Computer Science

- **M.C.S. Computer Science**
- **M.C.S. Computer Science, Accelerated Stream**
- **M.C.S. Computer Science with Specialization in Bioinformatics**
- **Ph.D. Computer Science**

M.C.S. Computer Science

About the Program

The M.C.S. program leads to a graduate degree in Computer Science. The program combines breadth knowledge in computer science through course work and depth knowledge in the area of specialization through research (M.C.S. Thesis option) or through course work and a project (M.C.S. non-Thesis option).

- Software Engineering
- Theory of Computing
- Computer Applications
- Computer Systems

Within these areas, the program emphasizes problems of current practical significance and advances in computer science knowledge. The program fosters collaborative and interdisciplinary work with the scientific and industrial (private and public) communities.

Academic Regulations

See the General Regulations section of this Calendar.

Admission Requirements for M.C.S. and M.C.S. Bioinformatics

See the General Regulations section of this Calendar for detailed admission requirements. Applicants should have an Honours bachelor's degree in computer science or the equivalent. By equivalent is meant an Honours degree in a program that includes at least twelve computer science half-credits, two of which must be at the 4000-level, and eight half- credits in mathematics, one of which must be at the 3000- or 4000-level. These courses must include the topics indicated below:

Computer Science

Data structures/file management, operating systems, computer architecture, algorithm design and analysis, assembly language and two high-level languages

Mathematics

Calculus, linear algebra, algebraic structures or discrete mathematics, probability and statistics, numerical analysis.

Applicants who have a general (3-year) bachelor's degree, or who otherwise lack the required undergraduate preparation, may be admitted to a qualifying-year program. Refer to the General Regulations section of this Calendar for regulations governing the qualifying year.

Admission Requirements for M.C.S. Accelerated Stream

Applicants must have a Carleton B.C.S. Honours degree with at least two COMP courses at the 5000-level with a grade of B+ or higher. See the General Regulations section of this Calendar for detailed admission requirements.

Program Requirements

Normally, students in the program will be expected to complete a thesis; however, students who have substantial relevant work experience may be permitted to take the non-thesis option, which must include a graduate research project course. Students in the Accelerated Stream must complete a thesis.Each candidate submitting a thesis will be required to undertake an oral defence of the thesis.

M.C.S. Computer Science - Thesis option (5.0 credits) (except for accelerated stream)

1. 2.5 credits in course work		2.5
2. Fulfilment of the graduate seminar requirement		
3. 2.5 credits in:		2.5
COMP 5905 [2.5]	M.C.S. Thesis (Each candidate submitting a thesis will be required to undertake an oral defence of the thesis.)	
Total Credits		5.0

M.C.S. Computer Science - Accelerated stream (4.0 credits)

1. 1.5 credits in course work		1.5
2. Fulfilment of the graduate seminar requirement		
3. 2.5 credits in:		2.5
COMP 5905 [2.5]	M.C.S. Thesis (Each candidate submitting a thesis will be required to undertake an oral defence of the thesis.)	
Total Credits		4.0

M.C.S. Computer Science - Non-thesis option (5.0 credits)

1. 4.0 credits in course work	4.0
2. Fulfilment of the graduate seminar requirement	
3. 1.0 credit in graduate project (a project may be completed in one or two terms)	1.0
Total Credits	5.0

Notes:

1. Course selections must be approved by the student's academic adviser, and must include at least (see OCICS course listing): 0.5 credit in software engineering, 0.5 credit in the theory of computing, and 0.5 credit in either computer applications or computer systems. For students in the Accelerated Stream, the 5000-level COMP courses taken as part of the B.C.S. degree can be used to satisfy area requirements.
2. The graduate seminar requirement includes a seminar presentation and participation in at least ten sessions in the joint graduate student seminar series.
3. Both course and thesis work may be completed either by full-time or part-time study.
4. A candidate can be permitted to carry out thesis work off campus provided suitable arrangements are made for supervision and experimental work, and prior approval is given by the Institute.

M.C.S. Computer Science with Specialization in Bioinformatics - Thesis Option (5.0 credits)

1. 1.0 credit in:		1.0
BIOL 5515 [0.5]	Bioinformatics	
BIOL 5517 [0.5]	Bioinformatics Seminar	
2. 1.5 additional credits in course work		1.5
3. Fulfullment of the graduate seminar requirement		
3. 2.5 credits in:		2.5
COMP 5905 [2.5]	M.C.S. Thesis (Each candidate submitting a thesis will be required to undertake an oral defence of the thesis.)	
Total Credits		5.0

Biomatics Related Courses

BIOL 5105 (BIO 5302)	Methods in Molecular Genetics
BIOL 5201 (BIO 8301)	Evolutionary Bioinformatics
BIOL 5409 (BIO 5306)	Modelling for Biologists
BIOL 5501 (BIO 8100)	Directed Studies in Biology
BIOL 5502 (BIO 8102)	Selected Topics in Biology
BIOL 5516 (BNF 5107)	Applied Bioinformatics
COMP 5306 (CSI 5100)	Data Integration
COMP 5307 (CSI 5101)	Knowledge Representation
COMP 5704 (CSI 5131)	Parallel Algorithms and Applications in Bioinformatics
COMP 5703 (CSI 5163)	Algorithm Analysis and Design
COMP 5108 (CSI 5126)	Algorithms in Bioinformatics
STAT 5708 (MAT 5170)	Probability Theory I
STAT 5709 (MAT 5171)	Probability Theory II
STAT 5703 (MAT 5181)	Data Mining
STAT 5702 (MAT 5182)	Modern Applied and Computational Statistics
STAT 5600 (MAT 5190)	Mathematical Statistics I
STAT 5501 (MAT 5191)	Mathematical Statistics II
MATH 6508 (MAT 5314)	Topics in Probability and Stats
MATH 6507 (MAT 5319)	Topics in Probability and Stats
SYSC 5104 (ELG 6114)	Methodologies For Discrete-Event Modeling And Simulation

Co-operative Option

A co-operative option is also available to full-time students in the Masters of Computer Science. Co-operative education is based on the principle that academic studies combined with work experience are desirable for effective professional preparation.

In addition to all other requirements for the degree, students admitted to the co-operative option must satisfactorily complete two work terms placements with a suitable employer in order to graduate with a co-op designation on their transcripts and diplomas. It is desirable that the work placements be related to the student's research. Placements are subject to the approval of the Supervisor of Graduate Studies and of the student's research supervisor. These work terms are four months in duration and students will conduct job searches through the university's co-op office. During a work term, students will register in COMP 5913.While on a work term, students in this option are limited to taking one additional 0.5-credit course, or registering in their thesis.

Students in the co-op option normally apply for admission to the co-operative option during their first academic term. This option requires an initial study period of two academic terms, typically followed by two work terms and a final academic period to complete the remaining requirements of the degree. The student must submit a work term report or make a formal oral presentation upon the completion of each work placement, and receive a grade of Satisfactory in order to meet the requirements for the successful completion of that work term's requirement.

Guidelines for Completion of Master's Degree

The following completion times are estimates only, based on full-time study, and are intended to provide guidance only.

Students are urged to check with the supervisor of graduate studies to determine the exact requirements of the degree program and other related information. Part-time students should calculate the completion times requirement by doubling the time estimates given below.

Students should complete the course work within the first two terms.

Selection of courses should be done in consultation with the student's faculty advisor. Approval from the Graduate Supervisor of the Institute is only required for courses not listed as valid OCICS courses. Subject to the approval of the Graduate Supervisor, M.C.S. students may take courses in other relevant disciplines. At least half of the course credits of an M.C.S. student must be valid OCICS courses. At most, two Fourth Year undergraduate courses may be taken with the permission of the Graduate Supervisor. A thesis supervisor and thesis topic must be selected by the end of the second term. The supervisor of graduate studies should be formally notified of this selection. The expected completion time for the M.C.S. degree is four to six terms of full-time study depending on the type of thesis and the area of research.

Students wishing to pursue the co-op option normally apply for admission to the co-operative option during their first academic term. This option requires an initial study period of two academic terms, typically followed by two work terms and a final academic period to complete the remaining requirements of the degree. The student

must submit a work term report or make a formal oral presentation upon the completion of each work placement, and receive a grade of Satisfactory in order to meet the requirements for the successful completion of that work term's requirement.

Ph.D. Computer Science

About the Program

The Ph.D. program leads to a Doctor of Philosophy degree in Computer Science. The program combines breadth knowledge in computer science through course work and depth knowledge in the area of specialization through research (Ph.D. Thesis option).

The Ph.D. areas of specialization are:

- **Software Engineering**
- **Theory of Computing**
- **Computer Applications**
- **Computer Systems**

Within these areas, the program emphasizes problems of current practical significance and advances in computer science knowledge. The program fosters collaborative and interdisciplinary work with the scientific and industrial (private and public) communities.

Academic Regulations

See the General Regulations section of this Calendar.

Admission Requirements

Admission to the Ph.D. in Computer Science requires a Masters in Computer Science with thesis, or equivalent including demonstrated significant research ability.

In exceptional cases, students who are currently in the M.C.S. program and who have completed all course requirements with a grade of no less than A in each course may be permitted to transfer into the Ph.D. program.

Program Requirements

Ph.D. Computer Science (10.0 credits)		
1. 1.5 credits in courses at the graduate level in at least three different research areas (see OCICS course grouping by area).		1.5
The admission committee and the student's advisory committee may impose additional program requirements according to the student's background and research topic.		
2. Presentation of at least two seminars in the Ottawa-Carleton Institute for Computer Science seminar series: Minimally, the student must make one presentation for the graduate seminar, and one presentation for the departmental seminar.		
3. 0.0 credit in:		0.0
COMP 6907 [0.0]	Doctoral Comprehensive (involving breadth and depth components, must be taken within the first 4 terms)	
4. 0.0 credit in:		0.0
COMP 6908 [0.0]	Doctoral Proposal (defended at an oral examination)	
5. 8.5 credits in:		8.5
COMP 6909 [11.5]	Ph.D. Thesis (defended at an oral examination)	
Total Credits		10.0

Guidelines for Completion of Doctoral Degree

The following completion times are estimates based on full-time study.

- During the first term, the student and his or her faculty adviser should select graduate courses related to their area(s) of research and interests. Approval from the Graduate Supervisor of the Institute is only required for courses not listed as valid OCICS courses.
- Subject to the approval of the Graduate Supervisor, Ph.D. students may take courses in other relevant disciplines. At least half of the course credits of a Ph.D. student must be valid OCICS courses.
- An advisory committee comprised of three to five faculty members must be established before the student registers in the comprehensive examination. The committee is responsible for the comprehensive examination, the thesis proposal, and for guiding the student's research. The advisory committee must include at least one representative from EECS at the University of Ottawa. The advisory committee must be approved by the director or associate director of the Institute.
- All course requirements must be completed within the first 6 terms.
- Within the first 8 terms, the student must submit a written thesis proposal and defend it in an oral examination (see COMP 6908).
- The expected completion time for the Ph.D. program is approximately twelve terms depending on the type of thesis and the area of research.
- Before the completion of the program, the student is expected to present at least two seminars in the Ottawa-Carleton Institute for Computer Science seminar series.

Residence Requirement

Students must fulfill a residence requirement of at least four terms of full-time study.

Graduate Courses

Not all of the following courses are offered in a given year. For an up-to-date statement of course offerings or to determine the term of offering, consult central.carleton.ca

Subject to the approval of the Graduate Supervisor, M.C.S. and Ph.D. students may take courses in other relevant disciplines. The courses in the following list are offered by the two departments forming OCICS.

Carleton University

COMP School of Computer Science

University of Ottawa

CSI School of Electrical Engineering and Computer Science

Software Engineering

COMP 5001 (CSI 5113)	Foundations of Programming Languages
COMP 5104 (CSI 5314)	Object-Oriented Software Development
COMP 5106 (CSI 5123)	Languages for Parallel Computing
COMP 5400 (CSI 5310)	Software Patterns
COMP 6104 (CSI 7314)	Advanced Topics in Object-Oriented Systems
COMP 6603 (CSI 7161,CSI 7561)	Advanced Topics in Programming Systems and Languages
CSI 5107 (COMP 5609)	Program Construction and Fault Tolerance
CSI 5109 (COMP 5701)	Specification Methods for Distributed Systems
CSI 5111 (COMP 5501)	Software Quality Engineering
CSI 5112 (COMP 5207)	Software Engineering
CSI 5115 (COMP 5503)	Database Analysis and Design
CSI 5118 (COMP 5302)	Automated Verification and Validation of Software
CSI 5122 (COMP 5301)	Software Usability
CSI 5134 (COMP 5004)	Fault Tolerance
CSI 5143 (COMP 5403)	Real-time Systems Development
CSI 5184 (COMP 5804)	Logic Programming
CSI 5507 (COMP 5609)	Les programmes: construction et tolerance aux fautes
CSI 5509 (COMP 5701)	Methodes pour la specification de systemes repartis
CSI 5584 (COMP 5804)	Programmation logique

Theory of Computing

COMP 5003 (CSI 5308)	Principles of Distributed Computing
COMP 5005 (CSI 5390)	Learning Systems for Random Environments
COMP 5008 (CSI 5164)	Computational Geometry
COMP 5107 (CSI 5185)	Statistical and Syntactic Pattern Recognition
COMP 5203 (CSI 5173)	Data Networks
COMP 5306 (CSI 5100)	Data Integration
COMP 5307 (CSI 5101)	Knowledge Representation
COMP 5308 (CSI 5102)	Topics in Medical Computing
COMP 5404 (CSI 5144)	Computer-Aided Program Verification
COMP 5408 (CSI 5121)	Advanced Data Structures
COMP 5409 (CSI 5127)	Applied Computational Geometry
COMP 5703 (CSI 5163)	Algorithm Analysis and Design
COMP 5807 (MATH 5807,CSI 5104)	Formal Language and Syntax Analysis
COMP 6601 (CSI 7160)	Advanced Topics in the Theory of Computing
COMP 6602 (CSI 7170,CSI 7970)	Advanced Topics in Distributed Computing
CSI 5107 (COMP 5609)	Program Construction and Fault Tolerance
CSI 5108 (COMP 5700)	Software Specification and Verification
CSI 5110 (COMP 5707)	Principles of Formal Software Development
CSI 5126 (COMP 5108)	Algorithms in Bioinformatics
CSI 5148 (COMP 5103)	Wireless Ad Hoc Networking
CSI 5149 (COMP 5007)	Graphical Models
CSI 5161 (COMP 5606)	Topics in System Simulation and Optimization
CSI 5162 (COMP 5702)	Order: Its Algorithms and Graphical Data Structures
CSI 5165 (COMP 5709)	Combinatorial Algorithms
CSI 5166 (COMP 5805)	Applications of Combinatorial Optimization
CSI 5169 (COMP 5304)	Wireless Networks and Mobile Computing
CSI 5174 (COMP 5604)	Validation Methods for Distributed Systems
CSI 5367 (COMP 5300)	Structure in Complexity Theory
CSI 5507 (COMP 5609)	Les programmes: construction et tolerance aux fautes
CSI 5508 (COMP 5700)	Specification et verification de logiciels
CSI 5510 (COMP 5707)	Principes de developpement formel de logiciels
CSI 5526 (COMP 5180)	Algorithmes en bioinformatique
CSI 5562 (COMP 5702)	Ordre: algorithmes et structures graphiques de donnees
CSI 5565 (COMP 5709)	Algorithmes combinatoires

Computer Applications

COMP 5002 (CSI 5128)	Swarm Intelligence
COMP 5100 (CSI 5180,CSI 5580)	Topics in Artificial Intelligence
COMP 5204 (CSI 5124)	Computational Aspects of Geographic Information Systems
COMP 5206 (CSI 5183)	Evolutionary Computation and Artificial Life
COMP 5305 (CSI 5129)	Advanced Database Systems
COMP 5306 (CSI 5100)	Data Integration

COMP 5307 (CSI 5101)	Knowledge Representation
COMP 5308 (CSI 5102)	Topics in Medical Computing
COMP 5401 (CSI 5389, CSI 5789)	Electronic Commerce Technologies
COMP 5406 (CSI 5105)	Network Security and Cryptography
COMP 5407 (CSI 5116)	Authentication and Software Security
COMP 6604 (CSI 7162)	Advanced Topics in Computer Applications
CSI 5114 (COMP 5504)	Automated Office Systems
CSI 5126 (COMP 5108)	Algorithms in Bioinformatics
CSI 5145 (COMP 5109)	Statistical Approaches to Natural Language Processing
CSI 5146 (COMP 5202)	Computer Graphics
CSI 5147 (COMP 5201)	Computer Animation
CSI 5151 (COMP 5205)	Virtual Environments
CSI 5162 (COMP 5702)	Order: Its Algorithms and Graphical Data Structures
CSI 5168 (COMP 5309)	Digital Watermarking
CSI 5304 (COMP 5602)	Knowledge Engineering
CSI 5380 (COMP 5405)	Systems and Architectures for Electronic Commerce
CSI 5386 (COMP 5505)	Natural Language Processing
CSI 5387 (COMP 5706)	Data Mining and Concept Learning
CSI 5388 (COMP 5801)	Topics in Machine Learning
CSI 5514 (COMP 5504)	Bureautique
CSI 5526 (C0MP 5180)	Algorithmes en bioinformatique
CSI 5562 (COMP 5702)	Ordre: algorithmes et structures graphiques de donnees
CSI 5580 (COMP 5100)	Sujet en intelligence artificielle
CSI 5780 (COMP 5405)	Systemes et architectures des logiciels pour le commerce electronique
CSI 5787 (COMP 5706)	Fouille des donnees et apprentissage des concepts

Computer Systems

COMP 5003 (CSI 5308)	Principles of Distributed Computing
COMP 5009 (CSI 5141)	Associative Data Structures and Advanced Databases
COMP 5101 (CSI 5311)	Distributed Databases and Transaction Processing Systems
COMP 5102 (CSI 5312)	Distributed Operating Systems
COMP 5107 (CSI 5185)	Statistical and Syntactic Pattern Recognition
COMP 5203 (CSI 5173)	Data Networks
COMP 5305 (CSI 5129)	Advanced Database Systems
COMP 5401 (CSI 5389, CSI 5789)	Electronic Commerce Technologies
COMP 5402 (CSI 5142)	Protocols for Mobile and Wireless Networks
COMP 5406 (CSI 5105)	Network Security and Cryptography
COMP 5407 (CSI 5116)	Authentication and Software Security
COMP 5704 (CSI 5131)	Parallel Algorithms and Applications in Bioinformatics
COMP 6100 (CSI 7131)	Advanced Parallel and Systolic Algorithms
COMP 6602 (CSI 7170,CSI 6970)	Advanced Topics in Distributed Computing
COMP 6605 (CSI 7163)	Advanced Topics in Computer Systems
CSI 5109 (COMP 5701)	Specification Methods for Distributed Systems
CSI 5114 (COMP 5504)	Automated Office Systems
CSI 5132 (COMP 5105)	Parallel Processing Systems
CSI 5133 (COMP 5608)	Simulation and Testing of Logic Circuits
CSI 5134 (COMP 5004)	Fault Tolerance
CSI 5143 (COMP 5403)	Real-time Systems Development
CSI 5147 (COMP 5201)	Computer Animation
CSI 5148 (COMP 5103)	Wireless Ad Hoc Networking
CSI 5161 (COMP 5606)	Principles of Distributed Simulation
CSI 5168 (COMP 5309)	Digital Watermarking
CSI 5169 (COMP 5304)	Wireless Networks and Mobile Computing
CSI 5170 (COMP 5800)	Distributed Data Processing
CSI 5171 (COMP 5303)	Network Architectures, Services, Protocols and Standards
CSI 5174 (COMP 5604)	Validation Methods for Distributed Systems
CSI 5380 (COMP 5405)	Systems and Architectures for Electronic Commerce
CSI 5509 (COMP 5701)	Methodes pour la specification de systemes repartis
CSI 5514 (COMP 5504)	Bureautique
CSI 5780 (COMP 5405)	Systemes et architectures des logiciels pour le commerce electronique

Others	
COMP 5900 (CSI 5140)	Selected Topics in Computer Science
COMP 5901 (CSI 5901)	Directed Studies (M.C.S.)
COMP 5902 (CSI 5900)	Graduate Project (M.C.S./M.Sc. [ISS])
COMP 5903 (CSI 6900)	Intensive Graduate Project (M.C.S.)
COMP 5904 (CSI 5902)	Master's Seminar
COMP 5905 (CSI 7999)	M.C.S. Thesis
COMP 5913	Master's Co-operative Workterm
COMP 6901 (CSI 7901)	Directed Studies (Ph.D.)
COMP 6902 (CSI 7900)	Graduate Project (Ph.D.)
COMP 6907 (CSI 9998)	Doctoral Comprehensive
COMP 6908 (CSI 9997)	Doctoral Proposal
COMP 6909 (CSI 9999)	Ph.D. Thesis

Computer Science (COMP) Courses

COMP 5001 [0.5 credit] (CSI 5113)
Foundations of Programming Languages
Advanced study of programming paradigms from a practical perspective. Paradigms may include functional, imperative, concurrent, distributed, generative, aspect- and object-oriented, and logic programming. Emphasis on underlying principles. Topics may include: types, modules, inheritance, semantics, continuations, abstraction and reflection.
Prerequisite(s): COMP 3007 or the equivalent.

COMP 5002 [0.5 credit] (CSI 5128)
Swarm Intelligence
Collective computation, collective action, and principles of self-organization in social agent systems. Algorithms for combinatorial optimization problems, division of labour, task allocation, task switching, and task sequencing with applications in security, routing, wireless and ad hoc networks and distributed manufacturing.

COMP 5003 [0.5 credit] (CSI 5308)
Principles of Distributed Computing
Formal models; semantics of distributed computations; theoretical issues in design of distributed algorithms; computational complexity; reducibility and equivalence of distributed problems. Related topics: systolic systems and computations, oligarchical systems and control mechanisms.

COMP 5004 [0.5 credit]
Fault Tolerance

COMP 5005 [0.5 credit] (CSI 5390)
Learning Systems for Random Environments
Computerized adaptive learning for random environments and its applications. Topics include a mathematical review, learning automata which are deterministic/stochastic, with fixed/variable structures, of continuous/discretized design, with ergodic/absorbing properties and of estimator families.
Prerequisite(s): MATH 2600 or MATH 3500, or SYSC 5503 or equivalent.

COMP 5007 [0.5 credit]
Graphic Models

COMP 5008 [0.5 credit] (CSI 5164)
Computational Geometry
Study of design and analysis of algorithms to solve geometric problems; emphasis on applications such as robotics, graphics, and pattern recognition. Topics include: visibility problems, hidden line and surface removal, path planning amidst obstacles, convex hulls, polygon triangulation, point location.
Prerequisite(s): COMP 3804 or equivalent.

COMP 5009 [0.5 credit] (CSI 5141)
Associative Data Structures and Advanced Databases
Concepts and advanced topics in the design, implementation and analysis of physical storage schemes with emphasis on their application to specialized database and information retrieval systems. Topics include: associative searching techniques; multidimensional storage structures; algorithms for spatial data modeling; formulation and optimization of database queries.
Prerequisite(s): COMP 3005 and COMP 3804, or the equivalent.

COMP 5100 [0.5 credit] (CSI 5180, CSI 5580)
Topics in Artificial Intelligence
Areas in knowledge-based systems including recent approaches to machine learning and data mining, inference methods, knowledge-based and fuzzy systems, heuristic search, and natural language processing.
Precludes additional credit for COMP 4106.
Prerequisite(s): COMP 3007 or equivalent.

COMP 5101 [0.5 credit] (CSI 5311)
Distributed Databases and Transaction Processing Systems
Principles in the design and implementation of distributed databases and distributed transaction processing systems. Topics include: distributed computing concepts, computing networks, distributed and multi-database system architectures and models, atomicity, synchronization and distributed concurrency control algorithms, data replication, recovery techniques, reliability in distributed databases.
Precludes additional credit for COMP 4101.
Prerequisite(s): COMP 3005, COMP 4001, and COMP 4003 or equivalent.

COMP 5102 [0.5 credit] (CSI 5312)
Distributed Operating Systems
Design issues of advanced multiprocessor distributed operating systems: multiprocessor system architectures; process and object models; synchronization and message passing primitives; memory architectures and management; distributed file systems; protection and security; distributed concurrency control; deadlock; recovery; remote tasking; dynamic reconfiguration; performance measurement, modeling, and system tuning.
Prerequisite(s): COMP 3000 and COMP 3203 or equivalent.

COMP 5103 [0.5 credit]
Wireless Ad Hoc Networking

COMP 5104 [0.5 credit] (CSI 5314)
Object-Oriented Software Development
Issues in modeling and verifying quality and variability in object-oriented systems. Testable models in model-driven and test-driven approaches. System family engineering. Functional conformance: scenario modeling and verification, design by contract. Conformance to non functional requirements: goals, forces and tradeoffs, metrics.
Prerequisite(s): COMP 2004 or equivalent.

COMP 5106 [0.5 credit] (CSI 5123)
Languages for Parallel Computing
Survey of major language paradigms for parallel computing: sequential imperative, parallel imperative, logic, functional (reduction and dataflow), object and message-passing based languages; communicating sequential processes; and massive data-level parallelism. Topics include detection, determinism, data partitioning, task scheduling, task granularity, synchronization methods, resource management, and debugging.
Prerequisite(s): COMP 5001.

COMP 5107 [0.5 credit] (CSI 5185)
Statistical and Syntactic Pattern Recognition
Topics include a mathematical review, Bayes decision theory, maximum likelihood and Bayesian learning for parametric pattern recognition, non-parametric methods including nearest neighbor and linear discriminants. Syntactic recognition of strings, substrings, subsequences and tree structures. Applications include speech, shape and character recognition.
Prerequisite(s): permission of the School.

COMP 5108 [0.5 credit]
Algorithms in Bioinformatics

COMP 5111 [0.5 credit]
Data Management for Business Intelligence
Application of computational techniques to support business such as decision making, business understanding, data analysis, business process automation, learning from data, producing and using business models, data integration, data quality assessment and cleaning, use of contextual data.
Also offered at the undergraduate level, with different requirements, as COMP 4111, for which additional credit is precluded.

COMP 5112 [0.5 credit] (CSI 5104)
Algorithms for Data Science
Algorithmic techniques to handle (massive/big) data arising from, for example, social media, mobile devices, sensors financial transactions. Algorithmic techniques may include locality-sensitive hashing, dimensionality reduction, streaming, clustering, VC-dimension, external memory, core sets, link analysis and recommendation systems.

COMP 5201 [0.5 credit]
Computer Animation

COMP 5202 [0.5 credit]
Computer Graphics

COMP 5203 [0.5 credit] (CSI 5173)
Data Networks
Mathematical and practical aspects of design and analysis of communication networks. Topics include: basic concepts, layering, delay models, multi-access communication, queuing theory, routing, fault-tolerance, and advanced topics on high-speed networks, ATM, mobile wireless networks, and optical networks.
Prerequisite(s): COMP 4804 or permission of the School.

COMP 5204 [0.5 credit] (CSI 5124)
Computational Aspects of Geographic Information Systems
Computational perspective of geographic information systems (GIS). Data representations and their operations on raster and vector devices: e.g., quadtrees, grid files, digital elevation models, triangular irregular network models. Analysis and design of efficient algorithms for solving GIS problems: visibility queries, point location, facility location.
Prerequisite(s): COMP 3804 or the equivalent.

COMP 5205 [0.5 credit]
Virtual Environments

COMP 5206 [0.5 credit] (CSI 5183)
Evolutionary Computation and Artificial Life
Study of algorithms based upon biological theories of evolution, applications to machine learning and optimization problems. Possible topics: Genetic Algorithms, Classifier Systems, and Genetic Programming. Recent work in the fields of Artificial Life (swarm intelligence, distributed agents, behavior-based AI) and of connectionism.
Precludes additional credit for COMP 4107.
Prerequisite(s): COMP 3007 or the equivalent.

COMP 5207 [0.5 credit]
Software Engineering

COMP 5209 [0.5 credit] (CSI 5104)
Visual Analytics
Principles, techniques, technology and applications of information visualization for data analysis. Topics include human visual perception, cognitive processes, static and dynamic models of image semantics, interaction paradigms, big data visual analysis case studies.

COMP 5300 [0.5 credit]
Struct in Complexity Theory

COMP 5301 [0.5 credit]
Software Usability

COMP 5302 [0.5 credit]
Automated Verification & Valid

COMP 5304 [0.5 credit]
Wireless Netwks & Mobile

COMP 5305 [0.5 credit] (CSI 5129)
Advanced Database Systems
In-depth study on developments in database systems shaping the future of information systems, including complex object, object-oriented, object-relational, and semi-structured databases. Data structures, query languages, implementation and applications.
Prerequisite(s): COMP 3005 or the equivalent.

COMP 5306 [0.5 credit] (CSI 5100)
Data Integration
Materialized and virtual approaches to integration of heterogeneous and independent data sources. Emphasis on data models, architectures, logic-based techniques for query processing, metadata and consistency management, the role of XML and ontologies in data integration; connections to schema mapping, data exchange, and P2P systems.
Precludes additional credit for COMP 5900 section 'G' offered fall term 2002 and 2004.
Prerequisite(s): COMP 3005 or equivalent.

COMP 5307 [0.5 credit] (CSI 5101)
Knowledge Representation
KR is concerned with representing knowledge and using it in computers. Emphasis on logic-based languages for KR, and automated reasoning techniques and systems; important applications of this traditional area of AI to ontologies and semantic web.
Precludes additional credit for COMP 5900 section 'X' offered in winter term from 2003-2004 to 2005-2006 inclusive.
Prerequisite(s): COMP 1805 and COMP 3005, or equivalents.

COMP 5308 [0.5 credit] (CSI 5102)
Topics in Medical Computing
Introductory course on data structures, algorithms, techniques, and software development related to medical computing (in particular spatial modeling). Topics may include: computational geometry algorithms for cancer treatment, medical imaging, spatial data compression algorithms, dynamic programming for DNA analysis.
Precludes additional credit for COMP 5900 section 'Y' offered 2001-2002 to 2005-2006 inclusive.
Prerequisite(s): COMP 3804 or equivalent.

COMP 5309 [5.0 credits]
Digital Watermarking

COMP 5400 [0.5 credit] (CSI 5310)
Software Patterns
Current developments in software patterns, three-part rules expressing relations between software contexts, problems and solutions. Pattern categories discussed include architectural, design, analysis, refactoring, general-purpose, anti-patterns, and idioms. Students are required to apply existing patterns and to develop and defend new ones.
Prerequisite(s): COMP 3004 or equivalent.

COMP 5401 [0.5 credit] (CSI 5389, CSI 5789)
Electronic Commerce Technologies
Introduction to business models and technologies. Search engines. Cryptography. Web services and agents. Secure electronic transactions. Value added e-commerce technologies. Advanced research questions.
Prerequisite(s): COMP 2005 and COMP 4104, or CSI 4128 and CSI 3140, or equivalent.

COMP 5402 [0.5 credit] (CSI 5142)
Protocols for Mobile and Wireless Networks
Link and network layer protocols of wireless networks; applications of wireless networks may be discussed. Topics may include: protocol implementation, mobile IP, resource discovery, wireless LANs/PANs, and Spreadspectrum.
Precludes additional credit for SYSC 5306.
Prerequisite(s): COMP 3203 or equivalent.

COMP 5404 [0.5 credit] (CSI 5144)
Computer-Aided Program Verification
Automatic verification techniques for concurrent, reactive, and real-time programs. Topics may include temporal logics, the basic model-checking algorithm, symbolic model checking, compositional techniques, exploiting abstraction and symmetry, models based on partial orders, model-checking for the mu-calculus, applications to communication protocols, computer security and digital circuits.
Prerequisite(s): COMP 4004 or equivalent.

COMP 5405 [0.5 credit]
Syst & Archit for Elec Com

COMP 5406 [0.5 credit] (CSI 5105)
Network Security and Cryptography
Advanced methodologies selected from symmetric and public key cryptography, network security protocols and infrastructure, identification, secret-sharing, anonymity, intrusion detection, firewalls, defending network attacks and performance in communication networks.
Prerequisite(s): COMP 3203 and COMP 4109, or equivalent, or permission of the instructor.

COMP 5407 [0.5 credit] (CSI 5116)
Authentication and Software Security
Specialized topics in security including advanced authentication techniques, user interface aspects, electronic and digital signatures, security infrastructures and protocols, software vulnerabilities affecting security, untrusted software and hosts, protecting software and digital content.
Prerequisite(s): COMP 3000 and COMP 4108, or equivalent; or permission of the instructor.

COMP 5408 [0.5 credit] (CSI 5121)
Advanced Data Structures
Simple methods of data structure design and analysis that lead to efficient data structures for several problems. Topics include randomized binary search trees, persistence, fractional cascading, self-adjusting data structures, van Emde Boas trees, tries, randomized heaps, and lowest common ancestor queries.
Prerequisite(s): COMP 4804 or equivalent.

COMP 5409 [0.5 credit] (CSI 5127)
Applied Computational Geometry
Computer-based representation and manipulation of geometric objects. Design and analysis of efficient algorithms for solving geometric problems in applied fields such as Computer-Aided Design and Manufacturing, Cartography, Materials Science, and Geometric Network Design.
Prerequisite(s): COMP 4804 or equivalent.

COMP 5501 [0.5 credit]
Software Quality Engineering

COMP 5503 [0.5 credit]
Database Analysis & Design

COMP 5505 [0.5 credit]
Natural Language Processing

COMP 5604 [0.5 credit]
Validation Meth Distri Sys

COMP 5606 [0.5 credit]
Top in Syst Simul & Optim

COMP 5702 [0.5 credit]
Order

COMP 5703 [0.5 credit] (CSI 5163)
Algorithm Analysis and Design
Topics of current interest in the analysis and design of sequential and parallel algorithms for non-numerical, algebraic and graph computations. Lower bounds on efficiency of algorithms. Complexity classes.
Prerequisite(s): permission of the School.

COMP 5704 [0.5 credit] (CSI 5131)
Parallel Algorithms and Applications in Bioinformatics
Multiprocessor architectures from an application programmer's perspective: programming models, processor clusters and multi-core processors, algorithmic paradigms, efficient parallel problem solving, limits of parallelism, software scalability and portability. Projects with an emphasis on high performance computing in bioinformatics. Programming experience on parallel processing equipment.
Prerequisite(s): COMP 3804 or the equivalent.

COMP 5706 [0.5 credit]
Data Mining & Concept Learning

COMP 5707 [0.5 credit]
Prin Formal Software Devel

COMP 5709 [0.5 credit]
Combinatorial Algorithms

COMP 5800 [0.5 credit]
Distributed Data Proc

COMP 5801 [0.5 credit]
Topics in Machine Learning

COMP 5802 [0.5 credit] (CSI 5131)
Introduction to Information and Systems Science
An introduction to the process of applying computers in problem solving. Emphasis is placed on the design and analysis of efficient computer algorithms for large, complex problems. Applications in a number of areas are presented: data manipulation, databases, computer networks, queuing systems, optimization.
Also listed as MATH 5802, SYSC 5802, ISYS 5802.

COMP 5805 [0.5 credit]
Appli. of Combinatorial Optim

COMP 5807 [0.5 credit] (CSI 5104)
Formal Language and Syntax Analysis
Computability, unsolvable and NP-hard problems. Formal languages, classes of languages, automata. Principles of compiler design, syntax analysis, parsing (top-down, bottom-up), ambiguity, operator precedence, automatic construction of efficient parsers, LR, LR (O), LR(k), SLR, LL(k); syntax directed translation.
Also listed as MATH 5807.
Prerequisite(s): COMP 3002, or MATH 4805 or MATH 5605, or the equivalent.

COMP 5900 [0.5 credit] (CSI 5140)
Selected Topics in Computer Science
Selected topics, not covered by other graduate courses. Details will be available from the School at the time of registration.

COMP 5901 [0.5 credit] (CSI 5901)
Directed Studies (M.C.S.)
A course of independent study under the supervision of a member of the School of Computer Science.

COMP 5902 [0.5 credit]
Graduate Project (M.C.S./M.Sc. [ISS])

COMP 5903 [1.0 credit] (CSI 6900)
Intensive Graduate Project (M.C.S.)
A one- or two-session course. For M.C.S. non-thesis option students only. Not to be combined for credit with COMP 5902.

COMP 5904 [0.0 credit] (CSI 5902)
Master's Seminar
To complete this course, the student must attend 5 graduate seminars at Carleton, and 5 at SITE within a year. The student must also make one presentation in the context of this graduate seminar.

COMP 5905 [2.5 credits]
M.C.S. Thesis

COMP 5908 [1.5 credit] (CSI 6002)
M.Sc. Thesis in Information and Systems Science
Also listed as MATH 5908, SYSC 5908.

COMP 5913 [0.0 credit]
Master's Co-operative Workterm

COMP 6100 [0.5 credit] (CSI 7131)
Advanced Parallel and Systolic Algorithms
Continuation of COMP 5704.
Prerequisite(s): COMP 5704.

COMP 6104 [0.5 credit] (CSI 7314)
Advanced Topics in Object-Oriented Systems
Advanced object-oriented software engineering, in particular the issues of reuse and testing. Sample topics include: interaction modeling; class and cluster testing; traceability; design patterns and testing; the C++ standard template library. Students will carry out research.
Prerequisite(s): COMP 5104 or permission of instructor.

COMP 6601 [0.5 credit]
Advanced Topics in the Theory of Computing

COMP 6602 [0.5 credit]
Advanced Topics in Distributed Computing

COMP 6603 [0.5 credit]
Advanced Topics in Programming Systems and Languages

COMP 6604 [0.5 credit]
Advanced Topics in Computer Applications

COMP 6605 [0.5 credit]
Advanced Topics in Computer Systems

COMP 6901 [0.5 credit]
Directed Studies (Ph.D.)

COMP 6902 [0.5 credit]
Graduate Project (Ph.D.)

COMP 6907 [0.0 credit] (CSI 9998)
Doctoral Comprehensive
A committee must be assembled and approve at least 3 topics for written examination: typically, a major and two minor areas. An oral examination occurs if the written exam is passed. Both elements must take place within the first 4 terms following initial registration in the program. The comprehensive may be failed, passed conditionally (i.e., with extra course requirements) or passed unconditionally. If failed this course may be retaken at most one time.

COMP 6908 [0.0 credit] (CSI 9997)
Doctoral Proposal
Within 8 terms following initial registration in the program, a document generally defining the problem addressed, relating it to the literature, and outlining the hypotheses, goals, research methodology, initial results and validation approach must be submitted to an examination committee and successfully defended.

COMP 6909 [11.5 credits]
Ph.D. Thesis

Summer session: some of the courses listed in this Calendar are offered during the summer. Hours and scheduling for summer session courses will differ significantly from those reported in the fall/winter Calendar. To determine the scheduling and hours for summer session classes, consult the class schedule at central.carleton.ca

Not all courses listed are offered in a given year. For an up-to-date statement of course offerings for the current session and to determine the term of offering, consult the class schedule at central.carleton.ca