academic Context

*Outline the context that explains why the program is designed this way, e.g. relation of program to discipline, students’ interests, career paths, etc.*

The discipline of statistics is evolving rapidly with the recent emergence of “data science” and “big data”. Statistics is foundational to data science and statistical reasoning is essential to maximize the full potential of new sources of data.

Coupled with this external context, the Department of Statistical Sciences has seen astounding growth in our undergraduate programs in statistics. Enrolment in statistics major and specialist programs of study is currently 3500 students, an over 12-fold increase in 10 years. These students are attracted to our programs by the growing demand for experts who can think with data.

The proposed modifications in statistical sciences programs address the knowledge, skills, and habits of mind needed of statisticians in the era of data science, while building on the traditional strengths of our department. The program changes include greater focus on predictive modelling and data from a wide variety of sources. The new learning outcomes reflect greater emphasis on communication, computation, and problem solving in novel contexts.
**Faculty and TA Support**

_Indicate how the modifications will be supported with existing faculty and Teaching Assistant resources. If new resources are needed, give more detail here about approvals obtained._

The new program changes will require only minor changes in how our current teaching resources are distributed as students are reshuffled among some courses.

**Learning Outcomes**

_Explain how the change affects, or does not affect, the program learning outcomes, including disciplinary goals, relevant methodologies and skills acquired upon program completion._

The requirement changes of the program are aligned with the new program learning outcomes.

Statistical Science encompasses methods and tools for obtaining knowledge from data and for understanding the uncertainty associated with this knowledge. The purposes of the undergraduate programs are to: (1) equip students with a general framework for obtaining knowledge from data; (2) give students skills that they are able to flexibly apply to a variety of problems; and (3) to provide students with the ability to learn new methods as needs, data sources, and technology change.

Students in the Major and all Specialist programs of study in Statistics acquire core learning outcomes in statistical methods, theory, computation, and communication. Students in the Specialist program in Statistical Science: Methods will complete a focus in another discipline that permits students to become conversant in that discipline to the extent that they can effectively collaborate and will acquire advanced skills in communication, consultation and collaboration. The Specialist Program in Statistical Science: Theory and Methods through its emphasis on collaborative statistical practice and advanced exposure to an allied discipline. The program includes fundamental concepts in probability and statistical theory relevant to statistical practice, allowing students to acquire skills in mathematical thinking that are necessary to understand the development of statistical methods and evaluate their properties.

All of the programs of study prepare students for employment as a statistical scientist or for graduate studies in statistics or related disciplines.

**Depth of Knowledge**

_The achievement of several of a set of learning outcomes that contribute to mastery of an area through intensive study. Explain how particular courses allow students to achieve depth of knowledge, relating to the proposed change._

The new introductory course, STA130H1, introduces students to the broad range of competencies required by modern statisticians including statistical reasoning in a variety of contexts for a variety of purposes, computational facility, ethical reasoning, and oral and written communication skills. Required courses in mathematics, computer science, and statistical theory ensure that by the end of 2nd year, students will have acquired the essential mathematical and computing background and the fundamental ideas of probability and statistical reasoning that will provide the foundation for deeper study. The 300-level courses in statistics provide in-depth study of statistical methodology, approaches to statistical practice, greater development of computational and problem solving skills, and, in the theory courses, deeper development of foundational mathematical ideas that underpin statistical methods. Many of the 300-level courses are pre-requisites to the 400-level courses that cover advanced aspects of statistical methodology, computation, and theory. Important topics in statistical reasoning can be traced through courses in the program with increasing levels of sophistication each year (for example, the fundamental ideas in statistical reasoning and statistical models in 2nd year courses lead to the methods covered in the courses in linear models at the 300-level STA
Competencies

For these five categories, describe how each competency is developed within the modified program to the degree relevant to the area/discipline. If the program does not address a particular competency, explain why that competency is not relevant to your area/discipline and how students in your program are expected to attain that competency within their overall degree program.

Critical and Creative Thinking

The purposeful and reflective examination of knowledge and ideas beyond memory and recall, whereby students can make informed judgments, synthesize what they have learned, and apply their ideas in novel ways.

Statistical scientists need to be able to read and evaluate the relevance of both the statistics literature and the relevant literature in their area of application, they need to assess and evaluate alternative statistical methods in the context of any project they are working on, and they need to develop novel approaches and adapt existing methodology (and sometimes develop new methodology) in the process of applying their quantitative reasoning skills to imperfect practical problems in order to get the most information from the available data.

The second year courses in statistics develop the foundations of statistical reasoning and, for the student, initiate the development of a logical thought that is later brought to bear on problems requiring critical reflection prior to the use of statistical methods. In more advanced courses, this development continues as the creative process required to tackle complex practical problems is demonstrated by faculty members and reinforced and further developed through assignments and projects. In the final year of the program students will be required to take a 4th year course with an emphasis on applying advanced statistical methodology to solving authentic problems.

Through their collaboration in another discipline, students are exposed to the nature of the problems to which their quantitative reasoning can be applied and an understanding of the need for creative application of their statistical skills.
In the final year of the program the experiential learning component of the program, satisfied by the capstone course STA 490Y1 or an internship, requires students to integrate and apply this thinking to current problems in collaboration with a researcher from another discipline or in industry. Through this experience, students expand the critical and creative thinking skills developed in their statistics courses to thinking in a more broad, interdisciplinary manner to active problems.

All of the upper year Pharmacology courses within the proposed new focus rely on written examination questions and assignments and examine acquired knowledge as well as critical and logical thinking, ability to interpret and proficiency in communication associated with pharmacology and biomedical toxicology data.

**Communication**

*The ability to express ideas, arguments, and facts to convey an intended message in a manner that is cogent and effective.*

The development of oral and written communication skills begins in STA130H1 which includes communication intensive tutorials, developed in collaboration with the ELL and WIT programs. Communication is further developed throughout the program, with increasing sophistication. In courses in probability and statistical theory, students are required to produce concise mathematical arguments. In courses in statistical methodology, students are required to express the importance of their findings in the context of the practical problem for which the data were collected. All of the courses in the program emphasize the sound, logical, clear and direct presentation of arguments in solutions to assignments and tests.

Effective collaboration requires proficiency in oral and written communication. The development of these skills is a major objective of the capstone course STA 490Y1 which requires a collaborative project with a non-statistician and several presentations and written assignments prepared for audiences with various levels of statistical expertise. Students also develop the informal communication skills necessary to be an effective participant in a project team. Through their concentration in another discipline, students develop an understanding of the contributions statisticians can make to collaborative teams.

All of the upper year Pharmacology courses within the proposed new focus rely on written examination questions and assignments and examine acquired knowledge as well as critical and logical thinking, ability to interpret and proficiency in communication associated with pharmacology and biomedical toxicology data.

**Information Literacy**

*The ability to effectively find, evaluate, create, use and present knowledge, data and critical analyses for scholarly and other purposes.*

In many of the advanced courses in the program, students gain experience in combining various types of information into a coherent argument. Beginning in STA130H1 and throughout their programs, students become proficient in the use of statistical software. In doing so, they learn how to find sample code and documentation for the software they are using.

Through their concentration in another discipline, students acquire a sufficient introduction to the discipline to be able to read the literature and understand the contribution of quantitative reasoning. A critical component of their experience will be to gain an understanding of statistical science from the perspective of a researcher in another discipline.
Quantitative Reasoning
The ability to reason with basic mathematical, numerical and statistical concepts in order to enhance understanding of an area of study and to help navigate a data-driven world.

The practice of statistics concerns how to extract information from data to make reasoned conclusions and decisions in the presence of uncertainty. All of the mathematics and statistics courses required in the program develop students’ abilities in quantitative reasoning.

Social and Ethical Responsibility
The ability to engage in critical reflection upon questions of responsibility to oneself and society and to develop values of academic and personal integrity.

Appropriate use of statistical methods is essential to virtually all aspects of society. Statisticians have the obligation to carry out their work with competence, diligence and integrity, without bias, and conscious of the need to protect the privacy of data.

An introduction to ethical statistical practice is a specific topic in STA130H1. All of the courses in statistical methodology emphasize the importance of basing conclusions and decisions only on valid statistical models, the role bias can play in data collection and analysis, and the limitations of the statistical methods in the context of the practical problem for which the data were collected. Courses that emphasize data collection include discussions of the importance of careful planning to protect the subjects of the study from unnecessary risks and the researchers from unnecessary expense.

Aspects of professional practice are integrated throughout this program and explicitly in STA 490Y1. These include the responsibilities statisticians have to society and the importance of maintaining objectivity, protecting the privacy and dignity of human subjects, striving to advance public understanding, and carrying out work carefully and accurately and reporting results completely, without bias, and with a discussion of the limitations of the analysis. Students are exposed to the ethical guidelines for statistical practice of the Statistical Society of Canada, the American Statistical Association and /or the International Statistical Institute and the application of the guidelines in practice is explored through case studies.

The collaborative project in the final year of the program requires students to grapple with ethical dilemmas typical of statistical work such as the sacrifices necessary for pragmatic solutions and the temptation to satisfy a client’s interests at the expense of an unbiased analysis.

Integrative, Inquiry-based Activity
Activity that involves substantial investigation, synthesis of knowledge, and communication of results of the inquiry.

As part of our curriculum renewal project, the 4th year courses that students can choose among will include authentic assessments, requiring students to integrate the knowledge and skills acquired throughout the program towards the solutions of real-world problems. The development of facility to do this begins in STA130H1, which culminates with a project in which students analyze data towards learning from a current data set, typically from a business, non-governmental organization, or government agency, with results presented in a poster sessions.

The capstone course, STA 490Y1, has as its primary activity a collaborative project with a researcher from another discipline. Students in the course combine the application of their quantitative expertise with the development and understanding of ethical, communication, and collaborative skills in the context of an active, open research problem. Alternatively, students will have the opportunity to participate in our developing internship program.
Governance Path

<table>
<thead>
<tr>
<th>Level</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dean’s Office approval</td>
<td>December 19, 2018</td>
</tr>
<tr>
<td>Vice-Provost Sign-off</td>
<td>January 18, 2019</td>
</tr>
<tr>
<td>Undergraduate Curriculum Committee</td>
<td>January 31, 2019</td>
</tr>
<tr>
<td>Arts &amp; Science Council</td>
<td>February 13, 2019</td>
</tr>
<tr>
<td>AP &amp; P (for information)</td>
<td>May 8, 2019</td>
</tr>
</tbody>
</table>

Implementation of Change in 2019-20

Program modifications approved in the 2018-19 cycle will be published in the 2019-20 Calendar. To allow students time to plan their course and program choices for the 2019-20 year, program modifications will be in effect for students starting with the 2020 enrolment period. The Governance Unit and the Office of the Faculty Registrar can work with you to prepare for implementation and communicate the change to students.

Use this space to identify any planning concerns/considerations you may have that are associated with this change (for example, adding newly created courses to requirements, preparing for changes to enrolment requirements, messaging to students about the changes, etc).

We now have a departmental staff person working on identifying and creating an academic structure for internship opportunities for students in programs of study in statistical sciences. The structure of this opportunity will evolve with the infrastructure being created in the Faculty of Arts and Science.
Faculty of Arts & Science
Major Modification to Program

<table>
<thead>
<tr>
<th>Program Title (POSt Code)</th>
<th>Major in Statistics (ASMAJ2289)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit</td>
<td>Department of Statistical Sciences</td>
</tr>
<tr>
<td>Effective Date</td>
<td>March 1, 2020</td>
</tr>
</tbody>
</table>

**Brief Description of the Proposed Changes**

*Using bullet points, briefly summarize the main aspects of the changes (e.g. addition of required courses, restructuring higher-year course option, introduction of Streams, etc.). Specify changes to program description, requirements, and program learning outcomes.*

- Due to massive increases in demand, the statistics major will become a limited enrolment program effective for 2020 enrolment: admission will be based not only on completing specific first-year courses but on obtaining a minimum average grade across those courses, depending on demand.
- Program learning outcomes have been redefined.
- To reflect the new program learning outcomes, we are making program changes in a staged implementation. In 2017-18, we introduced new courses (STA237H1, STA238H1, STA314H1) and made our first year course (STA130H1) required. In 2018-19 we are making some changes to how students can choose among our 3rd and 4th year course requirements. Future changes will be implemented as resources permit.

**Program information**

**Program Description**

Statistical Science encompasses methods and tools for obtaining knowledge from data and for understanding the uncertainty associated with this knowledge. The purposes of the undergraduate programs are to: (1) equip students with a general framework for obtaining knowledge from data; (2) give students skills that they are able to flexibly apply to a variety of problems; and (3) to provide students with the ability to learn new methods as needs, data sources, and technology change.

The Major in Statistics gives students a broad understanding of the statistical methods and computational and communication skills appropriate for effective statistical problem solving. The successful student will also acquire a general understanding of the role of mathematical thinking to support the development and evaluate the properties of statistical methods. While the Major is designed to complement study in an area of application of quantitative methods, students in the Major may choose to have a greater focus in probability and statistical theory through elective courses.

**Enrolment Requirements**

*If a change in program type (e.g. Type 1 to Type 2) or a modification to existing enrolment restrictions is proposed, highlight changes to the previous requirements. Modifications to enrolment requirements will be reviewed in Committee on Admissions as well as Curriculum Committee.*

*(New enrolment requirements in effect for 2020 enrolment)*

This is a limited enrolment program that can only accommodate a certain number of students. Eligibility is based on the following:
For students entering the program after first year:
A. Completion of at least 4.0 FCEs including:
   - STA130H1,
   - MAT135H1, MAT136H1 or MAT137Y1 or MAT157Y1
   AND
B. The average of the grades in STA130H1 and (MAT135H1, MAT136H1)/MAT137Y1/MAT157Y1. Note that students who take (MAT135H1, MAT136H1) will typically require a higher average grade in these courses than students who take MAT137Y1/MAT157Y1.

For students entering the program after 2nd year:
A. Completion of:
   - CSC108H1/CSC110H1/CSC111H1/CSC148H1,
   - MAT223H1/MAT240H1,
   - MAT235Y1/MAT237Y1/MAT257Y1,
   - (STA237H1, STA238H1) or (STA247H1,STA248H1) or (STA257H1, STA261H1) or ECO227Y1
   AND
B. The average of the grades in (STA237H1, STA238H1)/ (STA247H1, STA248H1)/ (STA257H1,STA261Y1)/ECO227Y1 and MAT235Y1/MAT237Y1/MAT257Y1. Note that students who take (STA237H1, STA238H1)/(STA247H1, STA248H1) will typically require a higher average grade in these courses than students who took (STA257H1, STA261H1)/ECO227Y1.

It is difficult to predict the minimum average required for admission in any given year. More information will be posted on the department website as it becomes available.

---

**Completion Requirements**

*State the completion requirements as they are to appear in the Calendar. Indicate in particular which courses are required in first year. Begin with the current calendar copy and use highlight or track changes to show the changes. The total FCEs, including specific courses required for enrolment, must be: Minors – 4.0 FCE, Majors – 6.0-8.0 FCE, Specialists – 10.0-14.0 (exceptions up to 16.0) FCE.*

(7.0 full courses or their equivalent, including at least one STA 400-series course)

First Year:
STA130H1, CSC108H1/CSC120H1/CSC121H1/ CSC148H1, (MAT135H1, MAT136H1)/MAT137Y1/MAT157Y1. (MAT223H1/MAT240H1 recommended in 1st year)

Second Year:
MAT223H1/MAT240H1, MAT235Y1/MAT237Y1/MAT257Y1;
(STA247H1, STA248H1)/( STA237H1, STA238H1)/( STA257H1, STA261H1)/ECO227Y1
(STA237H1 and STA238H1 are strongly recommended. MAT221H1 may not be used for this requirement.)

Higher Years:
1. STA302H1
2. 0.5 FCE from STA314H1/365H1/347H1/355H1
3. 0.5 FCE from STA414H1/437H1/442H1/457H1/465H1/480H1
4. 1.0 FCE from all available STA300+ level courses, excluding STA310H5

2. 3 half (H) course equivalents from all available STA300+ level courses, excluding STA310H5 (For example, a student interested in economics/commerce/finance might think to include STA304H1, STA347H1, STA457H1 in their program, while someone engaged in a life science might
Rationale

Explain why the changes have been proposed, providing any additional information that may be helpful for review, or of relevance for Curriculum Committees. This may include connections to the unit’s priorities, recent reviews or institutional planning, or alignment with other programs. Be sure to note student input and benefit.

In the fall of 2016, the Department of Statistical Sciences began a major curriculum renewal project, supported by a grant from the Learning and Education Advancement Fund, and with the guidance of Jessie Richards, Curriculum Development Specialist in the office of the Vice-Provost, Innovations in Undergraduate Education. The curriculum changes proposed here reflect most of the outcomes of this exercise.

The curriculum changes are being implemented in a staged process. In 2017-18, minor modifications to the Statistics Major and Specialist were approved. Beginning in March 2019, the introductory course STA130H1 will now be required for all students to enroll in the program, making the Major a Type 2 program, and a new cluster of second year courses, STA237H1 and STA238H1 were approved, which will become the core of the statistics Major and a follow-up to STA130H1. In addition, a new course in machine learning, STA314H1, was added to our course offerings. The changes proposed in this document reflect the major re-organization of our 3rd and 4th year program requirements to incorporate the program changes.

Our revised program learning outcomes fall into five themes: Theory, Methods, Computational Thinking, Professional Practice, and Problem Solving Skills in Context of Real Word Problems. To map our students’ development of proficiency in each of these themes, our third year courses have been categorized as courses in statistical theory, courses in design and analysis (addressing the program learning outcomes in methods), and computationally intensive courses. The development of the professional practice and problem solving skills will be introduced and reinforced in various ways in all of these courses, for example, through exercises that require communication of results for non-technical audiences, problems that require the adaptation of methods learned, and assignments that require the discussion of the relative merits and limitations of statistical methods in the context of an authentic problem. A subset of our 4th year courses have been identified to include significant experiences in data analysis (often through a project), through which proficiency in many of the learning outcomes related to professional practice and problem solving will be developed and assessed. (See the Statistics curriculum map for the development of our program learning outcomes through the program.)

In future years, as resources permit, we plan to introduce a new course in statistical computation and re-organizing our 3rd year methods course sequence (STA302H1, STA303H1, STA304H1, STA305H1) to fully implement the outcomes of our modified program. We will also be working with instructors in key courses to enhance the development of skills in communication and computation and to introduce experiential learning components.
**Impact**

Specify the impact the changes may have on students or other units/programs. If courses listed in the program are offered by other units, include a letter of support from the head of that unit, speaking to enrolment controls and priority enrolment, if applicable.

Enrolment changes are most likely to affect Mathematics and Economics, since programs in these disciplines are frequently combined with a Statistics Major. In particular, we expect that students who do not meet the cut-off for the statistics major may now be attracted to either (1) related Type 1 programs in Mathematics, particularly Mathematical Applications in Economics and Finance Specialist, Mathematics and its Applications (Probability / Statistics specialist) and Mathematics Major or (2) related Type 2 programs in Economics for which the required minimum grades are expected to be lower than the anticipated cut-off for the Statistics Major, in particular Economics and Mathematics Specialist and Economics Major. The Mathematics and Economics departments have been consulted and have given support orally.

Regarding the addition of (STA237H1,STA238H1) as an option for the stream of courses that can be taken in 2nd year: This new course sequence is being proposed in part because analysis of student performance in a variety of third year courses in statistics has shown that students who completed the (STA220H1,STA255H1) sequence have performed, on average, several percentage points below students who completed the sequence (STA257H1,STA261H1) after controlling for their grade in the second year courses. We anticipate that (STA237H1,STA238H1) will help close that gap, particularly for courses in applied statistics. Many students struggle with the mathematical rigour in (STA257H1,STA261H1). The proposed sequence will give these students an option to drop down to the corresponding course in (STA237H1,STA238H1).

Regarding the revisions to required courses in 3rd year: A course in statistical methods (STA302H1) has always been a core, required 3rd year course. In the revised curriculum for the major students must complement that course with a course in statistical theory (one of STA347H1 or STA355H1) or a course in computationally intensive methods (STA314H1 or STA365H1); they will have the choice between the theoretical or computationally intensive course.

**Consultation**

Describe consultation that has already been done within the unit, with outside units and with students, in particular if other units are affected or if resources are necessary to mount the changes. Indicate date of sign-off from external units, dates of meetings with students, etc.

The proposed program changes are the result of a two-year curriculum renewal exercise. This exercise began in September 2016 with a department workshop, surveys of students and alumni, followed by a departmental learning outcomes development workshop. The new learning outcomes and programs were developed in 2016-17 by the departmental curriculum renewal committee and discussed at a departmental meeting. The new programs were discussed by the department meeting in 2017-18.

Students in Statistics programs of study have been extensively consulted throughout this curriculum renewal project (through a survey, a town hall, and through students serving on our curriculum committee).

The proposed program changes have been informed by our initial consultations. In subsequent consultations, the modified programs have been universally and enthusiastically supported. Faculty members have been particularly supportive of the new sequence of second year courses and increased emphasis on computation, beginning in first year. They anticipate students will have much better preparation for advanced courses. Students have been particularly enthusiastic about the greater emphasis on statistical computation, predictive models, and modern methods in machine learning and Bayesian analysis. These are in demand in the work force and will introduce students to some research areas that have recently emerged.
The Departments of Mathematics and Economics were consulted regarding the proposed enrolment requirements prior to discussion at the November 2018 Committee on Admissions meetings. Both units supported this necessary change.

**Diversity**

*How does the proposed program or modification support diversity? E.g through curriculum design supporting different learners, accommodation, etc.*

Regarding the addition of STA130H1 as a program requirement: Key learning outcomes in STA130H1 include the development of oral and written communication skills, with activities developed in collaboration with the English Language Learning (ELL) and Writing Instruction for TAs (WIT) teams, recognizing the large percentage (approximately 60%) of international students in statistics programs of study.

**Resource Implications**

*Provide a statement of the resource requirements for the program, and an indication of whether you can meet these requirements through your existing resources, or have received additional resources.*

No additional resources beyond those required to meet the demands of our current enrolment. There will be some reorganization of existing resources among courses.

**Academic Context**

*Outline the context that explains why the program is designed this way, e.g. relation of program to discipline, students’ interests, career paths, etc.*

The discipline of statistics is evolving rapidly with the recent emergence of “data science” and “big data”. Statistics is foundational to data science and statistical reasoning is essential to maximize the full potential of new sources of data.

Coupled with this external context, the Department of Statistical Sciences has seen astounding growth in our undergraduate programs in statistics. Enrolment in statistics major and specialist programs of study is currently 3500 students, an over 12-fold increase in 10 years. These students are attracted to our programs by the growing demand for experts who can think with data.

The proposed modifications in statistical sciences programs address the knowledge, skills, and habits of mind needed of statisticians in the era of data science, while building on the traditional strengths of our department. The program changes include greater focus on predictive modelling and data from a wide variety of sources. The new learning outcomes reflect greater emphasis on communication, computation, and problem solving in novel contexts.

**Faculty and TA Support**

*Indicate how the modifications will be supported with existing faculty and Teaching Assistant resources. If new resources are needed, give more detail here about approvals obtained.*

The new program changes will require only minor changes in how our current teaching resources are distributed as students are reshuffled among some courses.

The enrolment restrictions will relieve some of the challenges we are facing finding sufficient sessional and suitable contractually-limited term appointments and qualified teaching assistants to staff our courses.
Learning Outcomes

Explain how the change affects, or does not affect, the program learning outcomes, including disciplinary goals, relevant methodologies and skills acquired upon program completion.

The requirement changes of the program are aligned with the new program learning outcomes.

Statistical Science encompasses methods and tools for obtaining knowledge from data and for understanding the uncertainty associated with this knowledge. The purposes of the undergraduate programs are to: (1) equip students with a general framework for obtaining knowledge from data; (2) give students skills that they are able to flexibly apply to a variety of problems; and (3) to provide students with the ability to learn new methods as needs, data sources, and technology change.

Students in the major and all specialist programs of study in statistics will acquire core learning outcomes in statistical methods, theory, computation, and communication. The Major Program in Statistics gives students a broad understanding of the statistical methods and computational and communication skills appropriate for effective statistical problem solving. The successful student will also acquire a general understanding of the role of mathematical thinking to support the development and evaluate the properties of statistical methods. While the major program is designed to complement study in an area of application of quantitative methods, students in the major program may choose to have a greater focus in probability and statistical theory through elective courses.

All of the programs of study prepare students for employment as a statistical scientist or for graduate studies in statistics or related disciplines.

Depth of Knowledge

The achievement of several of a set of learning outcomes that contribute to mastery of an area through intensive study. Explain how particular courses allow students to achieve depth of knowledge, relating to the proposed change.

The new introductory course, STA130H1, introduces students to the broad range of competencies required by modern statisticians including statistical reasoning in a variety of contexts for a variety of purposes, computational facility, ethical reasoning, and oral and written communication skills. Required courses in mathematics, computer science, and statistical theory ensure that by the end of 2nd year, students will have acquired the essential mathematical and computing background and the fundamental ideas of probability and statistical reasoning that will provide the foundation for deeper study. The 300-level courses in statistics provide in-depth study of statistical methodology, approaches to statistical practice, greater development of computational and problem solving skills, and, in the theory courses, deeper development of foundational mathematical ideas that underpin statistical methods. Many of the 300-level courses are pre-requisites to the 400-level courses that cover advanced aspects of statistical methodology, computation, and theory. Important topics in statistical reasoning can be traced through courses in the program with increasing levels of sophistication each year (for example, the fundamental ideas in statistical reasoning and statistical models in 2nd year courses lead to the methods covered in the courses in linear models at the 300-level STA 302/303/305, with more complex and leading-edge models covered in 400-level courses such as STA 437/442/457/414).

See the Statistics program curriculum map which traces the development of the program learning outcomes throughout our courses.
Competencies

For these five categories, describe how each competency is developed within the modified program to the degree relevant to the area/discipline. If the program does not address a particular competency, explain why that competency is not relevant to your area/discipline and how students in your program are expected to attain that competency within their overall degree program.

Critical and Creative Thinking

The purposeful and reflective examination of knowledge and ideas beyond memory and recall, whereby students can make informed judgments, synthesize what they have learned, and apply their ideas in novel ways.

Statistical scientists need to be able to read and evaluate the relevance of both the statistics literature and the relevant literature in their area of application, they need to assess and evaluate alternative statistical methods in the context of any project they are working on, and they need to develop novel approaches and adapt existing methodology (and sometimes develop new methodology) in the process of applying their quantitative reasoning skills to imperfect practical problems in order to get the most information from the available data.

The second year courses in statistics develop the foundations of statistical reasoning and, for the student, initiate the development of a logical thought that is later brought to bear on problems requiring critical reflection prior to the use of statistical methods. In more advanced courses, this development continues as the creative process required to tackle complex practical problems is demonstrated by faculty members and reinforced and further developed through assignments and projects. In the final year of the program students will be required to take a 4th year course with an emphasis on applying advanced statistical methodology to solving authentic problems.

Communication

The ability to express ideas, arguments, and facts to convey an intended message in a manner that is cogent and effective.

The development of oral and written communication skills begins in STA130H1 which includes communication intensive tutorials, developed in collaboration with the ELL and WIT programs. Communication is further developed throughout the program, with increasing sophistication. In courses in probability and statistical theory, students are required to produce concise mathematical arguments. In courses in statistical methodology, students are required to express the importance of their findings in the context of the practical problem for which the data were collected. All of the courses in the program emphasize the sound, logical, clear and direct presentation of arguments in solutions to assignments and tests.

Information Literacy

The ability to effectively find, evaluate, create, use and present knowledge, data and critical analyses for scholarly and other purposes.

In many of the advanced courses in the program, students gain experience in combining various types of information into a coherent argument. Beginning in STA130H1 and throughout their programs, students become proficient in the use of statistical software. In doing so, they learn how to find sample code and documentation for the software they are using.
Quantitative Reasoning
The ability to reason with basic mathematical, numerical and statistical concepts in order to enhance understanding of an area of study and to help navigate a data-driven world.

The practice of statistics concerns how to extract information from data to make reasoned conclusions and decisions in the presence of uncertainty. All of the mathematics and statistics courses required in the program develop students’ abilities in quantitative reasoning.

Social and Ethical Responsibility
The ability to engage in critical reflection upon questions of responsibility to oneself and society and to develop values of academic and personal integrity.

Appropriate use of statistical methods is essential to virtually all aspects of society. Statisticians have the obligation to carry out their work with competence, diligence and integrity, without bias, and conscious of the need to protect the privacy of data.

An introduction to ethical statistical practice is a specific topic in STA130H1. All of the courses in statistical methodology emphasize the importance of basing conclusions and decisions only on valid statistical models, the role bias can play in data collection and analysis, and the limitations of the statistical methods in the context of the practical problem for which the data were collected. Courses that emphasize data collection include discussions of the importance of careful planning to protect the subjects of the study from unnecessary risks and the researchers from unnecessary expense.

Integrative, Inquiry-based Activity
Activity that involves substantial investigation, synthesis of knowledge, and communication of results of the inquiry.

As part of our curriculum renewal project, the 4th year courses that students can choose among will include authentic assessments, requiring students to integrate the knowledge and skills acquired throughout the program towards the solutions of real-world problems. The development of facility to do this begins in STA130H1, which culminates with a project in which students analyse data towards learning from a current data set, typically from a business, non-governmental organization, or government agency, with results presented in poster sessions.

Students in the statistics major will have the opportunity to participate in our developing internship program, or other advanced experiential learning opportunities such as STA490Y1 or research / reading courses, as space permits.

Governance Path

<table>
<thead>
<tr>
<th>Level</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Committee on Admissions</td>
<td>November 28, 2018</td>
</tr>
<tr>
<td>Dean’s Office approval</td>
<td>December 19, 2018</td>
</tr>
<tr>
<td>Vice-Provost Sign-off</td>
<td>January 18, 2019</td>
</tr>
<tr>
<td>Undergraduate Curriculum Committee</td>
<td>January 31, 2019</td>
</tr>
<tr>
<td>Arts &amp; Science Council</td>
<td>February 31, 2019</td>
</tr>
<tr>
<td>AP &amp; P (for information)</td>
<td>May 8, 2019</td>
</tr>
</tbody>
</table>
Implementation of Change in 2019-20

Program modifications approved in the 2018-19 cycle will be published in the 2019-20 Calendar. To allow students time to plan their course and program choices for the 2019-20 year, program modifications will be in effect for students starting with the 2020 enrolment period. The Governance Unit and the Office of the Faculty Registrar can work with you to prepare for implementation and communicate the change to students.

Use this space to identify any planning concerns/considerations you may have that are associated with this change (for example, adding newly created courses to requirements, preparing for changes to enrolment requirements, messaging to students about the changes, etc).

| The largest change affecting students enrolling in the statistics major in the 2020 enrolment period will be the change in the enrolment requirements of the program (from open to limited enrolment). |
## Program: Statistics

### Proposed Program Map

**Core**
- STA130: Introduction to Statistical Reasoning and Data Science
- CSC108/120/148: Introduction to Computer Programming
- MAT135+135/137/157: Univariate Calculus
- MAT223: Linear Algebra

**Core Option 1**
- STA237: Probability, Statistics and Data Analysis I
- STA238: Probability, Statistics and Data Analysis II

**Core Option 2**
- STA257: Probability and Statistics I
- STA261: Probability and Statistics II

**Both Specialists**
- STA210 (planned): Statistical Computation

**Core Total**
- STA302/3: Methods of Data Analysis (Linear models and GLM)
- STA304/5: Data Collection
- STA314: Statistical Methods for Machine Learning I
- STA357: Probability and Statistics I
- STA355: Theory of Statistical Practice
- STA410: Statistical Computation
- STA414: Statistical Methods for Machine Learning II
- STA437: Methods for Multivariate Data
- STA442: Methods of Applied Statistics
- STA447: Stochastic Processes
- STA452,453: Mathematical Statistics
- STA457: Time Series Analysis
- STA465: Theory and Methods for Complex Spatial Data
- STA480: Fundamentals of Statistical Genetics
- STA490: Statistical Consultation, Communication, and Collaboration
- STA492: Research Seminar in Statistics

**Statistics Specialist Total**
- STA410: Statistical Computation
- STA414: Statistical Methods for Machine Learning II
- STA437: Methods for Multivariate Data
- STA442: Methods of Applied Statistics
- STA447: Stochastic Processes
- STA452,453: Mathematical Statistics
- STA457: Time Series Analysis
- STA465: Theory and Methods for Complex Spatial Data
- STA480: Fundamentals of Statistical Genetics
- STA490: Statistical Consultation, Communication, and Collaboration
- STA492: Research Seminar in Statistics

**Applied Statistics Specialist Total**
- STA410: Statistical Computation
- STA414: Statistical Methods for Machine Learning II
- STA437: Methods for Multivariate Data
- STA442: Methods of Applied Statistics
- STA447: Stochastic Processes
- STA452,453: Mathematical Statistics
- STA457: Time Series Analysis
- STA465: Theory and Methods for Complex Spatial Data
- STA480: Fundamentals of Statistical Genetics
- STA490: Statistical Consultation, Communication, and Collaboration
- STA492: Research Seminar in Statistics

### Notes:
- PLO11: more advanced computational skills was written only for the Data Science program
- PLO16: interdisciplinary teamwork was written only for the Applied Statistics and Data Science programs