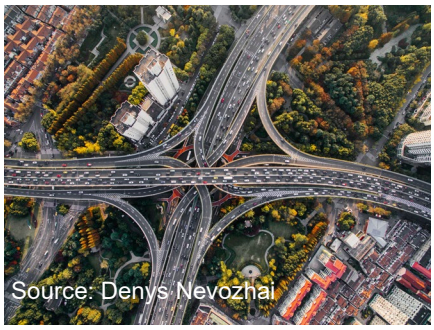
McGill

Bioresource Engineering

Course Outline



BREE 505

Course Title: **Sustainable Urban Metabolism**

Credits: **3**

Course Prerequisite(s): **BREE 420**

Course Corequisite (s): **NA**

Course Description: Urban metabolism is a metaphor for the churn of material and energy flows within and across urban boundaries. These flows influence environmental conditions inside and outside the city and lead to unequal access to resources and exposure to pollution. This course teaches students how to quantify and map the stocks and flows of energy and materials in cities. Students will use quantitative sustainability methods – Material Flow Analysis, Life-Cycle Assessment, Carbon Footprint – to estimate the environmental impacts of the urban metabolism. Solutions inspired by bioresource engineering, circular economics, and allied fields will be proposed and tested to promote more sustainable cities via a group project on a case city.

Lectures: **xxxx yyy – yyy (1.5 hrs)**
Xxxx yyy – yyy (1.5 hrs)

Tutorials: **xxxx yyy – yyy (2 hrs)**

Instructor: **Assistant Prof. Benjamin P. Goldstein**
(T: (514) 398-7809 E: ben.goldstein@mcgill.ca O: MS1-93)

Add/drop Deadline: January xx, 2024
(Course/University withdrawal (i) with refund: September 21, 2021;
(ii) Without refund: October 26, 2021)

Holiday: Easter, yyy
Winter Reading Break, yyy

Access to Instructor and Teaching assistant:

Prof. Goldstein (Instructor):	**TBD (MS1-093)** (*Student may request meetings in another time if the office hours conflicts with other courses)
TA: TBD	TBD

Course delivery Mode:

Course materials will be offered in person based on the course schedule. Some sessions will consist entirely of lectures and discussions. Other sessions will be a blend of lectures and tutorials. More details in the course schedule. A typical week consists of the following:

Lecture 1: Background on aspect of urban metabolism (e.g., transport), relation to bioresources and urban sustainability (e.g., fossil fuels, biofuels, agricultural land use), and solutions.

Lecture 2: Frameworks and methods for modeling this aspect of the urban metabolism.

Tutorial: Guided tutorial on python/QGIS in the context of modeling the metabolism of a case city.

Learning Outcomes:

By the end of this course, students should be able to

1. Understand the multi-scalar environmental impacts of cities to connect urban processes to environmental change at local, regional, and global scales.
    a. [CEAB Attribute: IE. 3 - Conducts social and/or environmental impact analyses]
2. Apply computational methods and spatial analysis to a variety of data forms to measure and map the urban metabolism.
    a. [CEAB Attribute: IN.1 - Conducts planned activities (literature review, experiments, measurements, laboratories, etc.) and analyzes data; ET.1 Selects and uses tools]
3. Imagine alternative urban futures to propose novel, place-based interventions for healthy, livable, urban communities.
    a. [CEAB Attribute: DE.3 - Researches and develops possible solutions to a complex engineering problem and recommends a final design]
4. Appreciate a plurality of perspectives, forms of knowledge, and lived experiences when considering how to tackle wicked problems of urban sustainability.
    a. [CEAB Attribute: IE. 3 - Conducts social and/or environmental impact analyses]
5. Recognize how local context constrains urban design as a way to design workable solutions to urban sustainability challenges.
    a. [CEAB Attribute: DE.3 - Researches and develops possible solutions to a complex engineering problem and recommends a final design]

Course Administration

Mycourses (webct Vista) will be used in this course. Please make sure that you are familiar with mycourses (webct), and that you can log-in and download materials (lectures, assignments, quizzes, practice exams, Zoom links for lectures, and recorded videos of each lecture and tutorial session) from the course related documents.

ITEM	CONTRIBUTION
Quizzes: Four (4) quizzes covering tutorial material. **[CEAB Attributes Assessed: IN.1, ET.1, IE.3]**	**5%**
Midterm: Focusing on the theory and methods of urban sustainability. **[CEAB Attributes Assessed: IN.1, ET.1, IE.3]**	**25%**
Group Project (3-5 students): Group project studying one metabolic aspect (e.g. Building energy, construction materials, etc.) of a case city. Groups must research the development of their metabolic aspect in their case city to provide historical context to their case study. Groups most both quantify and spatialize the stocks and flows of their metabolic aspect, and include one metric of environmental sustainability in their analysis. Groups must propose an engineering solution to reduce the environmental footprint of their metabolic aspect. **[CEAB Attributes Assessed: IN.1, ET.1, IE.3, DE.1]** **Note: More details in the group project outline.**	**40%**
Individual Paper: Pick an urban sustainability issue in your hometown (or another city you have lived in) and research how it relates to the urban metabolism of that city. Write up your findings in a report with a clearly defined Introduction, Literature Review, and cogent Discussion. **[CEAB Attributes Assessed: IN.1, IE.3]**	**20%**
Multimedia Reflection: Students select a relevant topic and learn about the topic using non-traditionally academic formats (i.e. podcasts, blog posts, etc.) Students then write a short reflection (approx.. 500 words) on the topic and how it relates to urban metabolism. Reflections will be assessed on completion, content, and correct formatting. Students should come to class prepared to discuss their topic and reflection points. **[CEAB Attributes Assessed: IN.1, IE.3]** **Note: More details given in class.**	**5%**
Tutorial Submission: Hand in completed tutorial reports as assigned (total of 7) with brief write up of methods and findings (300 words). **[CEAB Attributes Assessed: IN.1, IE.3]** **Note: More details given in class.**	**5%**

It is the responsibility of Students to exercise due diligence in familiarizing themselves with: (i) requirements of the Assessments to which they will be subjected in their Courses; (ii) the due date of Assessments; (iii) the date, time and location of their examinations; (iv) the regulatory framework governing: (a) academic integrity; (b) the conduct of examinations; (c) the format and substance of written forms of Assessment; (d) circumstances that would permit Reasonable Accommodation.

TEXT: No textbook for the course. Weekly readings will be posted to myCourses. Reading list provided below.

Software: At least one person in each group will require access to working laptop computer that can run Python, PyCharm, and Quantum Geographic Information System (QGIS).

Canadian Engineering Accreditation Board (CEAB) Curriculum Content

CEAB curriculum Category content	Number of AU's	Description
Mathematics		Mathematics include appropriate elements of linear algebra, differential and integral calculus, differential equations, probability, statistics, numerical analysis, and discrete mathematics.
Natural sciences		Natural sciences include elements of physics and chemistry, as well as life sciences and earth sciences. These subjects are intended to impart an understanding of natural phenomena and relationships through the use of analytical and/or experimental techniques.
Engineering Science	**10**	Engineering science subjects involve the application of mathematics and natural science to practical problems. They may involve the development of mathematical or numerical techniques, modeling, simulation, and experimental procedures. Such subjects include, among others, the applied aspects of strength of materials, fluid mechanics, thermodynamics, electrical and electronic circuits, soil mechanics, automatic control, aerodynamics, transport phenomena, and elements of materials science, geoscience, computer science, and environmental science.
Engineering Design	**15**	Engineering design integrates mathematics, natural sciences, engineering sciences, and complementary studies in order to develop elements, systems, and processes to meet specific needs. It is a creative, iterative, and open-ended process, subject to constraints which may be governed by standards or legislation to varying degrees depending upon the discipline. These constraints may also relate to economic, health, safety, environmental, societal or other interdisciplinary factors.
Complementary Studies	**15**	Complementary studies include the following areas of study to complement the technical content of the curriculum: humanities, social sciences, arts, management, engineering economics and communications. Some areas of study are essential in the education of an engineer. Accordingly, the curriculum must include studies in the following: Engineering economics; the impact of technology on society; Subject matter that deals with central issues, methodologies, and thought processes of the humanities and social sciences; oral and written communications; healthy and safety; professional ethics, equity and law; sustainable development and environmental stewardship.

Accreditation units (AU's) are defined on an hourly basis for an activity which is granted academic credit and for which the associated number of hours corresponds to the actual contact time: one hour of lecture (corresponding to 50 minutes of activity) = 1 AU; one hour of laboratory or scheduled tutorial = 0.5 AU. Classes of other than the nominal 50-minute duration are treated proportionally. In assessing the time assigned to determine the AU's of various components of the curriculum, the actual instruction time, exclusive of final examinations, is used.

*2013 CEAB Accreditation Criteria and Procedures

CEAB Graduating Student Attributes

This course contributes to the obtaining of the following CEAB Graduating Student Attributes:

Attribute	KB	PA	**IN** (IN.1)	**DE** (DE.1)	**ET** (ET.1)	IT	CS	PR	**IE** (IE.3)	EE	EP	LL
Level obtained: I – introduced D – developed A - applied	-	-	**A**	**A**	**A**	-	-	-	**A**	-	-	-

*2017 CEAB Accreditation Criteria and Procedures

KB *A knowledge base for engineering: Demonstrated competence in university level mathematics, natural sciences, engineering fundamentals, and specialized engineering knowledge appropriate to the program.*

PA *Problem analysis: An ability to use appropriate knowledge and skills to identify, formulate, analyze, and solve complex engineering problems in order to reach substantiated conclusions.*

IN ***Investigation: An ability to conduct investigations of complex problems by methods that include appropriate experiments, analysis and interpretation of data, and synthesis of information in order to reach valid conclusions.***

IN.1 - Conducts planned activities (literature review, experiments, measurements, laboratories, etc.) and analyzes data

DE **Design*: An ability to design solutions for complex, open-ended engineering problems and to design systems, components or processes that meet specified needs with appropriate attention to health and safety risks, applicable standards, and economic, environmental, cultural and societal considerations.***

DE.3 - Researches and develops possible solutions to a complex engineering problem and recommends a final design

ET ***Use of engineering tools: An ability to create, select, apply, adapt, and extend appropriate techniques, resources, and modern engineering tools to a range of engineering activities, from simple to complex, with an understanding of the associated limitations***

ET.1 - Selects and uses tools

IT *Individual and team work: An ability to work effectively as a member and leader in teams, preferably in a multi-disciplinary setting.*

CS *Communication skills: An ability to communicate complex engineering concepts within the profession and with society at large. Such ability includes reading, writing, speaking and listening, and the ability to comprehend and write effective reports and design documentation, and to give and effectively respond to clear instructions.*

PR *Professionalism: An understanding of the roles and responsibilities of the professional engineer in society, especially the primary role of protection of the public and the public interest.*

IE ***Impact of engineering on society and the environment: An ability to analyse social and environmental aspects of engineering activities. Such abilities include an understanding of the interactions that engineering has with the economic, social, health, safety, legal, and cultural aspects of society, the uncertainties in the prediction of such interactions; and the concepts of sustainable design and development and environmental stewardship.***

IE.3 - Conducts social and/or environmental impact analyses

EE *Ethics and equity: An ability to apply professional ethics, accountability, and equity.*

EP *Economics and project management: An ability to appropriately incorporate economics and business practices including project, risk, and change management into the practice of engineering and to understand their limitations.*

LL *Life-long learning: An ability to identify and to address their own educational needs in a changing world in ways sufficient to maintain their competence and contribute to the advancement of knowledge.*

Policies

Copyright:

Please note that the format for the delivery of this course is unusual. It is justified by our current extraordinary circumstances, and aims to allow you, as students, to start and complete this term with the requisite knowledge for this course, and to succeed in your assessments. ***I ask for everyone's collaboration and cooperation in ensuring that course materials prepared explicitly for this course (lecture notes, ppts, videos, etc) are not reproduced or placed in the public domain.*** *This means that each of you can use it for your own personal purposes, but you cannot allow others to use it, by putting it up on the internet or by giving it or selling it to others who will copy it and make it available. Thank you for your collaboration.*

Academic Integrity:

Mcgill University values academic integrity. Therefore, all students must understand the meaning and consequences of' cheating, plagiarism and other academic offences under the Code of Student Conduct and Disciplinary Procedures (see for more information).

L'université mcgill attache une haute importance à l'honnêteté académique. Il incombe par conséquent à tous les étudiants de comprendre ce que l'on entend par tricherie, plagiat et autres infractions académiques, ainsi que les conséquences que peuvent avoir de telles actions, selon le Code de conduite de l'étudiant et des procédures disciplinaires.

Available at: www.mcgill.ca/students/srr/honest

Language:

In accord with mcgill University's Charter of Students' Rights, students in this course have the right to submit in English or in French any written work that is to be graded. (Approved by Senate on 21 January 2009).

Extraordinary Circumstances:

In the event of extraordinary circumstances beyond the University's control, the content and/or evaluation scheme in this course is subject to change.

Grading:

Courses can be graded either by letter grades or in percentages, but the official grade in each course is the letter grade. Where appropriate, a class average appears on transcripts expressed as the letter grade most representative of the class performance. Since fall 2002, the University has only used letter grades on transcripts and verification forms.

Graduate students									
Grade	A	A-	B+	B	B-	F (Fail)			
Grade points	4.0	3.7	3.3	3.0	2.7	0			
Undergraduate students									
Grade	A	A-	B+	B	B-	C+	C	D	F (Fail)
Grade points	4.0	3.7	3.3	3.0	2.7	2.3	2.0	1.0	0
Numeric scale grade	85% – 100%	80% – 84%	75% – 79%	70% – 74%	65% – 69%	60% – 64%	55% – 59%	50% – 54%	0% – 49%

Course Schedule: Sustainable Urban Metabolism

A = assignment; L = lecture; P = project; T = tutorial

Week	Date	Activity	Activity	Readings	Deliverables/Outcomes
0		L0	Course Introduction	-	
1		L1	Cities and the Environment	Seto et al. (2012) UN-Habitat (2016)	-
		L2	Cities and Bioresources		
		T1	Intro to Python and PyCharm	-	Install Python and PyCharm on your computer
2		L3	Urban Metabolism I	Kennedy et al. (2007) Wolman (1965)	-
		L4	Urban Metabolism II	Heynen et al. (2006) Grimm et al. (2008)	
		T2	Variables and Data Structures		Assign variables and use different data structures in Python
		P1	Group Formation	-	Submit group form
3		L5	Cities as Systems	Bettencourt and West (2010) Sampson (2016)	-
		L6	Material Flow Analysis	Kennedy et al. (2014)	
		T3	Importing Data into Python		Import .csv and .txt formats into python. Access and view imported data.
		P2	Project Proposal Due		2-page project proposal due: Outlines city and stock/flow
4		L7	Life Cycle Assessment	Goldstein et al. (2013) Dorr et al. (2022)	

		L8	The Environmental Footprint Family: Carbon, Ecological, Water, Nutrient	Moran et al. (2018) Ramaswami et al. (2021)	
		T4	Loops and Boolean Logic		Use loops, while statements, and Boolean logic to manipulate data in Python.
5		L9	Spatializing Urban Metabolism I	Goldstein (2017)	
		L10	Spatializing the Urban Metabolism II	Horta and Keirsted (2018) Codoban and Kennedy (2008)	
		T5	Functions in Python		Create functions in Python
6		L11	Midterm Review		
		M1	Midterm 1		Covers Weeks 1-5
		T5	Group Work		
7		L12	Urban Energy Use I	Grubler et al. (2012)	
		L13	Urban Energy Use II	Goldstein et al. (2020)	
		T6	Intro to QGIS		Install QGIS and import/view vector and raster data
8		L14	Urban Food Systems I	Seto and Ramankutty (2016) McClintock (2010)	
		L15	Urban Food Systems II	Goldstein et al. (2015)	
		T7	Data manipulation in QGIS		Spatialize metabolism data, create new layers in QGIS, and export data
9		L16	Urban Form and Mobility I	IPCC (2022)	
		L17	Urban Form and Mobility II	Jones and Kammen (2014) Creutzig et al. (2015)	
		T8	Group Work		Groups work on projects
		A1	Individual Assignment Due		Submit individual assignment
10		L18	Urban Material Stocks I	Lanau and Liu (2020)	
		L19	Urban Material Stocks II	Arbabi et al. (2022)	
		P2	Project Presentation 1		Present preliminary results for your city and flow
11		L20	Modeling Sustainable Urban Futures I	Goldstein et al. (2017)	

		L21	Modeling Sustainable Urban Futures II	Goldstein et al. (2020)	
		T9	Scenarios of Urban Futures		Simple dynamic models of cities: Modeling urban agriculture potential in Boston
12		L22	Sustainable Urban Futures I	Ramaswami et al. (2016) IPCC (2022)	
		L23	Sustainable Urban Futures II	McDonnell and Macgregor-Fors (2016)	
		T10	Group Work		Groups work on projects
13		L24	Project Presentations		Final Presentations of Projects
		L25	Project Presentations		Final Presentations of Projects
		P4	Project Repot Due		Submit final report

***** Schedule can change. Changes will be communicated via email or through announcements on mycourses

****** Date refers to the submission deadline for assignments and project or the test date for quizzes and exams.

Readings

Week 1

K. C. Seto, A. Reenberg, C. G. Boone, M. Fragkias, D. Haase, T. Langanke, P. Marcotullio, D. K. Munroe, B. Olah, D. Simon, Urban land teleconnections and sustainability. *Proc. Natl. Acad. Sci. U. S. A.* **109**, 7687–7692 (2012).

UN-Habitat. (2016). *Chapter 5. "Just" Environmental Sustainabilities* in World Cities Report. United Nations Human Settlements Programme.

Week 2

Wolman, Abel. "The metabolism of cities." *Scientific American*213.3 (1965): 178-193.

Kennedy, C., Cuddihy, J., & Engel-Yan, J. (2007). The changing metabolism of cities. *Journal of Industrial Ecology*, 11(2), pp. 43-59.

Heynen, N. C., Kaika, M., & Swyngedouw, E. (2006). Urban political ecology: Politicizing the production of urban natures. In *In the Nature of Cities: Urban Political Ecology and the Politics of Urban Metabolism* (1st ed., pp. 1–20). Routledge.

Grimm, N. B., Faeth, S. H., Golubiewski, N. E., Redman, C. L., Wu, J., Bai, X., & Briggs, J. M. (2008). Global change and the ecology of cities. *Science*, 319(5864), 756

Week 3

Bettencourt, Luis, and Geoffrey West. "A unified theory of urban living." *Nature* 467.7318 (2010): 912-913.

Sampson, Robert J. "Urban sustainability in an age of enduring inequalities: Advancing theory and ecometrics for the 21st-century city." *Proceedings of the national academy of sciences* 114.34 (2017): 8957-8962

Kennedy, Christopher, Larry Baker, and Helge Brattebø. "Analyzing a city's metabolism." *Elgar*

Companion to Sustainable Cities. Edward Elgar Publishing, 2014.

Week 4
Goldstein, Benjamin, et al. "Quantification of urban metabolism through coupling with the life cycle assessment framework: concept development and case study." *Environmental Research Letters* 8.3 (2013): 035024

Dorr, Erica, et al. "A life cycle assessment method to support cities in their climate change mitigation strategies." *Sustainable Cities and Society* 85 (2022): 104052.

Moran, Daniel, et al. "Carbon footprints of 13 000 cities." *Environmental Research Letters* 13.6 (2018): 064041.

Ramaswami, Anu, et al. "Carbon analytics for net-zero emissions sustainable cities." *Nature Sustainability* 4.6 (2021): 460-463.

Week 5
Goldstein, Benjamin. "Geographically Explicit Urban Metabolism." Unpublished. (2017)

Horta, Isabel M., and James Keirstead. "Downscaling aggregate urban metabolism accounts to local districts." *Journal of Industrial Ecology* 21.2 (2017): 294-306.

Codoban, Natalia, and Christopher A. Kennedy. "Metabolism of neighborhoods." *Journal of urban planning and development* 134.1 (2008): 21-31.

Week 7
Grubler, Arnulf, Xuemei Bai, Thomas Buettner, Shobhakar Dhakal, David J. Fisk, Toshiaki Ichinose, James E. Keirstead et al. "Urban energy systems." (2012).

Goldstein, Benjamin, Dimitrios Gounaridis, and Joshua P. Newell. "The carbon footprint of household energy use in the United States." *Proceedings of the National Academy of Sciences* 117.32 (2020): 19122-19130

Week 8
Seto, Karen C., and Navin Ramankutty. "Hidden linkages between urbanization and food systems." *Science* 352.6288 (2016): 943-945

McClintock, Nathan. "Why farm the city? Theorizing urban agriculture through a lens of metabolic rift." *Cambridge journal of regions, Economy and Society* 3.2 (2010): 191-207.

Goldstein, Benjamin, et al. "Surveying the environmental footprint of urban food consumption." *Journal of Industrial Ecology* 21.1 (2017): 151-165

Week 9
IPCC 2022: Transport. In IPCC, 2022: *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK and New York, NY, USA. doi: 10.1017/9781009157926.012 **(Sections 10.1 and 10.2)**

Jones, Christopher, and Daniel M. Kammen. "Spatial distribution of US household carbon footprints reveals suburbanization undermines greenhouse gas benefits of urban population density." *Environmental science & technology* 48.2 (2014): 895-902

Creutzig, Felix, et al. "Global typology of urban energy use and potentials for an urbanization mitigation wedge." *Proceedings of the national academy of sciences* 112.20 (2015): 6283-6288

Week 10
Arbabi, Hadi, et al. "A scalable data collection, characterization, and accounting framework for urban material stocks." *Journal of Industrial Ecology* 26.1 (2022): 58-71.

Lanau, Maud, and Gang Liu. "Developing an urban resource cadaster for circular economy: A case of Odense, Denmark." *Environmental science & technology* 54.7 (2020): 4675-4685.

Week 11
Goldstein, Benjamin P., et al. "Contributions of local farming to urban sustainability in the Northeast United States." *Environmental Science & Technology* 51.13 (2017): 7340-7349

Goldstein, Benjamin, Dimitrios Gounaridis, and Joshua P. Newell. "The carbon footprint of household energy use in the United States." *Proceedings of the National Academy of Sciences* 117.32 (2020): 19122-19130

Week 12
Ramaswami, Anu, et al. "Meta-principles for developing smart, sustainable, and healthy cities." *Science* 352.6288 (2016): 940-943

IPCC, 2022: *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK and New York, NY, USA. doi: 10.1017/9781009157926.010 **(Sections 8.3, 8.4, and 8.6)**

McDonnell, Mark J., and Ian MacGregor-Fors. "The ecological future of cities." *Science* 352.6288 (2016): 936-938

Important dates:

Tentative Due Dates and Exam Dates	
Project Proposal	**October 18**, 2021
Midterm	**November 15**, 2021
Individual Paper	
Group Presentation 1	
Group Presentation 2	
Group Project	

Accommodations for missed assessments during the term

Sickness/Illness during the term:
Students currently in the province of Quebec seeking the support of a Local Wellness Advisor (LWA) can now secure an intake appointment by filling out the appropriate webform at http://mcgill.ca/lwa. Because clinical agreements limit our 1:1 sessions to students who are physically located in the province of Quebec at the time of their appointments, we continue to invite all students to refer to http://mcgill.ca/covidsupport for an updated list of virtual support services which they can access from anywhere in the world.

If you need to seek accommodation for in-course assignments, for medical or other health emergencies, please send medical documentation along with the filled out form for medical accommodation (https://www.mcgill.ca/macdonald/studentinfo/undergrads/forms) by email to the

Macdonald Campus Student Affairs Office (meline.chatoyan@mcgill.ca). When approved, the professor(s) will be notified by SAO, by email, to accommodate the student.

Non-medical:
It is at the discretion of the instructor to arrange accommodation for students who have missed in-term exams or due dates for non-medical reasons (e.g. Travel constraints, slept in, etc.). Complicated cases can be directed to SAO.

Religious:
The Policy for the Accommodation of Religious Holy Days (https://www.mcgill.ca/secretariat/files/secretariat/religious_holy_days_policy_on_accomodation_of.pdf) applies to these situations. "Students are not to be penalized if they cannot write examinations or be otherwise evaluated on their religious holy days where such activities conflict with their religious observances."

A student seeking accommodation must contact the instructor **at least 14 days in advance** so that arrangements can be made.

COVID-19 information

Information regarding the prevention of transmission of COVID-19 and the protocols for individuals who may have symptoms can be found here:
Https://www.mcgill.ca/coronavirus/

Resources for remote learning can be found here:
Https://www.mcgill.ca/tls/students/remote-learning-resources