Computer Science and Engineering (CSE)

PROFESSORS

Donald W. Anderson, Ph.D., *Emeritus*
Scott B. Baden, Ph.D.
Vineet Bafna, Ph.D.
Mihir Bellare, Ph.D.
Francine D. Berman, Ph.D.
Kenneth L. Bowles, Ph.D., *Emeritus*
Walter A. Burkhard, Ph.D.
J. Lawrence Carter, Ph.D., *Emeritus*
Chung-Kuan Cheng, Ph.D.
Garrison W. Cottrell, Ph.D.
Charles P. Elkan, Ph.D.
Jeanne Ferrante, Ph.D.
Yoav Freund, Ph.D.
Fan Chung Graham, Ph.D.
Ronald L. Graham, Ph.D.
William G. Griswold, Ph.D.
Rajesh Gupta, Ph.D.
William E. Howden, Ph.D.
T. C. Hu, Ph.D., *Emeritus*
Russell Impagliazzo, Ph.D.
Ramesh Jain, Ph.D., *Emeritus*
Andrew B. Kahng, Ph.D.
Sidney Karin, Ph.D., *Emeritus*
David Kriegman, Ph.D.
Keith Marzullo, Ph.D., *Chair*
Daniele Micciancio, Ph.D.
Alex Orailoglu, Ph.D.
Alon Orlitsky, Ph.D.
Yannis Papakonstantinou, Ph.D.
Joseph Pasquale, Ph.D.
Ramamohan Paturi, Ph.D.
Pavel Pevzner, Ph.D.
Walter J. Savitch, Ph.D., *Emeritus*
Larry L. Smarr, Ph.D.
Dean M. Tullsen, Ph.D.
Amin Vahdat, Ph.D.
Alexander Vardy, Ph.D.
George Varghese, Ph.D.
Victor D. Vianu, Ph.D.
Geoffrey Voelker, Ph.D.
S. Gill Williamson, Ph.D., *Emeritus*
Yuanyuan Zhou, Ph.D.

ASSOCIATE PROFESSORS

Serge J. Belongie, Ph.D.
Sanjoy Dasgupta, Ph.D.
Alin Deutsch, Ph.D.
Henrik Wann Jensen, Ph.D.
Ryan Kastner, Ph.D.
Ingolf Krueger, Ph.D.
Lawrence K. Saul, Ph.D.
Stefan Savage, Ph.D.
Alex Snoeren, Ph.D.

ASSISTANT PROFESSORS

Ranjit Jhala, Ph.D.
Sorin Lerner, Ph.D.
Tajana S. Rosing, Ph.D.
Hovav Shacham, Ph.D.
Steven J. Swanson, Ph.D.
Michael Taylor, Ph.D.

ADJUNCT FACULTY

Samuel R. Buss, Ph.D., *Mathematics*
Bradley G. Calder, Ph.D., *Computer Science and Engineering*
Andrew Chien, Ph.D., *Computer Science and Engineering*
Kimberly Claffy, Ph.D., *San Diego Supercomputer Center*
Jim Hollan, Ph.D., *Cognitive Science*
Falko Kuester, Ph.D., *Structural Engineering*
Jeffrey B. Remmel, Ph.D., *Mathematics*
J. Benjamin Rosen, Ph.D., *Computer Science and Engineering*
Terrence Sejnowski, Ph.D., *Biology*
Allan Snavely, Ph.D., *San Diego Supercomputer Center*
Matthias Zwicker, Ph.D., *Computer Science and Engineering*

AFFILIATED FACULTY

Barry Brown, Ph.D., *Communication*
Trey Ideker, Ph.D., *Bioengineering*
Glenn Tesler, Ph.D., *Mathematics*

RESEARCH FACULTY

Philip Papadopoulos, Ph.D., *Associate Research Professor*

LECTURERS WITH SECURITY OF EMPLOYMENT

Paul Kube, Ph.D.
Elizabeth Simon, Ph.D.

CONTINUING LECTURERS

Gary Gillespie, Ph.D.
Susan Marx, Ph.D.
Richard Ord, M.S.

ACADEMIC COORDINATOR

Paul Kube, Ph.D., Lecturer with Security of Employment

OFFICES:
Undergraduate Affairs Room 1200D
Graduate Affairs Room 1200D
Engineering Building Unit 3B, Warren College
http://www.cse.ucsd.edu

THE UNDERGRADUATE PROGRAM

Degree and Program Options

The Department of Computer Science and Engineering (CSE) offers four degree programs: the B.S. degree in computer science, the B.A. degree in computer science, the B.S. degree in computer engineering, and the B.S. degree in computer science with a specialization in bioinformatics.

The B.A. degree in computer science is a flexible program that allows comprehensive studies beyond computer science and engineering.

All CSE programs of study provide a broad and rigorous curriculum and are designed to provide students with the strong technical education necessary for placement in the competitive high-tech job market as well as for advanced studies in graduate school.

CSE offers courses in the following areas:

- Theory
- Artificial intelligence
- Software
- Hardware
- Computer security and cryptography
- Computer vision and graphics
- Databases and XML
- Systems and networking
- Bioinformatics
- Software engineering

In addition, CSE seniors can participate in challenging project-courses in: software systems, where teams create multiplayer games; Internet systems, where students create sophisticated Web transaction systems; and mobile wireless computing, where teams create applications for handheld devices.

The CSE department supports and encourages students to explore opportunities outside the classroom. Students assist in many CSE courses as paid lab tutors and readers, getting an excellent opportunity to interact more closely with faculty and other students. In addition, CSE students participate in research projects with graduate students and faculty in CSE, the San Diego Supercomputer Center, and the California Institute for Telecommunications and Information Technology (Calit2). Under the direction of our faculty, CSE students may also earn credit by participating in independent research projects. The CSE department has strong ties with local and national high-tech industry, where students can earn course credit while applying their academic knowledge toward exciting commercial technologies in paid internships.

B.S. COMPUTER SCIENCE PROGRAM

The lower-division B.S. computer science program is designed to provide a strong foundation in mathematics, physics, electrical engineering, programming methodology and skills, and computer organization. Upper-division core courses deal with the theory and design of algorithms, hardware, and software. Students can gain additional breadth and/or depth in computer science and engineering by an appropriate selection of upper-division technical electives.

Students should have sufficient background in high school mathematics so that they can take freshman calculus in their first quarter. Courses in high school physics and computer programming, although helpful, are not required for the program.

The department requires a total of 128 units for the B.S. computer science program (not including the general-education requirements). There are

three varieties of requirements: lower-division, upper-division, and technical electives.

Advisory placement exam for CSE 3, CSE 8A/8AL and CSE 11: An advisory placement test is encouraged of all CSE majors to help accurately place students into the right starting point in the CSE undergraduate curriculum. This information is found at the following Web site: http://www-cse.ucsd.edu/undergraduate-education.html. Contact the CSE student affairs advising office at ugradinfo@cs.ucsd.edu if further assistance is needed.

1. Lower-Division Requirements

Students are expected to complete the following fifty-two units by the end of their sophomore year.

Computer Science and Engineering

CSE 8B or CSE 11, CSE 12, CSE 15L, CSE 20 or Math. 15A, CSE 21 or Math. 15B, CSE 30, , and CSE 91; twenty-four units.

Note: Students with little computer experience are encouraged to take CSE 3. Students without prior programming experience are advised to take CSE 8A, CSE 8AL, and then CSE 8B, instead of CSE 11. CSE 11 is a faster paced version of CSE 8A, CSE 8AL, and CSE 8B, and requires experience in programming with a compiled language.

Mathematics

Math. 20A, Math. 20B, Math. 20C, and Math. 20F; sixteen units.

General Science

Phys 2A. and Phys. 2B, or Chem. 6A and Chem. 6B, or Chem. 6AH and Chem. BH, or BILD 1 and BILD 2, or BILD 3 and BICD 100; eight units.

Students who received high grades in both calculus and physics in high school may substitute the major's sequence, Phys. 4A-B-C for Phys. 2A-B-C.

Probability and Statistics

Math. 183 or CSE 103; four units.

2. Upper-Division Requirements

All B.S. computer science students are required to take CSE 100 or Math. 176, CSE 101 or Math. 188, CSE 105 or Math. 166, CSE 110, CSE 120, 130, 131, 140, 140L, 141 and 141L; forty units.

Students are expected to complete almost all of these courses by the end of their junior year. If students want to accelerate their program, they should consider taking CSE 100 or Math. 176, CSE 105, and/or CSE 140 and 140L in the sophomore year.

3. Technical Electives

B.S. computer science students are required to complete one upper-division cluster of three to five CSE courses. The three to five CSE courses are part of the nine technical electives required for a total of thirty-six units. The purpose of the clusters is to help students identify groups of complementary courses, thus improving their education. Clusters are designed by the CSE faculty by grouping existing courses. Students who wish can also design their own clusters, with approval by the CSE Undergraduate Committee. For a complete list of clusters, visit www.ucsd.edu or see an advisor in the CSE advising offices.

- 1. Choose one upper-division cluster consisting of three to five CSE courses. A three-course cluster is permitted when the cluster is a natural extension of one of the core upper-division requirements.
- 2. A five-course cluster will be permitted when an additional foundational course may be required by other courses in the cluster.
- 3. Within a cluster there can be choices, such as "take four of the five" or a choice between two course alternatives.
- 4. May use up to eight units of CSE 198, CSE 199, or CSE 199H to meet the CSE upper-division technical requirement.
- 5. Twelve credits of non-198, CSE 199, or CSE 199H must be completed.

Two technical electives (of the required nine technical electives) can be chosen from the wider set of courses that includes computer science and engineering upper-division courses, graduate courses, and other electives as listed under the section titled "Electives." Other restrictions in the selection of technical electives are also given in the section "Electives."

4. B.S. Computer Science, Sample Program starting with CSE 3

FALL	WINTER	SPRING
FRESHMAN YEAR		
CSE 3	CSE 8A and 8AL	CSE 8B
Math. 20A	CSE 91 (2 units)	CSE 20 or Math. 15A
GE	Math. 20B	Math. 20C
	GE	GE
SOPHOMORE YEAR		
CSE 12	CSE 30	CSE 110
CSE 15L (2 units)	CSE 100 or Math. 176	CSE 140
CSE 21 or Math. 15B	Major General Science	CSE 140L (2 units)
Major General Science	GE	GE
JUNIOR YEAR		
CSE 101 or Math. 188	CSE 105 or Math. 166	CSE 103 or Math. 183
CSE 141	CSE 120	CSE Tech. Elec.
CSE 141L (2 units)	Math. 20F	CSE Tech. Elec.
GE	GE	GE
SENIOR YEAR		
CSE 130	CSE 131	CSE Tech. Elec.
CSE Tech. Elec.	CSE Tech. Elec.	CSE Tech. Elec.
CSE Tech. Elec.	CSE Tech. Elec.	CSE Tech. Elec.
GE	GE	GE

B.S. Computer Science, Sample Program starting with CSE 8A/8AL

FALL	WINTER	SPRING
FRESHMAN YEAR		
CSE 8A and CSE 8AL	CSE 8B	CSE 12
CSE 91 (2 units)	CSE 20 or Math. 15A	CSE 15L (2 units)
Math. 20A	Math. 20B	Math. 20C
GE	GE	GE
SOPHOMORE YEAR		
CSE 30	CSE 100 or Math. 176	CSE 101 or Math. 188
CSE 21 or Math. 15B	CSE 110	Math. 20F
Major General Science	Major General Science	CSE Tech. Elec.
GE	GE	GE
JUNIOR YEAR		
CSE 105 or Math. 166	CSE 120	CSE 103 or Math. 183
CSE 140	CSE 141	CSE Tech. Elec.
CSE 140L (2 units)	CSE 141L (2 units)	CSE Tech. Elec.
GE	GE	GE
SENIOR YEAR		
CSE 130	CSE 131	CSE Tech. Elec.
CSE Tech. Elec.	CSE Tech. Elec.	CSE Tech. Elec.
CSE Tech. Elec.	CSE Tech. Elec.	GE
GE	GE	

B.S. Computer Science, Sample Program starting with CSE 11

FALL	WINTER	SPRING
FRESHMAN YEAR		
CSE 11	CSE 12	CSE 30
CSE 91	CSE 15L (2 units)	CSE 20 or Math. 15A
Math. 20A	Math. 20B	Math. 20C
GE	GE	GE
SOPHOMORE YEAR		
CSE 21 or Math. 15B	CSE 100 or Math. 176	CSE 101 or Math. 188
CSE 140	CSE 110	CSE 141
CSE 140L	CSE Tech. Elec.	CSE 141L (2 units)
GE	Major General Science	Major General Science
JUNIOR YEAR		
CSE 105 or Math. 166	CSE 130	CSE 131
CSE 120	CSE Tech. Elec	CSE 103 or Math. 183
CSE Tech. Elec.	CSE Tech. Elec.	GE
GE	GE	GE
SENIOR YEAR		
CSE Tech. Elec.	CSE Tech. Elec.	CSE Tech. Elec.
CSE Tech. Elec.	CSE Tech. Elec.	GE
GE	GE	GE
GE	GE	GE

Notes for Selecting and Scheduling Classes for B.S. Computer Science

(All courses must be taken for a letter grade.)

1. Advisory placement exam: Students may self-select which course they wish to take and are encouraged to take the advisory placement exam to help decide. Students with little computer experience are encourage to take CSE 3. Students without experience in programming in a compiled language are advised to take CSE 8A and CSE 8AL, and then CSE 8B, instead of CSE 11. CSE 11 is a faster paced version of CSE 8A, CSE 8AL, and CSE 8B. CSE 8B or CSE 11 must be taken before CSE 12.
2. Computer Science Advanced Placement Credit: A Exam (Java Programming) two units
   - Score of 4 exempts CSE 8A and CSE 8AL. Student should take CSE 11.

- Score of 5 exempts CSE 11. Student should take CSE 12.

3. CSE 8A/8AL, or CSE 8B, or CSE 11 may be taken concurrently with CSE 20/Math. 15A. Please obtain department approval for enrollment permission for CSE 20/Math. 15A at ugradinfo@cs.ucsd.edu.
4. CSE 15L and CSE 70 are new courses starting fall 2007.
5. Effective fall 2010, CSE 70 is renumbered to CSE 110.
6. CSE 15L must be taken prior to or concurrently with CSE 12.
7. The CSE Undergraduate Committee would like students to start taking technical electives as soon as possible after completing CSE 30. Effective fall 2010, students must complete nine technical electives. Students must complete one cluster consisting of three to five courses. Students may use a CSE graduate course for technical elective credit with approval. Once a graduate course is used for an undergraduate degree, that course may not be reused for a graduate degree. In addition, only four units of CSE 197may be used toward technical elective credit.
8. Students may take use up to eight units of CSE 198, CSE 199, or CSE 199H to meet the CSE upper-division technical requirement.
9. 12 credits of non-198, CSE 199, or CSE 199H must be completed. Two of the technical electives may be chosen from a list of approved electives. This list is at http://www.cse.ucsd.edu/undergrad/degreeprograms/electives.html. If you want to deviate from this list of approved electives, you must petition the CSE student advisor at ugradinfo@cs.ucsd.edu.

B.S. COMPUTER ENGINEERING PROGRAM

(Curriculum is the same in both the CSE and ECE departments.)

The B.S. computer engineering program is jointly administered by the Departments of Computer Science and Engineering and Electrical and Computer Engineering. Students wishing to take the computer engineering program must be admitted to one of the departments.

The lower-division computer engineering program is designed to provide a strong foundation in mathematics, physics, electrical engineering, programming methodology and skills, and computer organization. Upper-division core courses deal with the theory and design of algorithms, hardware and software, as well as electronic systems. Students can gain additional breadth and/ or depth in computer science and engineering by an appropriate selection of technical electives.

Students should have sufficient background in high school mathematics so that they can take freshman calculus in their first quarter. Courses in high school physics and computer programming, although helpful, are not required for the program.

B.S. computer engineering program requires a total of 152 units (not including the general-education requirements). There are three varieties of requirements: lower-division, upper-division, and technical electives.

Advisory placement exam for CSE 3, CSE 8A/8AL, and CSE 11: An advisory placement test is encouraged of all CSE majors to help accurately place students into the right starting point in the CSE undergraduate curriculum. This information is found at the following Web site: http://www-cse.ucsd.edu/undergraduate-education.html. Contact the CSE student affairs advising office at ugradinfo@cs.ucsd.edu if further assistance is needed.

1. Lower-Division Requirements

Students are expected to complete the following seventy-six units by the end of their sophomore year.

Computer Science and Engineering

CSE 8B or CSE 11, CSE 12, CSE 15L, CSE 20 or Math. 15A, CSE 21 or Math. 15B, CSE 30, , and CSE 91; twenty-four units.

Note: Students with little computer experience are encouraged to take CSE 3. Students without prior programming experience are advised to take CSE 8A, CSE 8AL, and then CSE 8B, CSE 8AL, instead of CSE 11. CSE 11 is a faster paced version of CSE 8A and CSE 8B, and requires experience in programming with a compiled language.

Mathematics

Math. 20A, Math. 20B, Math. 20C, Math. 20D, and Math. 20F; twenty units.

Physics

Phys. 2A, Phys. 2B, Phys. 2C, Phys. 2D; sixteen units. Math. 20A is a prerequisite for Phys. 2A. Students whose performance on the Department of Mathematics placement test permits them to start with Math. 20B or a higher course may take Phys. 2A in the fall quarter of the freshman year; all others will take Phys. 2A in the winter quarter of the freshman year. Students who received high grades in both calculus and physics in high school may substitute the major's sequence, Phys. 4A-B-C-D for Phys. 2A-B-C-D.

Introduction to Electrical Engineering

ECE 35, 45, 65; twelve units. These courses give a comprehensive introduction to electrical engineering.

Probability and Statistics

ECE 109; four units. This course can be taken in the sophomore year.

2. Upper-Division Requirements

All B.S. Computer engineering students are required to take CSE 100 or Math. 176, CSE 101 or Math. 188, CSE 105 or Math. 166, CSE 110, CSE 120, 130, 131, 140, 140L, 141, and 141L; forty units.

In addition, all B.S. Computer engineering students have to fulfill the following upper-division ECE requirements.

Linear Systems

ECE 101; four units. The department recommends that this course be taken in the junior year.

Electronic Circuits and Systems

ECE 102, ECE 108; eight units. The department recommends that these courses be taken in the junior year.

If students want to accelerate their program, they should consider taking CSE 100 or Math. 176, CSE 105 or Math. 166, and/or CSE 140 and 140L in the sophomore year.

3. Technical Electives

All B.S. Computer engineering students are required to take six technical electives for a total of twenty-four units. One of these courses must be either ECE 111 or ECE 118. Of the remaining five courses, four must be computer science and engineering or electrical and computer engineering upper-division or graduate courses.

The remaining course can be any computer science and engineering or electrical and computer engineering upper-division or graduate course, or any other course listed under the section titled Electives. Other restrictions in the selection of technical electives are also given in the section Electives.

4. B.S. Computer Engineering, Sample Program

FALL	WINTER	SPRING
FRESHMAN YEAR		
CSE 8A, CSE 8AL, or CSE 11	CSE 15L	CSE 21 or Math. 15B
Math. 20A	CSE 12	Math. 20C
GE	Math. 20B	GE
CSE 91	CSE 20 or Math. 15A	GE
SOPHOMORE YEAR		
CSE 30	CSE 110	CSE 140
Math. 20D	CSE 100 or Math. 176	CSE 140L
Phys. 2A	ECE 45	ECE 65
ECE 35	Phys. 2B	Phys. 2C
JUNIOR YEAR		
CSE 101 or Math. 188	CSE 120	CSE 105 or Math. 166
CSE 141	Phys. 2D	(Req. Tech. Elec.- ECE 111 or ECE 118)
CSE 141L	ECE 102	ECE 108
ECE 101	Math. 20F	CSE/ECE Tech. Elec.
SENIOR YEAR		
CSE 130	CSE 131	CSE/ECE Tech. Elec.
CSE/ECE Tech. Elec.	CSE/ECE Tech. Elec.	ECE 109
GE.	CSE/ECE Tech. Elec	GE
	GE	

Notes for Selecting and Scheduling Classes for B.S. Computer Engineering

(All courses must be taken for a letter grade.)

1. Advisory placement exam: Students may self-select which course they wish to take and are encouraged to take the advisory placement exam to help decide. Students with little computer experience are encouraged to take CSE 3. Students without experience in programming

in a compiled language are advised to take CSE 8A and CSE 8AL, and then CSE 8B, instead of CSE 11. CSE 11 is faster paced version of CSE 8A, CSE 8AL, and CSE 8B. CSE 8B or CSE 11 must be taken before CSE 12.

2. Computer Science Advanced Placement Credit: A Exam (Java Programming) two units:
   - Score of 4 exempts CSE 8A and CSE 8AL. Student should take CSE 11.
   - Score of 5 exempts CSE 11. Students should take CSE 12, CSE 8A/8AL, or CSE 8B, or CSE 11 may be taken concurrently with and CSE 20/Math. 15A. Please obtain department approval for enrollment permission in CSE 20/Math. 15A at ugradinfo@cs.ucsd.edu. CSE 15L and CSE 70 are new courses starting fall 2007.
3. CSE 15L must be taken prior to or concurrently with CSE 12.
4. Effective fall 2006, ECE 35 and ECE 45 are new courses in computer engineering. These courses replace ECE 35A and 35B, respectively.
5. Students must complete six technical electives. Four of the six technical electives must be CSE or ECE upper-division courses.
6. Students must complete ECE 111 or ECE 118 to meet the design requirement.
7. Students must obtain approval to use a CSE graduate course for technical elective credit. Once a graduate course is used for an undergraduate degree that course may not be reused for a graduate degree. In addition, only four units of either a CSE 197, 198, or 199 may be used toward technical elective credit.
8. One of the technical electives may be chosen from a list of approved electives. This list is at http://www.cse.ucsd.edu/undergrad/degreeprograms/electives.html. If you want to deviate from this list of approved electives, you must petition the CSE student advisor at: ugradinfo@cs.ucsd.edu.

B.S. COMPUTER SCIENCE WITH A SPECIALIZATION IN BIOINFORMATICS

The explosion in biological knowledge spawned by the various genome projects has created entirely new fields and industries, and a need for trained computational biologists who are familiar with biology, mathematics, and computer sciences. The computer science and engineering department offers rigorous, interdisciplinary training in the new and rapidly evolving field of bioinformatics.

Bioinformatics refers to advanced computational and experimental methods that model the flow of information (genetic, metabolic, and regulatory) in living systems to provide an integrated understanding of the system properties of organisms.

This interdisciplinary major is offered by three other programs (Division of Biological Sciences, Department of Chemistry and Biochemistry, and Department of Bioengineering). The computer science and engineering requirements comprise of 152 units to be taken from the divisions of physical sciences, biology, and engineering.

1. Lower-Division Requirements

Lower-division requirements, sixty-four units: Students are expected to complete all lower-division requirements by the end of their sophomore year.

1. Math. 20A, Math. 20B, Math. 20C, and Math. 20F, (16 units)
2. Chem. 6A, Chem. 6B, Chem. 6C, and one Chem. lab (15 units)
3. BILD 1, BILD 2, and BILD 94 (9 units)
4. CSE 11, CSE 12, and CSE 21 or Math. 15B (12 units)
5. Phys. 2A, Phys. 2B, and Phys. 2C (12 units)

2. Upper-Division Requirements

Upper-division requirements, eighty-eight units (includes five CSE technical electives)

1. CSE 100 or Math. 176 (Data Structures), (4 units)
2. CSE 101 or Math. 188 (Algorithms), (4 units)
3. Chem. 140A–140B (Organic Chemistry), (8 units)
4. Chem. 114B (Biochemical Energetics and Metabolism) or BIBC 102 (Structural and Metabolic Biochemistry), (4 units)
5. BIBC 103 (Biochemical Techniques), (4 units)
6. BICD 100 (Genetics), (4 units)
7. BIMM 100 (Molecular Biology) or Chem. 114D (Molecular and Cellular Biochemistry), (4 units)
8. BIMM 101 (Recombinant DNA Lab), (4 units)
9. BICD 110 (Cell Biology), (4 units)
10. BIBC 110 (Physical Biochemistry) or Chem. 127 (Physical Chemistry), (4 units)
11. Five additional CSE upper-division electives (electives 1, 2, 3, 4, and 5).

    At least one course from each of the three groups for a total of five electives:
    - Group I: CSE 30, 111, 131A, 131B, 134A
    - Group II: CSE 105, 150, 151, Math. 184A
    - Group III: CSE 132A, 132B, 133

    The bioinformatics series comprises the following six courses, twenty-four units:
12. CSE 181 or BIMM 181 or BENG 181 (Molecular Sequence Analysis), (4 units)
13. CSE 182 or BIMM 182 or BENG 182 or Chem. 182 (Biological Databases), (4 units)
14. BENG 183 (Applied Genomic Technologies), (4 units)
15. CSE 184 or BIMM 184 or BENG 184 (Computational Molecular Biology), (4 units)
16. BIMM 185 (Bioinformatics lab), (4 units)
17. Math. 186 (Probability and Statistics), (4 units)

3. B.S. Computer science with a specialization in bioinformatics, sample program

FALL	WINTER	SPRING
FRESHMAN YEAR		
CSE 8A/8AL + 8B or 111	CSE 12	BILD 942
Math. 20A	Math. 20B	Math. 20C
Chem. 6A	Chem. 6B	Chem. 6C
GE 1	BILD 1	Chem. 6BL
	GE 2	GE 3
SOPHOMORE YEAR		
CSE 21 or Math. 15B	Math. 20F	Chem. 140B
BILD 2	Phys. 2B	BIBC 103
Phys. 2A	Chem. 140A	Phys. 2C
GE 4	GE 5	GE 6
JUNIOR YEAR		
CSE 100 or Math. 1763	CSE 101 or Math. 188	CSE 1814
BICD 100	Math. 186	BIMM 101 or Chem. 112B
GE 7	BIBC 102 or Chem. 114B	BICD 110
GE 8	BIMM 100 or Chem. 114D	Chem. 127
SENIOR YEAR		
CSE 182	CSE 184	BIMM 185
BENG 183	Elec. 2	Elec. 4
Elec. 15	Elec. 3	Elec. 5
GE 9	GE 10	GE 11

1 Students may take the slower paced version, CSE 8A + CSE 8AL + CSE 8B, instead of CSE 11.

2 BILD 94 (1 unit seminar) is recommended in students first spring quarter of study at UCSD. This course gives an overview of issues and topics in bioinformatics.

3 CSE 30 prerequisite will be waived.

4 New courses for the bioinformatics program: CSE 181 is cross-listed with BIMM 181 and BENG 181; CSE 182 is cross-listed with BIMM 182, Chem. 182, and BENG 182; CSE 184 is cross-listed with BIMM 184 and BENG 184; and (BENG 183, BIMM 185, and Math. 186 are not cross-listed with any other courses).

5 Students must complete five CSE technical electives from the approved list.

B.A. COMPUTER SCIENCE PROGRAM

The B.A. computer science program gives students more latitude in designing their course of study. The lower-division program is designed to provide a strong foundation in mathematics, physics, programming methodology and skills, and computer organization. Upper-division core courses deal with the theory and design of algorithms, hardware, and software. Students can gain additional breadth and/or depth in computer science and engineering by an appropriate selection of technical electives. By requiring fewer technical electives, the B.A. computer science program serves those students desiring more time for undergraduate studies outside their major subject.

The department requires a total of 116 units for the B.A. computer science program (not including the general-education requirements). There are three varieties of requirements: lower-division, upper-division, and technical electives.

Advisory placement exam for CSE 3, CSE 8A/8AL, and CSE 11: An advisory placement test is encouraged of all CSE majors to help accurately place students into the right starting point in the CSE undergraduate curriculum. This information is found at the following Web site: http://www-cse.ucsd.edu/undergraduate-education.html. Contact the CSE student affairs advising office at ugradinfo@cs.ucsd.edu if further assistance is needed.

1. Lower-Division Requirements

Students are expected to complete the following forty-eight units by the end of their sophomore year.

Computer Science and Engineering

CSE 8B or CSE 11, CSE 12, CSE 15L, CSE 20 or Math. 15A, CSE 21 or Math. 15B, CSE 30, and CSE 91; twenty- four units.

Note: Students with little computer experience are encouraged to take CSE 3. Students without prior programming experience are advised to take CSE 8A, CSE 8AL, and then CSE 8B, instead of CSE 11. CSE 11 is a faster paced version of CSE 8A, CSE 8AL, and CSE 8B, and requires experience in programming with a compiled language.

Mathematics

Math. 20A, Math. 20B, Math. 20C, and Math. 20F; sixteen units.

General Science

Phys. 2A and Phys. 2B, or Chem. 6A and Chem. 6B, or Chem. 6AH and Chem. BH, or BILD 1 and BILD 2, or BILD 3 and BICD 100; eight units .

Students who received high grades in both calculus and physics in high school may substitute the major's sequence, Phys. 4A-B-C for Phys. 2A-B-C.

2. Upper-Division Requirements

All B.A. computer science students are required to take CSE 100 or Math. 176, CSE 101 or Math. 188, CSE 105 or Math. 166, CSE 110, CSE 120, 131, 140, 140L, 141, and 141L; forty units.

Students are expected to complete almost all of these courses by the end of their junior year. If students want to accelerate their program, they should consider taking CSE 100 or Math. 176, CSE 105 or Math. 166, and/or CSE 140 and 140L in the sophomore year.

3. Technical Electives

B.A. computer science students are required to take seven technical electives for a total of twenty-eight units. Five technical electives must be computer science and engineering upper-division or graduate courses.

Two technical electives (of the required seven technical electives) can be chosen from a wider set of courses that includes computer science and engineering upper-division courses, graduate courses, and other electives as listed under the section titled "Electives." Other restrictions in the selection of technical electives are also given in the section "Electives."

4. B.A. Computer Science, Sample Program starting with CSE 3

FALL	WINTER	SPRING
FRESHMAN YEAR		
CSE 3	CSE 8A and 8AL	CSE 8B
Math. 20A	CSE 91 (2 units)	CSE 20 or Math. 15A
GE	Math. 20B	Math. 20C
	GE	GE
SOPHOMORE YEAR		
CSE 12	CSE 30	CSE 110
CSE 15L (2 units)	CSE 100 or Math. 176	CSE 140
CSE 21 or Math. 15B	Major General Science	CSE 140L (2 units)
Major General Science	GE	GE
JUNIOR YEAR		
CSE 101 or Math. 188	CSE 105 or Math. 166	CSE 120
CSE 141	CSE Tech. Elec.	CSE Tech. Elec.
CSE 141L (2 units)	Math. 20F	CSE Tech. Elec.
GE	GE	GE
SENIOR YEAR		
CSE 130	CSE 131	CSE Tech. Elec.
CSE Tech. Elec.	CSE Tech. Elec.	CSE Tech. Elec.
GE	GE	GE

B.A. Computer Science, Sample Program starting with CSE 8A/8AL

FALL	WINTER	SPRING
FRESHMAN YEAR		
CSE 8A and 8AL	CSE 8B	CSE 12
CSE 91 (2 units)	CSE 20 or Math. 15A	CSE 15L (2 units)
Math. 20A	Math. 20B	Math. 20C
GE	GE	GE
SOPHOMORE YEAR		
CSE 21 or Math. 15B	CSE 100 or Math. 176	CSE 101 or Math. 188
CSE 30	CSE 110	CSE 140
Major General Science	Major General Science	CSE 140L (2 units)
GE	GE	GE
JUNIOR YEAR		
CSE 105 or Math. 166	CSE 120	CSE Tech. Elec.
CSE 141	CSE Tech. Elec.	CSE Tech. Elec.
CSE 141L (2 units)	Math. 20F	GE
GE	GE	
SENIOR YEAR		
CSE 130	CSE 131	CSE Tech. Elec.
CSE Tech. Elec.	CSE Tech. Elec.	CSE Tech. Elec.
GE	GE	GE

B.A. Computer Science, Sample Program starting with CSE 11

FALL	WINTER	SPRING
FRESHMAN YEAR		
CSE 11	CSE 12	CSE 20 or Math. 15A
CSE 91	CSE 15L (2 units)	CSE 30
Math. 20A	Math. 20B	Math. 20C
GE	GE	GE
SOPHOMORE YEAR		
CSE 21 or Math. 15B	CSE 100 or Math. 176	CSE 141
Math. 20F	CSE 140	CSE 141L (2 units)
Major General Science	CSE 140L (2 units)	CSE Tech. Elec.
GE	Major General Science	GE
JUNIOR YEAR		
CSE 105	CSE 130	CSE 131
CSE 120	CSE Tech. Elec.	CSE Tech. Elec.
CSE Tech. Elec	GE	GE
GE		
SENIOR YEAR		
CSE Tech. Elec	CSE Tech. Elec.	CSE Tech. Elec.
GE	GE	GE
GE	GE	GE

Notes for Selecting and Scheduling Classes for B.A. Computer Science

(All courses must be taken for a letter grade.)

1. Advisory placement exam: Students may self-select which course they wish to take and are encouraged to take the advisory placement exam to help decide. Students with little computer experience are encouraged to take CSE 3. Students without experience in programming in a compiled language are advised to take CSE 8A and CSE 8AL, and then CSE 8B, instead of CSE 11. CSE 11 is a faster paced version of CSE 8A, CSE 8AL, and CSE 8B. CSE 8B or CSE 11 must be taken before CSE 12.
2. Computer Science Advanced Placement Credit: A Exam (Java Programming) two units
   - Score of 4 exempts CSE 8A and CSE 8AL. Student should take CSE 11.
   - Score of 5 exempts CSE 11. Student should take CSE 12.
3. CSE 8A/8AL, or CSE 8B, or CSE 11 may be taken concurrently with CSE 20/Math. 15A, Please obtain department approval for enrollment permission in CSE 20/Math. 15A at ugradinfo@cs.ucsd.edu.
4. CSE 15L and CSE 70 are new courses starting fall 2007.
5. CSE 15L must taken prior to or concurrently with CSE 12.
6. Effective fall 2010, CSE 70 is renumbered to CSE 110.
7. Effective fall 2010, students must complete seven technical electives. Four of the severn technical electives must be CSE upper-division courses. Students can use a CSE graduate course for technical elective credit with approval.. Once a graduate course is used for an undergraduate degree that course may not be reused for a graduate degree. In addition, only four units of CSE 197may be used toward technical elective credit.
8. Students may take use up to eight units of CSE 198, CSE 199, or CSE 199H to meet the CSE upper-division technical requirement.
9. Two of the technical electives may be chosen from a list of approved electives. This list is at http://www.cse.ucsd.edu/undergrad/degreeprograms/electives.html. If you want to deviate from this list of approved electives, you must petition the CSE student advisor at ugradinfo@cs.ucsd.edu.

ELECTIVES

The discipline of computer science and engineering interacts with a number of other disciplines in a mutually beneficial way. These disciplines include mathematics, electrical engineering, and cognitive science. The following is a list of upper-division courses from these and other disciplines that can be counted as technical electives.

Restrictions

- 1. At most four units of CSE 197 may be used towards technical elective requirements.
- 2. CSE 195 cannot be used towards course requirements.
- 3. Undergraduate students must get instructor's permission and departmental stamp to enroll in a graduate course.
- 4. Students may not get duplicate credit for equivalent courses.
- 5. The UC San Diego General Catalog should be consulted for equivalency information and any restrictions placed on the courses.
- 6. Additional restrictions are noted below. Any deviation from this list must be petitioned.

Computer Science with a Specialization in Bioinformatics

Students must petition department for technical elective credit not on approved list.

Mathematics

All upper-division courses except Math. 168A (Math. 183—Computer Engineering majors only), 184A, and 195–199.

If a student has completed CSE 167, then he or she cannot get elective credit for Math. 155A. Students may receive elective credit for only one of the following courses: CSE 164A, Math. 174, Math. 173, Phys. 105A-B, CENG 100, MAE 107. No credit for any of these courses will be given if Math. 170A-B-C is taken. Students may receive credit for either one of the following: Math. 166 or CSE 105 (but not both), Math. 188 or CSE 101 (but not both), Math. 176 or CSE 100 (but not both).

Credit will be given for only one of the following: ECE 109 or Math. 183 or Econ. 120A.

Electrical and Computer Engineering

All ECE upper-division courses except 195–199.

Students may not get credit for both CSE 123A and ECE 158A or CSE 143 and ECE 165. Credit will be given for only one of the following: ECE 109 or Math. 183 or Econ. 120A.

Cognitive Science

Sensation and Perception 101A; Learning, Memory, and Attention 101B, Language 101C, Distributed Cognition 102A, Cognitive Ethnography 102B, Cognitive Engineering 102C, Neuroanatomy and Physiology 107A, Systems Neuroscience 107B, Cognitive Neuroscience 107C, Programming Methods for Cognitive Science 108D, Neural Network Models of Cognitive I 108E, Advanced Programming Methods for Cognitive Science 108F, Human Computer Interaction 120, Human Computer Interaction Programming 121, Natural and Artificial Symbolic Representational Systems 170, Neural Network Models of Cognition II 181, Representation, Search, and the Web 188.

Students may not get credit for both CSE 150 and Advanced Programming Methods for Cognitive Science 108F.

Mechanical and Aerospace Engineering

All upper-division MAE courses except MAE 140 (ONLY Computer Science majors may take MAE 140) and 195–199.

Students may receive elective credit for only one of the following courses: CSE 164A, Math. 174, Math. 173, Phys. 105A-B, CENG 100, MAE 107. Students may only get credit for one of the two courses, CSE 167 or MAE 152.

Economics

Microeconomics 100A-B-C, Game Theory 109, Macroeconomics 110A-B-C, Mathematical Economics 113, Econometrics 120A-B-C, Applied Econometrics 121, Decisions Under Uncertainty 171, Introduction to Operations Research 172A-B-C, Economic and Business Forecasting 178.

Credit will be given for only one of the following: ECE 109 or Math. 183 or Econ. 120A.

Linguistics

Phonetics 110, Phonology I 111, Phonology II 115, Morphology 120, Syntax I 121, Syntax II 125, Semantics 130, Mathematical Analysis of Language 160, Computers and Language 163, Computational Linguistics 165, Principles of Discourse and Dialog 169, Psycholinguistics 170, Language and the Brain 172, and Sociolinguistics 175.

Engineering

Principles of Team Engineering 100, Team Engineering Laboratory 100L, Team Engineering 101.

Computer Science and Computer Engineering

Students are eligible to receive six units of technical elective credit for completing a combination of ENG 100 (two units) and ENG 100L (two units). Students must complete one quarter of ENG 100 for two units, and two quarters of ENG 100L for a total of four units. With this combination, students will get credit for one technical elective. To receive credit for two technical electives, students must complete one more quarter of ENG 100L. This credit can be applied to fulfill the technical elective requirements.

Music

Computer Music II 172, Audio Production: Mixing and Editing 173.

Psychology

Introduction to Engineering Psychology 161.

CSE HONORS PROGRAM

The CSE Honors Program encourages eligible undergraduate students to perform advanced study in their major. Students in the honors program work closely with faculty on an undergraduate research project, typically completed over two quarters. As a result, the honors program is excellent preparation for further study in a graduate program. Students who complete the honors program also have an honors distinction officially bestowed upon them upon graduation.

Eligibility for Admission

In accordance with university Honors Program guidelines, to apply for the CSE honors program students must meet the following prerequisites:

- Junior-level standing in a CSE major
- 3.5 GPA in CSE major courses, 3.25 GPA overall
- Completion of CSE 101, CSE 105, and CSE 110
- Completion of at least twelve units of upper-division CSE courses at UCSD

Application Procedure

To apply for admission to the CSE Honors Program, students must submit a formal application that includes the following information:

- Name of CSE faculty advisor sponsoring the project
- Project proposal (one page)
- Signature from the faculty advisor acknowledging that the faculty member has agreed to advise the student in the honors program, and corroborates the specifics of the project
- Submit the application no later than the end of fall quarter of senior year. Submission during spring quarter of the junior year is strongly encouraged.

The application form is available online from the CSE department Web site and from the CSE undergraduate advising office. Admission to the honors program will be formally approved by the CSE honors committee based upon the materials provided in the application.

Completion Requirements

In accordance with university Honors Program guidelines, to complete the CSE Honors Program students must meet the following requirements upon graduation:

- 3.25 GPA in a CSE major
- Eight units of CSE 199H with a GPA of 3.0 (letter grade of B) or higher
- Written honors thesis
- Presentation of honors project
- Signature from faculty advisor on an honors completion form
- Completion of requirements by the end of the spring quarter of graduation

Depending on students' performance on their honors project, students are eligible to receive the following honors designations on their diploma:

- "With distinction": Complete the eight units of CSE 199H with a GPA of 3.0 or higher
- "With high distinction": Complete the eight units of CSE 199H with a GPA of 3.5 or higher
- "With highest distinction": Complete the eight units of CSE 199H with a GPA of 3.8 or higher

Students must write a thesis describing their honors research project. The thesis must have the content, rigor, and format of scholarly publications in computer science and engineering. The faculty advisor must have reviewed and approved the honors thesis prior to submission by the student.

Students must orally present their project as a requirement for the honors program. Students have many opportunities for fulfilling this requirement:

- UCSD Annual Undergraduate Research Conference
- JSOE Engineering Undergraduate Research Konference & Assembly (EUReKA)
- An ORU research review or workshop (e.g., Calit2, CNS, CWC, CCMS, ITA Center)
- A conference or workshop presentation
- A graduate research seminar

The faculty advisor can also provide an alternative presentation opportunity.

Unit Considerations

The CSE HonorsP does not increase the units required for graduation in a CSE major. Students participating in the Honors Program may apply eight units in CSE 199H for the equivalent of two technical elective courses for their major. Students may also apply unit credit in CSE 199H towards the cluster requirement in the undergraduate program.

MINOR AND PROGRAM OF CONCENTRATION

The CSE minor requires successful completion of a total of nine CSE courses. Lower-division courses are CSE 8B or CSE 11, CSE 12, CSE 20, CSE 21, and CSE 30. The remaining four CSE courses are CSE 100, CSE 101, and two additional CSE upper-division courses subject to enforcement of prerequisites.

CS Minor

Three-year plan for students starting with CSE 8A

FALL	WINTER	SPRING
1st Year		
CSE 8A and CSE 8AL	CSE 8B	CSE 12
2nd Year		
CSE 20	CSE 21	CSE 30
3rd Year		
CSE 100	CSE 101	CSE Elective
CSE Elective		

CS Minor

Three-year plan for students starting with CSE 11

FALL	WINTER	SPRING
1st Year		
CSE 11	CSE 20	CSE 12
2nd Year		
CSE 21	CSE 30	CSE 100
3rd Year		
CSE 101	CSE Elective	CSE Elective

Scheduling Notes

Students without any programming experience are advised to take CSE 3 and CSE 5A before taking CSE 8A and CSE 8AL. Concurrent enrollment is required in CSE 8A and CSE 8AL. Students may also start with CSE 11, but they should be aware that CSE 11 is a faster paced version of CSE 8A, CSE 8AL, and CSE 8B, and requires experience in programming with a compiled language.

Students should consult their college provost's office concerning the rules for the minor or program of concentration.

Restriction

Effective fall 2000, mathematics/computer science majors will not be allowed the minor in computer science.

COMPUTING COURSES FOR NON-MAJORS

The department offers a slow-pace course providing a practical introduction to computers, computation, and programming: CSE 5A—an introduction to structured programming using the C/Java programming language. We also offer an introduction in fluency in information technology: CSE 3—an introduction to basic information students need to deal with information technology. It is more of a concepts course than a programming course, but some simple programming will be done as part of the teaching of concepts.

ADMISSION TO MAJOR

Freshmen Students

Freshmen students are invited to declare the CSE computer science, computer engineering, or computer science with a specialization in bioinformatics major. Starting fall 2008 the Department of CSE removed the "Impacted/Closed Status" and admission restrictions for freshmen applicants. This means the Department of CSE will accept all students that apply to the Department of CSE and are admitted by the UC San Diego Admissions Office.

Furthermore, freshmen students that start at UC San Diego as undeclared or in another major may also switch into a computer science or computer engineering major. Students may use the Major/Minor link under Tools at http://tritonlink.ucsd.edu to make this change.

Major choices for your selection

B.A. Computer Science (CS28)
B.S. Computer Science (CS26)
B.S. Computer Science with a Specialization in Bioinformatics (CS27)
B.S. Computer Engineering (CS25)

Admission to the department as a major, transfer, or minor is in accordance with the general requirements established by the Jacobs School of Engineering.

Transfer Students

Transfer students are invited to declare the CSE computer science, computer engineering, or computer science with a specialization in bioinformatics majors. Starting fall 2008 the Department of CSE removed the "Impacted/Closed Status" and admission restrictions for transfer applicants. This means the Department of CSE will accept all students that apply to the Department of CSE and are admitted by the UC San Diego Admissions Office.

Furthermore, transfer students that start at UC San Diego as undeclared or in another major may also switch into a computer science or computer engineering major. Students may use the Major/Minor link under Tools at http://tritonlink.ucsd.edu to make this change.

Major choices for your selection

B.A. Computer Science (CS28)
B.S. Computer Science (CS26)
B.S. Computer Science with a Specialization in Bioinformatics (CS27)
B.S. Computer Engineering (CS25)

Preparation for Success

To reduce the amount of time needed to complete degree requirements, transfer students should try to complete as many prerequisite courses they can take at a community college before starting at UC San Diego.

Recommended courses and recommended 3.0 GPA

- Calculus I—for Science and Engineering (Math. 20A)
- Calculus II—for Science and Engineering (Math. 20B)
- Calculus and Analytic Geometry (Math. 20C)
- Differential Equations (Math. 20D)
- Linear Algebra (Math. 20F)
- Complete calculus-based physics series (Phys. 2A-B-C) [For computer engineering majors]
- Highest level of introductory computer programming language (i.e. Java, C or C++) course offerings at the community college

B.S. in Computer Science with a Specialization in Bioinformatics

Freshmen and transfer students are invited to declare the CSE bioinformatics major. Starting fall 2008 the Department of CSE has removed the "Impacted/Closed Status" and admission restrictions for freshman and transfer applicants. This means the Department of CSE will accept all students that apply to the Department of CSE and are admitted by the UC San Diego Admissions Office.

Furthermore, freshmen and transfer students that start at UC San Diego as undeclared or in another major may also switch into the B.S. in Computer Science with a Specialization in Bioinformatics major (major code CS27). Students may use the Major/Minor link under Tools at http://tritonlink.ucsd.edu to make this change.

It is strongly recommended that students meet with an advisor in the Department of CSE to discuss requirements for the bioinformatics program.

Advanced Placement Credit: Application to Major Requirements

Effective January 14, 2005, the following CSE advanced placement equivalencies have been approved (a four-unit maximum for both tests).

- Computer Science A Exam (Java Programming), two units:
  - Score of 4 = exempt CSE 8A and 8AL; student should take CSE 11
  - Score of 5 = exempt CSE 11
- Computer Science AB Exam (Java Programming, and Data Structures and Object-Oriented Programming), four units:
  - Score of 4 or 5 = exempt CSE 11
  - Score of 5 = exempt CSE 12 with department approval

ENROLLMENT IN CSE COURSES

All CSE and non-CSE majors may enroll in lower- and upper-division CSE courses. Students must meet course prerequisites.

Please note: Student demands exceed capacity in many CSE graduate courses. Accordingly, many CSE graduate courses may have enrollment restrictions, which give priority to students in the following order:

1. CSE M.S. and CSE Ph.D. students.
2. All others, with permission of the Department of Computer Science and Engineering.

Enrolling in Upper-Division Courses

The Department of Computer Science and Engineering will attempt to provide sufficient sections of all lower-division courses. Students will, however, be screened to ensure that they meet all course enrollment restrictions.

Admission to upper-division courses will be restricted to students having completed all prerequisites with a C– or better (or consent of the instructor.) You may also contact ugradinfo@cs.ucsd.edu for more information.

UC Education Abroad Program (EAP) and UCSD's Opportunities Abroad Program (OAP)

CSE majors are encouraged to participate in the UC Education Abroad Program (EAP) or UCSD's Opportunities Abroad Program (OAP). Subject to approval by the faculty director of the major, courses taken through EAP/OAP will be accepted for credit toward the major. Students interested in studying abroad should see a CSE undergraduate program advisor to discuss appropriate courses and programs for their plan of study. The advising office is located in Engineering Building Unit #3 (EBU 3B), Room 1231.

Information on EAP/OAP is given in the "Education Abroad Program" section of the *UC San Diego General Catalog*. Interested students should contact the Programs Abroad Office in the International Center and visit its Web site at http://programsabroad.ucsd.edu. Financial aid can be used for EAP/OAP study, and special study-abroad scholarships are also available.

GRADUATION REQUIREMENTS

All major requirements and technical electives except CSE 197, 198, or 199 must be taken for a letter grade. To graduate, a grade-point average of 2.0 will be required in upper-division courses in the major, including technical electives. In addition, each student must satisfy general-education course requirements determined by the student's college, as well as major requirements determined by the department. The five colleges at UCSD require widely different numbers of general-education courses. Each student should choose his or her college carefully, considering the special nature of the college and breadth of education, realizing that some colleges require considerably more courses than others.

THE GRADUATE PROGRAM

The graduate program offers master of science and doctor of philosophy degrees in computer science and computer engineering. To be accepted into either course of study, a student should have a B.A./B.S. degree in computer science, computer engineering, or a related area, or be able to demonstrate an equivalent competency.

The graduate program is concerned with fundamental aspects of computation. The computer science specialization is divided among the following areas:

- Algorithms and complexity
- Artificial intelligence
- Bioinformatics
- Computer architecture and compilers
- Computer graphics and computer vision
- Databases and information management
- Embedded systems and software
- High-performance computing
- Programming systems
- Security and cryptography
- Software engineering
- Systems and networking
- Ubiquitous Computing
- VLSI/CAD (computer-aided design)

The computer engineering specialization places a greater emphasis on hardware and the design of computer systems.

Admission to the graduate program is done through the Office of Graduate Admissions, Department of CSE. The application deadline is in December. Admissions are always effective the following fall quarter. For admission deadline and requirements, please refer to the departmental Web page: http://www.cse.ucsd.edu/gradedu/admissions/graduateadmissions.html.

Admission decisions for the M.S. and Ph.D. programs are made separately. A current M.S. student who wishes to enter the Ph.D. program must submit a petition, including a new statement of purpose and three new letters of recommendation, to the CSE Admissions Committee.

FIVE-YEAR BACHELOR'S-MASTER'S PROGRAM

Undergraduate students in the Department of Computer Science and Engineering who are enrolled in the B.S. or B.A. Computer Science or B.S. Computer Engineering degree programs, and who have a cumulative GPA of a 3.4 and also a GPA of 3.4 in at least seven core courses, are eligible to apply for the Five-Year Bachelor's-Master's Degree Program. Students must apply four quarters before graduation. Acceptance into this program is an honor that carries with it practical benefits—the graduate application process is simplified (no GREs required), and students accepted into this program can be admitted fall, winter, and spring quarter, based upon availability of openings in the program. Advanced students are given access to graduate level courses and have the opportunity to do graduate level research earlier under the direct supervision of UC San Diego's faculty, and students are able to complete the B.A., B.S., and M.S. degree within a five-year time period. Courses taken can be used toward either the B.A., B.S., or M.S. degree, but not counted toward both degrees. Additional information and applications can be obtained by contacting the CSE Student Affairs Office, EBU 3B, Room 1234. For an application, visit http://www.cse.ucsd.edu/gradedu/degreeprograms/bachelormasterscombined.html.

COMPUTER SCIENCE PROGRAM

MASTER OF SCIENCE PROGRAM

Thesis or Comprehensive Exam

The department offers the master of science degree in computer science. The degree can be pursued under either the Thesis Plan I or the Comprehensive Examination Plan II. There are two options for the Comprehensive Exam Plan II: the Standard Comprehensive Option or Interdisciplinary Comprehensive Option. Each plan requires forty-nine units of work. For full-time students, all the requirements can be completed within two years.

Required Courses

Students entering the M.S. Program in Computer Science will choose an area of concentration. Each concentration is an area in which the faculty has significant research expertise. A typical concentration is a collection of three courses that are designed to give the student in-depth training in the chosen field. Additionally, to ensure breadth, all students are required to take four core courses.

Core courses must be completed with an average grade of B. The four core courses required of all students are as follows:

CSE 202. Algorithms Design and Analysis
CSE 221. Operating Systems
CSE 240A. Principles of Computer Architecture
CSE 292. Faculty Research Seminar

The department expects to offer concentrations in the following areas:

Artificial Intelligence
Bioinformatics
Communication Networks
Computer Architecture and Compilers
Computer Graphics and Vision
Cryptography and Security
Databases
Design Automation for Microelectronic Designs
Distributed and Fault-Tolerant Computing
Embedded Systems and Software
Human–Computer Interaction
Parallel and Scientific Computing
Software Engineering
Storage Systems
Ph.D. Preparation

The specific courses involved in each of the concentrations are detailed in a separate bulletin which is available in the Graduate Student Affairs Office, EBU 3B 1234 or on the Web at http://www.cse.ucsd.edu/gradedu/advising/newstudentinfo/mastersconcentration.html.

Electives

In addition to completing the required core courses and fulfilling either the thesis or comprehensive examination requirements described above, the student must also complete additional approved courses to bring the total number of units to forty-nine. The number of units of electives depends upon whether the student chooses Plan I or Plan II. The electives consist of other CSE graduate courses or courses from a list of approved electives. Units obtained in the courses CSE 293, 298, 299, 500, 501, 599, and any of the seminar courses CSE 209, 229, 259, 269, 290, and 294 do not count toward the elective requirement.

Plan I: Thesis Option

This plan involves both course work and research, culminating in the preparation of a thesis. The student must take twelve units of CSE 298 (Independent Study) to fulfill the research requirement, and a thesis based on research must be written and subsequently reviewed by the thesis committee. This committee, which is appointed by the dean of Graduate Studies, consists of three faculty members, with at least two members from within the CSE department.

Computer Science—Thesis, Plan I
Forty-nine units

Core: CSE 202, CSE 221, CSE 240A, CSE 292

Concentration: twelve units in one of the concentration areas designated by the department. Concentration courses must be taken for a letter grade

Technical electives: twelve units (minimum of two courses in CSE, minimum of two courses graduate)

Research: twelve units of CSE 298

Capstone: thesis

Plan II: Comprehensive Examination

Under this plan, the student must pass the comprehensive examination designed to test the student's knowledge in basic computer science material. The examination can normally be passed with a thorough knowledge of topics covered in the undergraduate and first-year graduate computer science programs. Each student is allowed three attempts to pass the examination. The student must secure at least a master's-level pass in the comprehensive examination. More information regarding the comprehensive examination can be found in a separate document provided by the CSE graduate office. In particular, the comprehensive examination is structured around the three CSE core areas: algorithms and data structures; operating systems; and computer architecture and digital logic design.

Project

Students electing Plan II are required to execute a project with an advisor while enrolled in four units of CSE 293.

Computer Science, Comprehensive Exam, Plan II
Forty-nine units

Standard option:

Core: CSE 202, CSE 221, CSE 240A, CSE 292

Primary concentration: twelve units in one of the concentration areas designated by the department (current list is appended to this document). Concentration courses must be taken for a letter grade.

Technical electives: twenty units (minimum of three courses in CSE, minimum of three graduate level courses)

Project: four units of CSE 293

Capstone: comprehensive exam

*Interdisciplinary option***:**

Core: CSE 202, CSE 221, CSE 240A, CSE 292

Primary concentration: twelve units in one of the concentration areas designated by the department (current list is appended to this document). Concentration courses must be taken for a letter grade.

Secondary concentration: twelve units in one of the approved areas outside of CSE. The twelve units of the secondary concentration must be taken from only one area and approved by the M.S. Committee: the Departments of Cognitive Science, Electrical and Computer Engineering, Mechanical and Aerospace Engineering, Structural Engineering, or the Rady School of Management. Technical electives: eight units (within CSE, graduate level)

Project: four units of CSE 293

Capstone: comprehensive exam

COMPUTER ENGINEERING PROGRAM

The CSE computer engineering program offers master of science and doctoral degrees with the degree title computer science and engineering (computer engineering). Computer engineering explores the engineering analysis and design aspects of algorithms and technology. Specific research areas include computer systems, signal processing systems, architecture, networks, computer-aided design, fault tolerance, and data storage systems.

MASTER OF SCIENCE PROGRAM

The degree can be pursued under either the Thesis Plan I or the Comprehensive Examination Plan II. There are two options for the Comprehensive Exam Plan II: the Standard Comprehensive Option or Interdisciplinary Comprehensive Option. Each plan requires forty-nine units of work. For full-time students, all the requirements must be completed within two years. Students with an adequate background in computer engineering can complete the M.S. program within four to five quarters of full-time study.

Plan I: Thesis Option

This plan of study involves both course work and research, culminating in the preparation of a thesis. A thesis based on research must be written and subsequently reviewed by a committee consisting of three faculty members, with at least two members from within the CSE department. The committee is appointed by the dean of Graduate Studies. Twelve units of CSE 298 must be taken with a faculty member in CSE who agrees to act as advisor for the thesis to fulfill the research requirement. A total of forty-nine units of credit is required, as follows:

Computer Engineering—Thesis, Plan I
Forty-nine units

Core: Core courses must be completed with an average grade of B. The four core courses required of all students are as follows:

CSE 292

Three of the following courses: CSE 202, CSE 221, CSE237A, CSE 240A, CSE 241A

Concentration courses: twelve units from a list of computer engineering courses maintained by the department

Electives: twelve units (minimum of eight units taken within CSE, minimum of eight units graduate level)

Research: twelve units of CSE 298

Capstone: thesis

Plan II: Comprehensive Examination

There are two options for the Computer Engineering, Comprehensive Exam Plan II: the Standard Comprehensive Option or Interdisciplinary Comprehensive Option.

In order to receive the M.S. degree in computer engineering under this plan, a student must complete the course requirements listed below and pass the comprehensive examination.

The comprehensive examination is designed to test the student's knowledge in basic computer science and engineering material. The examination can normally be passed with a thorough knowledge of topics covered in the undergraduate and the first-year graduate computer science or computer engineering programs. Each student is allowed three attempts to pass the examination. The student must secure at least a master's-level pass in the comprehensive examination. This examination is the same for both the computer science and the computer engineering graduate programs. More information about the comprehensive examination can be obtained in a separate document from the CSE graduate office.

Computer Engineering—Comprehensive, Plan II
Forty-nine units

Core: core courses must be completed with an average grade of B . The four core courses required of all students are as follows:

CSE 292

Three of the following courses: CSE 202, CSE 221, CSE237A, CSE 240A, CSE 241A

Standard option:

- Primary concentration: twelve units from a list of computer engineering courses maintained by the department. Concentration courses must be taken for a letter grade.
- Technical electives: twenty units (minimum of twelve units in CSE, minimum of twelve units at graduate level)
- Project: four units of CSE 293
- Capstone: comprehensive exam
- Interdisciplinary option:
- Primary concentration: twelve units from a list of computer engineering courses maintained by the department. Concentration courses must be

taken for a letter grade.

- Secondary concentration: twelve units within one of the approved areas outside of CSE. The twelve units of the secondary concentration must all be taken from only one area and approved the by M.S. Committee: the Departments of Cognitive Science, Electrical and Computer Engineering, Mechanical and Aerospace Engineering, Structural Engineering, and the Rady School of Management.
- Technical electives: eight units (within CSE, graduate level)
- Project: four units of CSE 293
- Capstone: comprehensive exam

DOCTORAL PROGRAMS

PH.D. DEGREE PROGRAMS IN COMPUTER SCIENCE AND COMPUTER ENGINEERING

CSE offers doctor of philosophy degrees in computer science and in computer engineering, providing a research-oriented education in preparation for a research, industrial, or entrepreneurial career. These programs explore both the fundamental aspects and application of computation, spanning theory, software, hardware, and applications. Our particular areas of research expertise include

- algorithms
- artificial intelligence
- bioinformatics
- complexity theory
- computer architecture/compilers
- VLSI/CAD and embedded systems
- databases and information management
- distributed systems and networking
- graphics and vision
- high performance computing
- mobile computing
- security and cryptography
- software engineering

Competency Requirement

The competency requirement ensures that Ph.D. students already have or will acquire the necessary undergraduate background for Ph.D. studies. Competency at the advanced undergraduate level may be demonstrated by any of the following methods:

1. providing evidence of previous undergraduate or graduate course work; or
2. taking an undergraduate course at UCSD; or
3. taking the corresponding graduate course with consent of instructor; or
4. passing the final exam of an undergraduate course at UCSD.

Ph.D. students must demonstrate competency with respect to the following six undergraduate courses at UCSD. The corresponding graduate courses are listed in parentheses.

CSE 101. Design and Analysis of Algorithms
(CSE 202 Algorithm Design and Analysis)
CSE 105. Theory of Computability
(no corresponding graduate course)
CSE 120. Principles of Computer Operating Systems
(CSE 221 Operating Systems)
CSE 130. Programming Languages: Principles and Paradigms
(CSE 230. Principles of Programming Languages)
CSE 131. Compiler Construction
(CSE 231.Advanced Compiler Design)
CSE 141. Introduction to Computer Architecture
(CSE 240A. Principles of Computer Architecture)

A graduate course taken to satisfy the competency requirement may also be used to satisfy the breadth, depth, or elective course requirement.

Course Requirements

The course requirement is intended to ensure that students are exposed to (1) fundamental concepts and tools, (2) advanced, up-to-date views in topics outside their area (the *breadth requirement*), and (3) a deep, up-to-date view of their research area (the *depth requirement*). Ph.D. students are expected to complete the breadth and depth requirements within the first three years of the program. All required course work must be taken for a letter grade, with the exception of CSE 291 (Topics in CSE), CSE 292 (Faculty Research Seminar), CSE 299 (Research), and CSE 500 (Teaching Assistantship), for which only S/U grades are allowed.

Units obtained from a single course cannot count more than once towards satisfying the requirement in each of the breadth, depth, or elective areas. Ph.D. students who have taken similar courses elsewhere may petition for a waiver of the required courses or for substitution by alternative courses.

Breadth Requirement

The breadth requirement ensures that Ph.D. students share knowledge of fundamental concepts and tools from across broad areas of computer science and computer engineering. Each Ph.D. student must take each of these courses for a letter grade and maintain an overall breadth course GPA of 3.3 (except for CSE 292, for which a letter grade is not assigned). A student will typically complete all breadth courses within the first two years of graduate study.

Breadth courses are categorized into three areas: Theory, Systems, and Applications.

Students in **Computer Science** must take six (courses in the areas of Theory, Systems, and Applications: two in Theory, two in Systems, and two in Applications

Students in **Computer Engineering** must take six courses in the areas of Theory, Systems, and Applications following one of two plans:

Plan A: one in Theory, three in Systems, and two in Applications

or

Plan B: two in Theory, three in Systems, and one in Applications

Please refer to the department Web site for a complete list of all eligible courses by breadth area.

Depth Requirements

The depth requirement ensures that a Ph.D. student acquires some depth of knowledge in a general research area early in his or her career. Each Ph.D. student must select one of the following areas as his or her depth area. The student must take three courses (twelve units) from this depth area. The student must take each of these courses for a letter grade and maintain an overall depth course GPA of 3.4. However, one of these three courses can be a CSE Topics course (CSE 291) or an Independent Study (CSE 299), which are not taken for a letter grade. The department will maintain a list of appropriate courses for each depth area.

The depth areas are

- Theoretical Computer Science
- Programming Languages, Compilers, and Software Engineering
- Computer Systems
- Database Systems
- Computer Engineering
- Artificial Intelligence
- Graphics and Vision
- Bioinformatics

Electives

In addition to the above, each student must take three additional courses (twelve units) including at most eight units of 299, with no grade lower than C–. Upper-division undergraduate courses satisfying the competency requirement may be used as electives. Undergraduate upper-division courses CSE 291 and CSE 299 may also be used to fulfill this requirement. Units obtained in the CSE 209 series, 229 series, 239 series, 249 series, 259 series, 269 series, 279 series, 289 series, 290, 292, 293, 294, 298, and 500, and 599 do not count toward the elective requirement.

Research Exam Requirement

The research exam is intended to verify three components of the student's preparation for Ph.D. research: (1) breadth of comprehension sufficient to enable computer science research in areas beyond the topic(s) of the research exam and thesis; (2) ability to perform critical study, analysis, and writing in a focused area; and (3) research experience.

The research exam has both an oral part and a written part. The oral part of the research exam is distinct from, and cannot be combined with the University Qualifying Exam. Grading criteria for each part, and standards for passing, are available from the CSE department graduate office.

The research exam is conducted by a committee of three faculty members approved by the Graduate Committee and the chair of the department. At least two committee members must be CSE senate faculty. The student's advisor is not a member of the committee, but is free to attend the research examination. The normative time for passing the research exam is by the end of the second year of study. A petition to the CSE Graduate Committee is required

to take the research examination after the student's seventh quarter of study. The research exam must be passed by the end of the third year if the student is to continue in the Ph.D. Program. Passing the research exam may enable Ph.D. students to receive the M.S. degree if they have otherwise met their M.S. degree requirements concurrently. Ph.D. students who do not pass the exam after two attempts will be given the opportunity to write a thesis in order to receive a terminal M.S. degree. The M.S. degree is only granted to those students who do not already hold an M.S. degree prior to entering the CSE department at UCSD.

Teaching Assistant Requirement

All students enrolled in the Ph.D. Program must have one quarter of training as a teaching assistant. This is a formal degree requirement and must be completed before the student is permitted to graduate. The requirement is met by serving as a 50 percent teaching assistant and taking CSE 500 (Teaching Assistantship).

Qualifying Examination and Advancement to Candidacy

The qualifying examination is a requirement for advancement to candidacy. Prior to taking the qualifying examination a student must have satisfied the departmental competency, course, and research exam requirements and must have been accepted by a CSE faculty member as a Ph.D. thesis candidate. All doctoral students are expected to advance to candidacy by the end of their third year, and advancement is mandatory by the end of the fourth year. The examination is administered by a doctoral committee appointed by the dean of Graduate Studies and Research and consists of faculty from CSE and other departments. More information on the composition of the committee can be obtained from the CSE graduate office. The examination is taken after the student and his or her advisor have identified a topic for the dissertation and an initial demonstration of feasible progress has been made. The candidate is expected to describe his or her accomplishments to date as well as future work.

Dissertation

The dissertation defense is the final Ph.D. examination. A candidate for the Ph.D. is expected to write a dissertation and defend it in an oral examination conducted by the doctoral committee.

Departmental Ph.D. Time Limit Policies

Students must be advanced to candidacy by the end of four years. Total university support cannot exceed seven years. Total registered time at UCSD cannot exceed eight years.

Financial Aid

Financial support is available to qualified graduate students in the form of fellowships, loans, and assistantships. Anticipated stipends for half-time research assistantships are $2,100 per month, with the possibility of full-time employment during the summer months. For a half-time teaching assistantship, the anticipated stipend will be $1,840 per month. Requests for application forms for admission and financial support should be directed to the Department of Computer Science and Engineering.

COURSES

For course descriptions not found in the UC San Diego General Catalog, 2010–11, please contact the department for more information.

A tentative schedule of course offerings is available from the Department of CSE each spring for the following academic year. The tentative schedule for 2010–11 is also found at http://www.cse.ucsd.edu/undergrad/courses/ugradnextyearcourses.html.

LOWER-DIVISION

CSE 3. Fluency in Information Technology (4)
Introduces the concepts and skills necessary to effectively use information technology. Includes basic concepts and some practical skills with computer and networks. **Prerequisite:** none.

CSE 4GS. Mathematical Beauty in Rome (4)
Exploration of topics in mathematics and engineering as they relate to classical architecture in Rome, Italy. In depth geometrical analysis and computer modeling of basic structures (arches, vaults, domes), and on-site studies of the Colosseum, Pantheon, Roman Forum, and St. Peter's Basilica. **Prerequisites:** Math. 10A or Math. 20A; departmental approval, and co-requisite of CSE 6GS.

CSE 6GS. Mathematical Beauty in Rome Lab (4)
Companion course to CSE 4GS where theory is applied and lab experiments are carried out "in the field" in Rome, Italy. For final projects, students will select a complex structure (e.g., the Colosseum, the Pantheon, St. Peter's, etc.) to analyze and model, in detail, using computer-based tools. **Prerequisites:** Math. 10A or Math. 20B; departmental approval, and co-requisite of CSE 4GS.

CSE 5A. Introduction to Programming I (4)
(Formerly CSE 62A) Introduction to algorithms and top-down problem solving. Introduction to the C language including functions, arrays, and standard libraries. Basic skills for using a PC graphical user interface operating system environment. File maintenance utilities are covered. (A student may not receive credit for CSE 5A after receiving credit for CSE 10 or CSE 11 or CSE 8B or CSE 9B or CSE 62B or CSE 65.) **Prerequisite:** A familiarity with high-school level algebra is expected, but this course assumes no prior programming knowledge.

CSE 8A. Introduction to Computer Science: JAVA (3)
Introductory computer science course designed for students interested in computing. No prior programming experience is assumed. Learn fundamental concepts of applied computer science using media computation. Must be taken concurrently with CSE 8AL. CSE 8A is part of a three-track course (CSE 8A, CSE 8AL, and CSE 8B) that is equivalent to CSE 11. Students should take CSE 8B to complete this track. Students who have taken CSE 8B or CSE 11 may not take CSE 8A. Recommended prep: High school algebra and familiarity with computing concepts. **Prerequisite:** co-requisite of CSE 8AL.

CSE 8AL. Introduction to Computer Science: JAVA Lab (1)
Exercises in the theory and practice of computer science under the supervision of an instructor. Hands-on experience with designing, editing, compiling, and executing programming constructs and applications. Must be taken concurrently with CSE 8A. CSE 8AL is part of a three-track course (CSE 8A, CSE 8AL, and CSE 8B) that is equivalent to CSE 11. Students should take CSE 8B to complete this track. Students who have taken CSE 8B or CSE 11 may not take CSE 8AL. Recommended prep: High school algebra and familiarity with computing concepts. **Prerequisite:** co-requisite of CSE 8A.

CSE 8B. Introduction to Computer Science: Java B (4)
Continuation of the Java language. Continuation of programming techniques. More on inheritance. Exception handling. CSE 8A is part of a three-track course (CSE 8A, CSE 8AL, and CSE 8B) that is equivalent to CSE 11. Students who have taken CSE 11 may not take CSE 8B. Recommended prep: High school algebra and familiarity with computing concepts or CSE 8A and CSE 8AL.

CSE 11. Introduction to Computer Science and Object-Oriented Programming: Java (4)
Introduction to computer science and programming using the Java language. Basic UNIX. Modularity and abstraction. Documentation, testing and verification techniques. Basic object-oriented programming including inheritance and dynamic bind. Exception handling. Event-driven programming. Experience with AWT library or other similar library. **Prerequisites:** high-school algebra and a course in programming in a compiled language. Majors only.

CSE 12. Basic Data Structures and Object-Oriented Design (4)
Basic data structures including stacks, queues, lists, binary trees, hash tables. Basic object-oriented design including encapsulation, polymorphism, classes as the implementation of abstract data types. Memory management, pointers, recursion, and big-o notation. Uses the C/C++ and Java programming language. **Prerequisites:** CSE 8B or CSE 11, and CSE 15L.

CSE 15L. Tools and Technique Laboratory (2)
Hands-on exploration of software development tools and techniques. Investigation of the scientific process as applied to software development and debugging. Emphasis is on weekly hands-on laboratory experiences, development of laboratory notebooking techniques as applied to software design. **Prerequisites:** CSE 8B, or CSE 11. Concurrent enrollment with CSE 12.

CSE 20. Introduction to Discrete Mathematics (4)
Basic discrete mathematical structure: sets, relations, functions, sequences, equivalence relations, partial orders, and number systems. Methods of reasoning and proofs: propositional logic, predicate logic, induction, recursion, and pigeonhole principle. Infinite sets and diagonalization. Basic counting techniques; permutation and combinations. Applications will be given to digital logic design, elementary number theory, design of programs, and proofs of program correctness. Credit not offered for both Math. 15A and CSE 20. Equivalent to Math 15A. **Prerequisites:** CSE 8A or CSE 8B or CSE 11. CSE 8B or CSE 11 may be taken concurrently with CSE 20/ Math. 15A.

CSE 21. Mathematics for Algorithms and Systems (4)
This course will provide an introduction to the discrete mathematical tools needed to analyze algorithms and systems. Enumerative combinatorics: basic counting principles, inclusion-exclusion, and generating functions. Matrix notation. Applied discrete probability. Finite automata. Credit not offered for both Math. 15B and CSE 21. Equivalent to Math 15B. **Prerequisite:** CSE 20 or Math. 15A.

CSE 30. Computer Organization and Systems Programming (4)
Introduction to organization of modern digital computers—understanding the various components of a computer and their interrelationships. Study of a specific architecture/machine with emphasis on systems programming in C and Assembly languages in a UNIX environment. **Prerequisite:** CSE 12, CSE 15L, or consent of instructor.

CSE 70. Software Engineering (4)
Introduction to software development and engineering methods, including specification, design, implementation, testing, and process. An emphasis on team development, agile methods, and use of tools such as IDE's, version control, and test harnesses. Prerequisite: CSE 12.

CSE 80. UNIX Lab (2)
The objective of the course is to help the programmer create a productive UNIX environment. Topics include customizing the shell, file system, shell programming, process management, and UNIX tools. **Prerequisite:** CSE 8B or CSE 11. Majors only.

CSE 86. C++ for Java Programmers (2)
Helps the Java programmer to be productive in the C++ programming environment. Topics include the similarities and differences between Java and C++ with special attention to pointers, operator overloading, templates, the STL, the preprocessor, and the C++ Runtime Environment. **Prerequisite:** CSE 12 or consent of instructor.

CSE 91. Perspectives in Computer Science and Engineering (2)
A seminar format discussion led by CSE faculty on topics in central areas of computer science, concentrating on the relation among them, recent developments, and future directions. **Prerequisites:** majors only.

CSE 92. Reading and Writing in Computer Science (2)
This course helps students to read and write technical English better, and to read and write software better. They write short papers responding to a CSE-related book, learn the basics of functional programming, and do a project using a functional language. **Prerequisites:** CSE 12. Majors only.

CSE 87. Freshman Seminar (1)
The Freshman Seminar Program is designed to provide new students with the opportunity to explore an intellectual topic with a faculty member in a small seminar setting. Freshman seminars are offered in all campus departments and undergraduate colleges, and topics vary from quarter to quarter. Enrollment is limited to 15 to 20 students, with preference given to entering freshmen. **Prerequisite:** none.

CSE 99. Independent Study in Computer Science and Engineering (4)
Independent reading or research by special arrangement with a faculty member. **Prerequisites:** lower-division standing. Completion of 30 units at UCSD with a UCSD GPA of 3.0. Special Studies form required. Department stamp required. Consent of instructor and approval of the department. Majors onlY.

UPPER-DIVISION

CSE 100. Advanced Data Structures (4)
High-performance data structures and supporting algorithms. Use and implementation of data structures like (un) balanced trees, graphs, priority queues, and hash tables. Also memory management, pointers, recursion. Theoretical and practical performance analysis, both average case and amortized. Uses C++ and STL. Credit not offered for both Math. 176 and CSE 100. Equivalent to Math. 176. **Prerequisite:** CSE 21 or Math. 15B or consent of instructor.

CSE 101. Design and Analysis of Algorithms (4)
Design and analysis of efficient algorithms with emphasis of non-numerical algorithms such as sorting, searching, pattern matching, and graph and network algorithms. Measuring complexity of algorithms, time and storage. NP-complete problems. Credit not offered for both Math. 188 and CSE 101. Equivalent to Math 188. **Prerequisites:** CSE 12, CSE 21 or Math. 15B or Math. 100A or Math. 103A and CSE 100 or Math. 176. Majors only.

CSE 102. Storage System Architectures (4)
Descriptive and analytic introduction to storage system architectures. Disk drive storage media organization and run-time performance; external indexing data structures B+trees and linear hashing algorithms. Disk arrays, RAID data organization, reliability, sparing, data declustering, and video servers. **Prerequisites:** CSE 100 or Math. 176, CSE 120, CSE 123A, or consent of the instructor. Majors only.

CSE 103. A Practical Introduction to Probability and Statistics (4)
Distributions over the real line. Independence, expectation, conditional expectation, mean, variance. Hypothesis testing. Learning classifiers. Distributions over R^n, covariance matrix. Binomial, Poisson distributions. Chernoff bound. Entropy. Compression. Arithmetic coding. Maximal likelihood estimation. Bayesian estimation. CSE 103 is not duplicate credit for ECE 109, ECON 120A, or Math. 183. **Prerequisites:** Math. 20A and Math 20B.

CSE 105. Theory of Computability (4)
An introduction to the mathematical theory of computability. Formal languages. Finite automata and regular expression. Push-down automata and context-free languages. Computable or recursive functions: Turing machines, the halting problem. Undecidability. Credit not offered for both Math. 166 and CSE 105. Equivalent to Math 166. **Prerequisites:** CSE 12, CSE 21 or Math. 15B or Math. 100A or Math. 103A. Majors only.

CSE 107. Introduction to Modern Cryptography (4)
Topics include private and public-key cryptography, block ciphers, data encryption, authentication, key distribution and certification, pseudorandom number generators, design and analysis of protocols, zero-knowledge proofs, and advanced protocols. Emphasizes rigorous mathematical approach including formal definitions of security goals and proofs of protocol security. **Prerequisites:** CSE 21 or Math. 15B, CSE 101 or Math. 188, CSE 105 or Math. 166. Majors only.

CSE 110. Software Engineering (4)
Introduction to software development and engineering methods, including specification, design, implementation, testing, and process. An emphasis on team development, agile methods, and use of tools such as IDE's, version control, and test harnesses. CSE 70 is renumbered to CSE 110: students may not receive credit for both CSE 70 and CSE 110. **Prerequisite:** CSE 12, CSE 21, or Math. 15B.

CSE 111. Object Oriented Software Design (4)
Introduction to object-oriented analysis and design. Object-oriented modeling methods for analysis and design, object-oriented general design paradigms, object-oriented design techniques. Cyclic development of object-oriented systems. **Prerequisites:** CSE 8B or CSE 9B or CSE 10 or CSE 11, CSE 12, and CSE 100 or Math. 176. Majors only.

CSE 112. Advanced Software Engineering (4)
This course will cover software engineering topics associated with large systems development such as requirements and specifications, testing and maintenance, and design. Specific attention will be given to development tools and automated support environments. **Prerequisite:** CSE 111.

CSE 118. Ubiquitous Computing (4)
Explores emerging opportunities enabled by cheap sensors and networked computing devices. Small research projects will be conducted in teams, culminating in project presentations at the end of the term. Section will cover material relevant to the project, such as research methods, software engineering, teamwork, and project management. **Prerequisite:** any course from the following: CSE 131, CSE 132B, Cog Sci 102C, Cog Sci 121, Cog Sci 184, ECE 111, ECE 118, ECE 191, ECE 192, COMT 111B, COMT 115, or ICAM ; or consent of instructor.

CSE 120. Principles of Computer Operating Systems (4)
Basic functions of operating systems; basic kernel structure, concurrency, memory management, virtual memory, file systems, process scheduling, security and protection. **Prerequisites:** CSE 100 or Math. 176 and CSE 101 or Math. 188. Majors only.

CSE 121. Operating Systems: Architecture and Implementation (4)
(Formerly CSE 171B.) Case study of architecture and implementation of a selected modern operating system. In-depth analysis through a detailed study of source code. Topics include process creation, context-switching, memory allocation, synchronization mechanisms, interprocess communication, I/O buffering, device drivers, and file systems. **Prerequisite:** CSE 120.

CSE 123. Computer Networks (4)
(Renumbered from CSE 123A.) Introduction to concepts, principles, and practice of computer communication networks with examples from existing architectures, protocols, and standards with special emphasis on the Internet protocols. Layering and the OSI model; physical and data link layers; local and wide area networks; datagrams and virtual circuits; routing and congestion control; internetworking. Transport protocols. Credit may not be received for both CSE 123A and 158A or CSE 123B and 158B. **Prerequisites:** CSE 120 or consent of instructor. Majors only.

CSE 124. Networked Services (4)
(Renumbered from CSE 123B.) The architecture of modern networked services, including data center design, enterprise storage, fault tolerance, and load balancing. Protocol software structuring, the Transmission Control Protocol (TCP), remote procedure calls, protocols for digital audio and video communication, overlay and peer-to-peer systems, secure communication. Credit may not be received for both CSE 124 and ECE 158B. Students may not receive credit for both CSE 123B and CSE 124. **Prerequisites:** CSE 120 or consent of instructor. Majors only.

CSE 125. Software System Design and Implementation (4)
Design and implementation of large, complex software systems involving multiple aspects of CSE curriculum. Emphasis is on software system design applied to a single, large group project with close interaction with instructor. **Prerequisites:** senior standing with substantial programming experience, and consent of instructor. Department stamp required. Majors only.

CSE 127. Introduction to Computer Security (4)
Topics include basic cryptography, security/threat analysis, access control, auditing, security models, distributed systems security, and theory behind common attack and defense techniques. The class will go over formal models as well as the bits and bytes of security exploits. **Prerequisites:** CSE 21 or Math. 15B, and CSE 120. Majors only.

CSE 128. Concurrency (4)
Specification of concurrent programs safety, liveness, and fairness: producer-consumer; mutual exclusion; atomic read/writes; semaphores; monitors; distributed algorithms and memory coherency; programming with threads; concurrency in popular programming languages and operating systems. **Prerequisites:** CSE 120. Majors only.

CSE 130. Programming Languages: Principles and Paradigms (4)
(Formerly CSE 173.) Introduction to programming languages and paradigms, the components that comprise them, and the principles of language design, all through the analysis and comparison of a variety of languages (e.g., Pascal, Ada, C++, PROLOG, ML.) Will involve programming in most languages studied. **Prerequisites:** CSE 12 and CSE 100 or Math. 176. Majors only.

CSE 131. Compiler Construction (4)
(Formerly CSE 131B.) Introduction to the compilation of programming languages, practice of lexical and syntactic analysis, symbol tables, syntax-directed translation, type checking, code generation, optimization, interpretation, and compiler structure. (Students may receive repeat credit for CSE 131A and CSE 131B by completing CSE 131.) **Prerequisites:** CSE 100 or Math. 176, CSE 105 or Math. 166, CSE 110, and CSE 130.

CSE 132A. Database System Principles (4)
Basic concepts of databases, including data modeling, relational databases, query languages, optimization, dependencies, schema design, and concurrency control. Exposure to one or several commercial database systems. Advanced topics such as deductive and object-oriented databases, time allowing. **Prerequisites:** CSE 100 or Math. 176. Majors only.

CSE 132B. Database Systems Applications (4)
Design of databases, transactions, use of trigger facilities and datablades. Performance measuring, organization of index structures. **Prerequisite:** CSE 132 or CSE 132A or equivalent.

CSE 134A. Web Server Languages (4)
Design and implementation of interactive World Wide Web documentation using server-side programs. Languages covered include HTML, Perl, and JavaScript. Other languages as time allows. **Prerequisites:** CSE 100 or Math. 176. Majors only.

CSE 134B. Web Client Languages (4)
Design and implementation of interactive World Wide Web clients using helper applications and plug-ins. The main language covered will be Java. **Prerequisites:** CSE 100 or Math. 176. Majors only.

CSE 135. Server-side Web Applications (4)
Design and implementation of dynamic Web-based applications. Multi-tier architecture, scripting languages, SQL, XML, session handling, non-browser clients, Web services,

and scalability, security, and usability in the Web context. **Prerequisites:** CSE 100 or Math. 176. Majors only.

CSE 136. Enterprise-class Web Applications (4)
Design and implementation of large scale Web-based applications. Modeling organizational needs, design and revision management, J2EE or similar software platforms, Web and application server functionality, reuse of object-oriented components, model-view-controller and other design patterns, clustering, load-balancing, fault-tolerance, authentication, usage accounting. **Prerequisites:** CSE 135. Majors only.

CSE 140. Components and Design Techniques for Digital Systems (4)
(Formerly CSE 170A) Design of Boolean logic and finite state machines; two-level, multi-level combinational logic design, combinational modules and modular networks, Mealy and Moore machines, analysis and synthesis of canonical forms, sequential modules. **Prerequisites:** CSE 20 or Math. 15A, CSE 30. CSE 140L must be taken concurrently. Majors only.

CSE 140L. Digital Systems Laboratory (2)
(Formerly CSE 175B) Implementation with computer-aided design tools for combinational logic minimization and state machine synthesis. Hardware construction of a small digital system. **Prerequisites:** CSE 20, CSE 30. CSE 140 must be taken concurrently.

CSE 141. Introduction to Computer Architecture (4)
Introduction to computer architecture. Computer system design. Processor design. Control design. Memory systems. **Prerequisites:** CSE 140, CSE 140L, or consent of the instructor. CSE 141L should be taken concurrently. Majors only.

CSE 141L. Project in Computer Architecture (2)
Hands-on computer architecture project aiming to familiarize students with instruction set architecture, and design of process. Control and memory systems. **Prerequisites:** CSE 140, CSE 140L, or consent of the instructor. CSE 141 should be taken concurrently. Majors only.

CSE 142. Advanced Digital Logic Design (4)
(Formerly CSE 170C) Digital logic optimization; functional decomposition and symmetric functions; reliable design and fault diagnosis; structure of sequential machines; asynchronous circuit design. Assignments using logic synthesis tools. **Prerequisites:** CSE 140, CSE 140L.

CSE 143. Microelectronic System Design (4)
VSLI process technologies; circuit characterization; logic design styles; clocking strategies; computer-aided design tools; subsystem design; design case studies. System design project from hardware description, logic synthesis, physical layout to design verification. Students may not receive credit for both CSE 143 and ECE 161B. **Prerequisites:** CSE 140 and CSE 141. Majors only.

CSE 145. Embedded System Design Project (4)
Project class building an embedded computing system. Learn fundamental knowledge of microcontrollers, sensors, and actuators. Introduction to the hardware and software tools to build project in a team environment and end-to-end system building. **Prerequisite:** CSE 30.

CSE 146. Introduction to Reliable Hardware (4)
Fault models and tests, combinational circuit test generation, fault collapsing, fault simulation, synchronous sequential circuit testing, functional testing, memory testing. **Prerequisites:** CSE 140 and CSE 140L, or consent of instructor. Majors only.

CSE 148. Advanced Processor Architecture Design Project (4)
Students will use hardware description language tools to add advanced architectural features to a basic processor design. These features may include pipelining, superscalar execution, branch prediction, and advanced cache features. Designs will be implemented in programmable logic devices. **Prerequisites:** CSE 141, CSE 141L, or consent of instructor. Majors only.

CSE 150. Introduction to Artificial Intelligence: Search and Reasoning (4)
Search algorithms including BFS, DFS, iterative deepening and A*,randomized search algorithms including Walksat, syntax and semantics of first-order logic (FOL), knowledge representation in FOL including reasoning, basic reasoning with probabilities, basic Bayesian learning. **Prerequisites:** CSE 100 or Math. 176 or consent of instructors. Majors only.

CSE 151. Introduction to Artificial Intelligence: Statistical Approaches (4)
Reasoning with probabilities, reasoning and learning with Bayesian networks, decision-making under uncertainty, sequential decision-making, statistical learning methods, and reinforcement learning. **Prerequisites:** CSE 100 or Math. 176 or consent of instructor. Majors only.

CSE 152. Introduction to Computer Vision (4)
The goal of computer vision is to compute scene and object properties from images and video. This introductory course includes feature detection, image segmentation, motion estimation, object recognition, and 3-D shape reconstruction through stereo, photometric stereo, and structure from motion. **Prerequisites:** Math. 20F, CSE 100 or Math. 176, CSE 101 or Math. 188. Knowledge of C, C++ or Matlab programming. Majors only.

CSE 160. Introduction to Parallel Computing (4)
Introduction to high performance parallel computing: parallel architecture, algorithms, software, and problem-solving techniques. Areas covered: Flynns' taxonomy, processor-memory organizations, shared and non-shared memory models: message passing and multithreading, data parallelism; speedup, efficiency and Amdahl's law, communication and synchronization, isoefficiency and scalability. Assignments given to provide practical experience. **Prerequisites:** CSE 100 or Math. 176. Majors only.

CSE 166. Image Processing (4)
Principles of image formation, analysis, and representation. Image enhancement, restoration, and segmentation; stochastic image models. Filter design, sampling, Fourier and wavelet transforms. Selected applications in computer graphics and machine vision. **Prerequisites:** Math. 20F, CSE 100 or Math. 176. Majors only.

CSE 167. Computer Graphics (4)
(Formerly CSE 177) Representation and manipulation of pictorial data. Two-dimensional and three-dimensional transformations, curves, surfaces. Projection, illumination, and shading models. Raster and vector graphic I/O devices; retained-mode and immediate-mode graphics software systems and applications. **Prerequisites:** Math. 2EA/20F and CSE 100 or Math. 176. Majors only.

CSE 168. Computer Graphics II: Rendering (4)
Weekly programming assignments that will cover graphics rendering algorithms. During the course the students will learn about ray tracing, geometry, tessellation, acceleration structures, sampling, filtering, shading models, and advanced topics such as global illumination and programmable graphics hardware. **Prerequisites:** CSE 167 or concurrent enrollment. Majors only.

CSE 169. Computer Animation (4)
Advanced graphics focusing on the programming techniques involved in computer animation. Algo-rithms and approaches for both character animation and physically based animation. Particular subjects may include skeletons, skinning, key framing, facial animation, inverse kinematics, locomotion, motion capture, video game animation, particle systems, rigid bodies, clothing, and hair. **Prerequisites:** a good understanding of linear algebra. CSE 167 or consent of instructor. Majors only.

CSE 171. User Interface Design (4)
Explores usability, representation and coordination issues in user interface design with some focus on distributed cooperative work, semiotics, and the interplay between socio-cognitive and technical issues. Most examples and homework involve the Web. **Prerequisites:** CSE 8B or 11, CSE 20 or Math. 15A, and CSE 100 or Math. 176. Majors only.

CSE 175. Social and Ethical Issues in Information Technology (4)
Social aspects of information technology, with an emphasis on ethical issues. Topics include ethical theories, privacy and security, spam, e-commerce, the digital divide, open source software, medical informatics, actor-network theory, and some neo-classical economics. **Prerequisites:** CSE 100 or Math. 176. Majors only.

CSE 181. Molecular Sequence Analysis (4)
This course covers the analysis of nucleic acid and protein sequences, with an emphasis on the application of algorithms to biological problems. Topics include sequence alignments, database searching, comparative genomics, and phylogenetic and clustering analyses. Pairwise alignment, multiple alignment, DNS sequencing, scoring functions, fast database search, comparative genomics, clustering, phylogenetic trees, gene finding/DNA statistics. **Prerequisites:** CSE 100 or Math. 176, CSE 101 or Math. 188, BIMM 100 or Chem. 114D. Bioinformatics majors only. CSE 181 is crosslisted with BIMM 181 and BENG 181.

CSE 182. Biological Databases (4)
This course provides an introduction to the features of biological data, how that data are organized efficiently in databases, and how existing data resources can be utilized to solve a variety of biological problems. Relational databases, object oriented databases, ontologies, data modeling and description, survey of current biological database with respect to above, implementation of a database focused on a biological topic. **Prerequisites:** CSE 100 or Math. 176. Bioinformatics majors only. CSE 182 is crosslisted with BIMM 182, Chem. 182, and BENG 182.

CSE 184. Computational Molecular Biology (4)
This advanced course covers the application of machine learning and modeling techniques to biological systems. Topics include gene structure, recognition of DNA and protein sequence patterns, classification, and protein structure prediction. Pattern discovery, Hidden Markov models/support victor machines/neural network/profiles. Protein structure prediction, functional characterization or proteins, functional genomics/proteomics, metabolic pathways/gene networks. **Prerequisites:** BIMM 181 or BENG 181 or CSE 181, BIMM 182 or CSE 182 or CHEM 182. Bioinformatics majors only. CSE 184 is crosslisted with BIMM 184, BENG 184, and Chem. 184.

CSE 190. Topics in Computer Science and Engineering (4)
Topics of special interest in computer science and engineering. Topics may vary from quarter to quarter. May be repeated for credit with the consent of instructor. **Prerequisites:** consent of instructor. Department stamp required. Majors only.

CSE 191. Seminar in CSE (1–4)
A seminar course on topics of current interest. Students, as well as, the instructor will be actively involved in running the course/class. This course cannot be counted toward a technical elective. **Prerequisites:** consent of instructor. Department stamp required. Majors only.

CSE 195. Teaching (4)
Teaching and tutorial assistance in a CSE course under the supervision of the instructor. (P/NP grades only.) **Prerequisites:** consent of the department chair. Department stamp required.

CSE 197. Field Study in Computer Science and Engineering (4, 8, 12, or 16)
Directed study and research at laboratories away from the campus. (P/NP grades only.) **Prerequisite:** consent of the instructor and approval of the department. Department stamp required.

CSE 198. Directed Group Study (2 or 4)
Computer science and engineering topics whose study involves reading and discussion by a small group of students under the supervision of a faculty member. (P/NP grades only.) **Prerequisites:** consent of the instructor. Department stamp required.

CSE 199. Independent Study for Undergraduates (2 or 4)
Independent reading or research by special arrangement with a faculty member. (P/NP grades only.) **Prerequisites:** consent of the instructor. Department stamp required.

GRADUATE

CSE 200. Computability and Complexity (4)
Computability review, including halting problem, decidable sets, r.e. sets, many-one reductions; TIME(t(n)), SPACE(s(n)) and general relations between these classes;

L, P, PSPACE, NP; NP—completeness; hierarchy theorems; RP, BPP. **Prerequisite:** CSE 105 or equivalent.

CSE 201A. Advanced Complexity (4)
Polynomial-time hierarchy (PH); BPP in second level of pH; Savitch's theorem; NL=coNL; non-uniform and circuit complexity; some circuit lower bounds; IP=PSPACE; probabilistic proof checking (PCP); Application of PCP to approximation hardness; Complexity of proof systems; Parallel complexity classes NC and AC; P-completeness. **Prerequisite:** CSE 200.

CSE 202. Algorithm Design and Analysis (4)
The basic techniques for the design and analysis of algorithms. Divide-and-conquer, dynamic programming, data structures, graph search, algebraic problems, randomized algorithms, lower bounds, probabilistic analysis, parallel algorithms. **Prerequisite:** CSE 101 or equivalent.

CSE 203A. Advanced Algorithms (4)
Modern advances in design and analysis of algorithms. Exact syllabus varies. Topics include approximation, randomized algorithms, probabilistic analysis, heuristics, online algorithms, competitive analysis, models of memory hierarchy, parallel algorithms, number-theoretic algorithms, cryptanalysis, computational geometry, computational biology, network algorithms, VLSI CAD algorithms. **Prerequisite:** CSE 202.

CSE 204A. Combinatorial Optimization (4)
Linear programming, simplex method, duality, and column generating technique. Integer programming introduced via the Knapsack problem. The periodic nature of all integer programs. Why the round-off technique cannot work in general. The solution of the Knapsack problem in polonominal time since nonbasic columns form a group. **Prerequisite:** CSE 202 or linear algebra or consent of instructor.

CSE 205A. Logic in Computer Science (4)
(Formerly CSE 208D) Mathematical logic as a tool in computer science. Propositional logic, resolution, first-order logic, completeness and incompleteness theorems with computational viewpoint, finite model theory, descriptive complexity, logic programming, non-monotonic reasoning, temporal logic. Applications to databases, automatic theorem proving, program verification, and distributed systems. **Prerequisite:** CSE 200 or consent of instructor.

CSE 206A. Lattice Algorithms and Applications (4)
(Formerly CSE 207C) Introduction to the algorithmic theory of point lattices (A.K.A. algorithmic geometry of numbers), and some of its most important applications in cryptography and cryptanalysis. Topics usually include: LLL basis reduction algorithm, cryptanalysis of broadcast RSA, hardness of approximating lattice problems. **Prerequisites:** CSE 202, CSE 200, or concurrent.

CSE 207. Modern Cryptography (4)
Private and public key cryptography, introduction to reduction based proofs of security, concrete security, block ciphers, pseudorandom functions and generators, symmetric encryption, asymmetric encryption, computational number theory, RSA and discrete log systems, message authentication, digital signatures, key distribution and key management. **Prerequisite:** CSE 202 or consent of instructor.

CSE 207C. Lattices and Cryptology (4)
Renumbered to CSE 206A (see above).

CSE 208. Advanced Cryptography (4)
Zero-knowledge, secure computation, session-key distribution, protocols, electronic payment, one-way functions, trapdoor permutations, pseudorandom bit generators, hardcore bits. **Prerequisites:** CSE 202, CSE 200, and CSE 207 or consent of instructor.

CSE 208D. Logic in Computer Science (4)
Renumbered to CSE 205A (see above).

CSE 209A. Topics/Seminar in Algorithms, Complexity, and Logic (1–4)
Topics of special interest in algorithms, complexity, and logic to be presented by faculty and students under faculty direction. Topics vary from quarter to quarter. May be repeated for credit. **Prerequisite:** consent of instructor.

CSE 209B. Topics/Seminar in Cryptography (1–4)
Topics of special interest in cryptography to be presented by faculty and students under faculty direction. Topics vary from quarter to quarter. May be repeated for credit. **Prerequisite:** consent of instructor.

CSE 210. Principles of Software Engineering (4)
(Formerly CSE 264A.) General principles in modern software engineering. Both theoretical and practical topics are covered. Theoretical topics include proofs of correctness, programming language semantics, and theory of testing. Practical topics include structured programming, modularization techniques, design of languages for reliable programming, and software tools. **Prerequisites:** CSE 100, 131A, 120, or consent of instructor.

CSE 211. Software Testing and Analysis (4)
Survey of testing and analysis methods. Introduction to advanced topics in area as well as traditional production methods. Topics include inspections and reviews, formal analysis, verification and validation standards, non-statistical testing, statistical-testing and reliability models, coverage methods, testing and analysis tools, and organization management and planning. Methods special to special development approaches such as object-oriented testing will also be described. **Prerequisite:** undergraduate major in computer science or extensive industrial experience.

CSE 218. Advanced Topics in Software Engineering (4)
This course will cover a current topic in software engineering in depth. Topics in the past have included software tools, impacts of programming language design, and software system structure. (S/U grades permitted.) **Prerequisite:** none.

CSE 221. Operating Systems (4)
Operating system structures, concurrent computation models, scheduling, synchronization mechanisms, address spaces, memory management protection and security, buffering, streams, data-copying reduction techniques, file systems, naming, caching, disk organization, mapped files, remote file systems, case studies of major operating systems. **Prerequisites:** CSE 120 and 121, or consent of instructor.

CSE 222. Communication Networks (4)
Renumbered to CSE 222A (see below).

CSE 222A. Computer Communication Networks (4)
(Formerly CSE 222.) Computer communication network concepts, protocols, and architectures, with an emphasis on an analysis of algorithms, protocols, and design methodologies. Topics will include layering, error control, flow control, congestion control, switching and routing, quality of service management, mobility, naming, security, and selected contemporary topics. **Prerequisite:** CSE 123A or consent of instructor.

CSE 222B. Internet Algorithmics (4)
(Formerly CSE 228H.) Techniques for speeding up Internet implementations including system restructuring, new algorithms, and hardware innovations. Topics include: models for protocols, systems and hardware; efficiency principles; applying these principles to deriving techniques for efficient implementation of common endnode and router functions. **Prerequisite:** CSE 123A or CSE 222A or consent of instructor.

CSE 223. Distributed Systems (4)
Renumbered to CSE 223A (see below).

CSE 223A. Principles of Distributed Computing (4)
(Formerly CSE 223.) Logical and physical time, snapshot protocols, failure models, replication strategies, consensus and reliable broadcast, self-stabilization, atomic commit. **Prerequisite:** CSE 221 or consent of instructor.

CSE 223B. Distributed Computing and Systems (4)
Efficient primitives for distributed operating systems and high-performance network servers, including concurrent and event-driven server architectures, remote procedure calls, and load shedding. Distributed naming, directory, and storage services, replication for fault tolerance, and security in distributed systems. **Prerequisites:** CSE 221, CSE 222A, or consent of instructor.

CSE 225. High Performance Distributed Computing (and Computational Grids) (4)
Architecture of high performance distributed systems (e.g., frameworks and middleware). High performance distributed objects (DCOM, Corba, Java Beans) and networking with crosscut issues for performance, availability, and performance predictability. Scalable servers, metacomputing, and scientific computing. **Prerequisites:** CSE 121 and CSE 123A or consent of instructor.

CSE 226. Storage Systems (4)
(Formerly CSE 228B.) Secondary and tertiary storage systems, optical and magnetic media, performance analysis, modeling, reliability, redundant arrays of inexpensive disks, striping, log and maximum distance separable data organizations, sparing. **Prerequisite:** CSE 221 or consent of instructor.

CSE 227. Computer Security (4)
Security and threat models, risk analysis, authentication and authorization, auditing, operating systems security, access control mechanisms, protection mechanisms, distributed systems/network security, security architecture, electronic commerce security mechanisms, security evaluation. **Prerequisite:** CSE 221 or consent of instructor.

CSE 228B. Storage Systems (4)
Renumbered to CSE 226 (see above).

CSE 228H. Internet Algorithmics (4)
Renumbered to CSE 222B (see above).

CSE 229A. Topics/Seminar in Computer Systems (1–4)
Discussion on problems of current research interest in computer systems. Possible areas of focus include: distributed computing, computational grid, operating systems, fault-tolerant computing, storage systems, system services for the World Wide Web. Topics to be presented by faculty and students under faculty direction. Topics vary from quarter to quarter. May be repeated for credit. **Prerequisite:** consent of instructor.

CSE 229B. Topics/Seminar in Networks and Communication (1–4)
Discussion on problems of current research interest in computer networks and communication. Possible areas of focus include: wide-area networking, wireless networks, the Internet, computational grid, operating systems, fault-tolerant computing, storage systems. Topics to be presented by faculty and students under faculty direction. Topics vary from quarter to quarter. May be repeated for credit. **Prerequisite:** consent of instructor.

CSE 229C. Topics/Seminar in Computer Security (1–4)
Discussion on problems of current research interest in computer security. Topics to be presented by faculty and students under faculty direction. Topics vary from quarter to quarter. May be repeated for credit. **Prerequisite:** consent of instructor.

CSE 230. Principles of Programming Languages (4)
(Formerly CSE 273.) Functional versus imperative programming. Type systems and polymorphism; the ML language. Higher order functions, lazy evaluation. Abstract versus concrete syntax, structural and well-founded induction. The lambda calculus, reduction strategies, combinators. Denotational semantics, elementary domain theory. **Prerequisite:** CSE 130 or equivalent, or consent of instructor.

CSE 231. Advanced Compiler Design (4)
(Formerly CSE 264C.) Advanced material in programming languages and translator systems. Topics include compilers, code optimization, and debugging interpreters. **Prerequisites:** CSE 100, 131A–B, or consent of instructor.

CSE 232. Principles of Database Systems (4)
(Formerly CSE 264D.) Database models including relational, hierarchic, and network approaches. Implementation of databases including query languages and system architectures. **Prerequisite:** CSE 100 or consent of instructor.

CSE 232B. Database System Implementation (4)
A hands-on approach to the principles of databases implementation. Algebraic rewriters/optimizers, query processors, triggers. Beyond centralized relational databases. **Prerequisite:** CSE 232.

CSE 233. Database Theory (4)
Theory of databases. Theory of query languages, dependency theory, deductive databases, incomplete information, complex objects, object-oriented databases, and more. Connections to logic and complexity theory including finite model theory and descriptive complexity. **Prerequisite:** CSE 200.

CSE 237A. Introduction to Embedded Computing (4)
Embedded system technologies including processors, DSP, memory, and software. System interfacing basics, communication strategies, sensors, and actuators. Mobile and wireless technology in embedded systems. Using predesigned hardware and software components. Design case studies in wireless, multimedia, and/or networking domains. **Prerequisites:** basic courses in digital hardware, algorithms and data structures, elementary calculus, and probability; or consent of instructor.

CSE 237B. Software for Embedded Systems (4)
Embedded computing elements, device interfaces, time-critical IO handling. Embedded software design under size, performance, and reliability constraints. Software timing and functional validation. Programming methods and compilation for embeddable software. Embedded runtime systems. Case studies of real-time software systems. **Prerequisites:** CSE 237A; or basic courses in programming, algorithms and data structures, elementary calculus, discrete math, computer architecture; or consent of instructor.

CSE 237C. Validation and Testing of Embedded Systems (4)
Embedded system building blocks including IP cores. Co-simulation. Formal verification using model checking. Verification environments. Test challenges in core integration: compliance, feature, random, and collision testing. Core access and test integration. Interface-based verification and standards. **Prerequisites:** CSE 237A; or basic courses in algorithms and data structures, elementary calculus, discrete math, symbolic logic, computer architecture; or consent of instructor.

CSE 237D. Design Automation and Prototyping for Embedded Systems (4)
System representation and modeling. Abstract and language models. Simulation as a modeling activity. Computational and hw/sw system prototypes. System analysis using models. Constraint and interface modeling. Behavioral compilation and synthesis. **Prerequisites:** CSE 237A; or basic courses in digital logic design, algorithms and data structures, elementary calculus, discrete math, symbolic logic, computer architecture; or consent of instructor.

CSE 239A. Topics/Seminar in Databases (1–4)
Discussion on problems of current research interest in databases. Possible areas of focus include: core database issues, data management on the Web, data integration, new database models and applications, formal methods in databases. Topics to be presented by faculty and students under faculty direction. Topics vary from quarter to quarter. May be repeated for credit. **Prerequisite:** consent of instructor.

CSE 240. Principles in Computer Architecture I (4)
Renumbered to CSE 240A (see below).

CSE 240A. Principles of Computer Architecture (4)
(Formerly CSE 240.) This course will cover fundamental concepts in computer architecture. Topics include instruction set architecture, pipelining, pipeline hazards, bypassing, dynamic scheduling, branch prediction, superscalar issue, memory-hierarchy design, advanced cache architectures, and multiprocessor architecture issues. **Prerequisite:** CSE 141 or consent of instructor.

CSE 240B. Parallel Computer Architecture (4)
This course covers advanced topics in parallel computer architecture, including on-chip and off-chip interconnection networks, cache coherence, cache consistency, hardware multithreading, multi-core and tiled architectures. It incorporates the latest research and development on parallel architectures and compilation techniques for those architectures. CSE 240A recommended. **Prerequisite:** graduate standing.

CSE 240C. Advanced Microarchitecture (4)
This course covers advanced topics in computer architecture. It incorporates the latest research and development on topics such as branch prediction, instruction-level parallelism, cache hierarchy design, speculative multithreading, reliable architectures, and power-management techniques. CSE 240A recommended. **Prerequisite:** graduate standing.

CSE 240D. Application Specific Processors (4)
This course covers advanced topics in design concepts and implementation principles of application specific processors, including embedded system design principles and application specific processors, application specific instruction set processors, domain specific processor architectures, embedded memories and dynamically customizable processors. CSE 240A recommended. **Prerequisite:** graduate standing.

CSE 241A/ECE 260B. VLSI Integration of Computing Circuitry (4)
VLSI integrated-circuit building blocks of computing systems, and their implementation. Computer-aided design and performance simulations, design exercises and projects. Devices, standard cells and interconnects, clocking, power/ground distribution, arithmetic modules, memories. Methodologies and tradeoffs in system implementation. **Prerequisites:** layout (CSE 165 or ECE 260A) and logic design (CSE 140 or ECE 111), or consent of instructor.

CSE 242A. Integrated Circuit Layout Automation (4)
Couplings among timing, circuits and spatial embedding in nanometer-scale CMOS design. The role, and key problems, of physical layout in IC implementation. Example topics: RTL-to-GDSII methodologies, analyses and estimations, partitioning, floor planning, placement, routing, special net routing, cell generation, compaction. **Prerequisite:** CSE 241A or consent of instructor.

CSE 243A. Introduction to Synthesis Methodologies in VLSI CAD (4)
Hardware software co-design, architectural level synthesis, control synthesis and optimization, scheduling, binding, register and bus sharing, interconnect design, module selection, combinational logic optimization, state minimization, state encoding, and retiming. **Prerequisite:** CSE 241A or consent of instructor.

CSE 244A. VLSI Test (4)
Design for test, testing economics, defects, failures and faults, fault models, fault simulation, automatic test pattern generation, functional testing, memory, PLA, FPGA, microprocessor test, and fault diagnosis. **Prerequisite:** CSE 241A or consent of instructor.

CSE 244B. Testable and Fault Tolerant Hardware Design (4)
Scan path design, BIST architectures, test point insertion, self-checking circuits, test and fault tolerance in architectural synthesis, reconfigurable fault tolerant hardware, and SOC test design. **Prerequisite:** CSE 244A or consent of instructor.

CSE 245. Computer Aided Circuit Simulation and Verification (4)
This course is about the computer algorithms, techniques, and theory used in the simulation and verification of electrical circuits. **Prerequisite:** CSE 241A or consent of instructor.

CSE 246. Computer Arithmetic Algorithms and Hardware Design (4)
Number representation, fixed point adders, subtracters, and multipliers; modified booth's recoding, high-radix multiplication, (non)restoring dividers, SRT division, high-radix dividers, division by convergence, square-rooting, floating point arithmetic, rounding schemes, errors and error control, and floating point adders, subtracters, multipliers, dividers. **Prerequisite:** CSE 241A or consent of instructor.

CSE 247. Application Specific and Reconfigurable Computer Architecture (4)
This course covers architecture concepts used to tailor processors to a specific application or sets of applications. It covers Field-Programmable Gate Arrays (FPGAs), various forms of Application Specific Integrated Circuit (ASIC) designs, Application Specific Integrated Processors (ASIP), and augmenting customizable VHDL cores. **Prerequisite:** CSE 241A or consent of instructor.

CSE 248. Algorithmic and Optimization Foundations for VLSI CAD (4)
Algorithmic techniques and optimization frameworks for large-scale, difficult optimizations. Primal-dual multicommodity flow approximations, approximations for geometric and graph Steiner formulations, continuous placement optimization, heuristics for Boolean satisfiability, multilevel methods, semidefinite programming, and application to other formulations (e.g., scheduling). **Prerequisites:** CSE 241A or CSE 242A or consent of instructor.

CSE 249A. Topics/Seminar in Computer Architecture (1–4)
Topics of special interest in computer architecture to be presented by faculty and students under faculty direction. Topics vary from quarter to quarter. May be repeated for credit. **Prerequisite:** consent of instructor.

CSE 249B. Topics/Seminar in VLSI (1–4)
Topics of special interest in VLSI to be presented by faculty and students under faculty direction. Topics vary from quarter to quarter. May be repeated for credit. **Prerequisite:** consent of instructor.

CSE 249C. Topics/Seminar in CAD (1–4)
Topics of special interest in CAD to be presented by faculty and students under faculty direction. Topics vary from quarter to quarter. May be repeated for credit. **Prerequisite:** consent of instructor.

CSE 250A. Artificial Intelligence: Search and Reasoning (4)
Heuristic search algorithms including A*, constraint satisfaction algorithms including DPLL, randomized search, knowledge representation in first-order logic (FOL), resolution methods for reasoning in FOL, reasoning about action and planning, reasoning with Bayesian networks. CSE 101 recommended. **Prerequisite:** graduate standing in CSE or consent of instructor.

CSE 250B. Artificial Intelligence: Learning (4)
Classifier learning including linear separators, decision trees, and nearest neighbors. Generalization and overfitting; design of learning experiments; the PAC model. Possible topics include ensemble methods, boosting, kernel methods, online learning, and reinforcement learning. **Prerequisite:** graduate standing or consent of instructor.

CSE 252A. Computer Vision I (4)
Comprehensive introduction to computer vision providing broad coverage including low-level vision (image formation, photometry, color, image feature detection), inferring 3-D properties from images (shape-from shading, stereo vision, motion interpretation) and object recognition. Companion to CSE 252B covering complementary topics. **Prerequisites:** Math. 10D and Math. 20A–F or equivalent.

CSE 252B. Computer Vision II (4)
Comprehensive introduction to computer vision providing focused coverage of multiview geometry, structure from motion, image segmentation, motion segmentation, texture analysis and recognition, object detection, and image-based rendering. Companion to CSE 252A covering complementary topics. **Prerequisites:** Math. 10D and Math. 20A–F or equivalent.

CSE 252C. Selected Topics in Vision and Learning (1–4)
Selected topics in computer vision and statistical pattern recognition, with an emphasis on recent developments. Possible topics include: grouping and segmentation, object recognition and tracking, multiple view geometry, kernel-based methods, dimensionality reduction, and mixture models. **Prerequisite:** CSE 252 or equivalent and CSE 250B or equivalent.

CSE 253. Neural Networks for Pattern Recognition (4)
Probability density estimation, perceptrons, multilayer neural networks, radial basis function networks, support vector machines, error functions, data preprocessing. Possible topics include unsupervised learning methods, recurrent networks, and mathematical learning theory. CSE 250B recommended. **Prerequisite:** graduate standing.

CSE 254. Statistical Learning (4)
Learning algorithms based on statistics. Possible topics include minimum-variance unbiased estimators, maximum

likelihood estimation, likelihood ratio tests, resampling methods, linear logistic regression, feature selection, regularization, dimensionality reduction, manifold detection. An upper-division undergraduate course on probability and statistics such as Math. 183 or 186, or any graduate course on statistics, pattern recognition, or machine learning is recommended. **Prerequisite:** graduate standing.

CSE 256/LING 256. Statistical Natural Language Processing (4)
Introduction to modern statistical approaches to natural language processing: part-of-speech tagging, word-sense disambiguation and parsing, using Markov models, hidden Markov models and probabilistic context-free grammars. Recommended **Prerequisite:** one of LIGN 165, LIGN 245, CSE 151, CSE 250A, CSE 254. **Prerequisite:** graduate standing or consent of instructor.

CSE 257. Computational Biology (4)
Computational methods are indispensable to an understanding of the vast datasets emerging from human and other organisms' genomes. This course surveys algorithms underlying genome analysis, sequence alignment, phylogenetic trees, protein folding, gene expression, metabolic pathways, and biological knowledge base design. **Prerequisite:** Pharm. 201 or consent of instructor.

CSE 257B. Algorithms in Computational Biology (4)
Renumbered to CSE 206B (see above).

CSE 258A. Cognitive Modeling (4)
Connectionist models and a sampling of other cognitive modeling techniques. Models of language processing, memory, sequential processes, and vision. Areas covered may vary depending on student and faculty interests. Can be repeated for credit. CSE 151 or CSE 250B or CSE 253 or CSE 254, or equivalent experience recommended. **Prerequisite:** graduate standing.

CSE 259. Seminar in Artificial Intelligence (1)
A weekly meeting featuring local (and occasional external) speakers discussing their current research in Artificial Intelligence Neural Networks, and Genetic Algorithms. (S/U grades only.) **Prerequisite:** none.

CSE 259C. Topics/Seminar in Machine Learning (1–4)
Topics of special interest in machine learning to be presented by faculty and students under faculty direction. Topics vary from quarter to quarter. May be repeated for credit. **Prerequisite:** consent of instructor.

CSE 260. Parallel Computation (4)
(Formerly CSE 274A.) This course provides an overview of parallel hardware, algorithms, models, and software. Topics include Flynn's taxonomy, interconnection networks, memory organization, a survey of commercially available multiprocessors, parallel algorithm paradigms and complexity criteria, parallel programming environments and tools for parallel debugging, language specification, mapping, performance, etc. **Prerequisite:** graduate standing or consent of instructor.

CSE 262. System Support for Applications of Parallel Computation (4)
This course will explore design of software support for applications of parallel computation. Topics include: programming languages, run time support, portability, and load balancing. The course will terminate in a project. **Prerequisite:** consent of instructor.

CSE 271. User Interface Design: Social and Technical Issues (4)
Web technologies (HTML, Java, JavaScript, etc.) can quickly build superb new systems, as well as phenomenally ugly systems that still fully meet their performance and functional requirements. This course explores interface usability and representation issues, with some focus on hypermedia and cooperative work. **Prerequisites:** CSE 20, CSE 100, or equivalent.

CSE 272. Advanced Image Synthesis (4)
Computer graphics techniques for creating realistic images. Topics include ray tracing, global illumination, subsurface scattering, and participating media. CSE 168 or equivalent recommended.

CSE 274. Selected Topics in Graphics (2–4)
Selected topics in computer graphics, with an emphasis on recent developments. Possible topics include computer animation, shape modeling and analysis, image synthesis, appearance modeling, and real-time rendering. CSE 168 or CSE 169 recommended. **Prerequisite:** graduate standing or consent of instructor.

CSE 280A. Algorithms in Computational Biology (4)
(Formerly CSE 206B.) The course focuses on algorithmic aspects of modern bioinformatics and covers the following topics: computational gene hunting, sequencing, DNA arrays, sequence comparison, pattern discovery in DNA, genome rearrangements, molecular evolution, computational proteomics, and others. **Prerequisite:** CSE 202 preferred or consent of instructor.

CSE 280B. Advanced Topics in Computational Biology (4)
The advanced topics include, but are not limited to: population genetics, pathways, RNA, database filtering, comparative genomics, and others. Students are expected to pick one of the topics for an intensive research project, and report on their findings at the end of the class. **Prerequisites:** CSE 280A preferred or consent of instructor.

CSE 282/BENG 202. Bioinformatics II: Sequence and Structure Analysis—Methods and Applications (4)
(Formerly CSE 257A/BENG 202.) Introduction to methods for sequence analysis. Applications to genome and proteome sequences. Protein structure, sequence-structure analysis. **Prerequisite:** Pharm. 201 or consent of instructor.

CSE 283/BENG 203. Bioinformatics III: Functional Genomics (4)
Annotating genomes, characterizing functional genes, profiling, reconstructing pathways. **Prerequisites:** Pharm. 201, BENG 202/CSE 282 or consent of instructor.

CSE 290. Seminar in Computer Science and Engineering (1–4)
(Formerly CSE 280A.) A seminar course in which topics of special interest in computer science and engineering will be presented by staff members and graduate students under faculty direction. Topics vary from quarter to quarter. May be repeated for credit. (S/U grades only.) **Prerequisite:** consent of instructor. (Offered as faculty resources permit.)

CSE 291. Topics in Computer Science and Engineering (1–8)
(Formerly CSE 281A). Topics of interest in computer science and engineering. Topics may vary from quarter to quarter. May be repeated for credit with the consent of instructor. (S/U grades permitted.) **Prerequisite:** consent of instructor. (Offered as faculty resources permit.)

CSE 292. Faculty Research Seminar (1)
(Formerly CSE 282.) Computer science and engineering faculty will present one hour seminars of the current research work in their areas of interest. **Prerequisite:** CSE graduate status.

CSE 293. Special Project in Computer Science and Engineering (1–12)
The student will conceive, design, and execute a project in computer science under the direction of a faculty member. The project will typically include a large programming or hardware design task, but other types of projects are possible. **Prerequisites:** CSE graduate student status. (CS 75, 76, 77, 78, 79, 80, 81) (S/U grades only.)

CSE 294. Research Meeting in CSE (2)
Advanced study and analysis of active research in computer science and computer engineering. Discussion of current research and literature in the research specialty of the staff member teaching the course. **Prerequisite:** consent of instructor.

CSE 298. Independent Study (1–16)
Open to properly qualified graduate students who wish to pursue a problem through advanced study under the direction of a member of the staff. (S/U grades only.) **Prerequisite:** consent of instructor.

CSE 299. Research (1–16)
Research. **Prerequisite:** consent of faculty.

CSE 500. Teaching Assistantship (2–4)
A course in which teaching assistants are aided in learning proper teaching methods by means of supervision of their work by the faculty: handling of discussions, preparation and grading of examinations and other written exercises, and student relations. May be used to meet teaching experience requirement for candidates for the Ph.D. degree. Number of units for credit depends on number of hours devoted to class or section assistance. **Prerequisites:** graduate standing and consent of instructor.

CSE 501. Teaching Assistantship (2–4)
Renumbered to CSE 500 (see above).

CSE 599. Teaching Methods in Computer Science (2)
Training in teaching methods in the field of computer science. This course examines theoretical and practical communication and teaching techniques particularly appropriate to computer science. **Prerequisite:** consent of faculty.