

MICRO 6155: MICROBIAL ECOLOGY & EVOLUTION

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Please **email us through Carmen, and email both of us together when contacting us.**
Office hours are by emailed appointment.

Credit hours: 3. From the Ohio Department of Higher Education guidelines, this equates to ~3 hrs of in-class time each week, and “requires students to work at out-of-class assignments an average of two hours for every hour of formalized instruction”.

Lecture time/location: F 9:30am-12:15pm / 916 Riffe (the 9th floor conference room).

I. Course objective/goals: The course will cover the ecology and evolution of microbes, at a graduate level and focused around key primary literature. We will explore a variety of essential concepts, methods, and ongoing ‘unknowns’ in the field. In this course, the term “microbial” is shorthand for prokaryotes + viruses, but we will briefly introduce microbial eukaryotes through guest lectures as available.

We will cover the following **overarching scientific themes:**

- Microbial ecology: What are the patterns and drivers of microbial communities? How do we grapple with scale, & statistical power? What are approaches to time series analyses, and to multi-disciplinary systems datasets (including WCGNA analyses)? What ‘central dogma’ considerations should inform our interpretation of multi-omic experiments? What are the defining ecological characteristics, at the microbial scale, of oceans, soils, and engineered systems?
- Microbial evolution: How is selection examined in microbes, and what is known about microbial evolutionary rates and processes? How are lineages traced, and their relationships examined?
- Microbial evolution in an ecological context: How can the above concepts be applied in unified systems frameworks, such as for understanding symbioses, or the co-evolution of viruses & microbes, or microbial metabolic hand-offs & their evolution?

The course **learning objectives** for this material are:

- Develop knowledge of foundational concepts and methods in microbial ecology and evolution.
- Explore principles of sound experimental design in these fields.
- Learn how to read, summarize, and critique primary literature in these fields.
- Improve professional communication skills as a scientist: writing & presenting, peer-evaluation of writing & presenting, and leading scientific discussions.

The course learning objectives specifically support these **Microbiology PhD Program learning goals:**

- Broad Knowledge: PhD graduates of Microbiology should be able to demonstrate a broad base of knowledge in several areas.
- In-Depth Knowledge: PhD graduates of Microbiology should be able to demonstrate in-depth in an area of interest. *This course advances this goal for students continuing in these areas of study.*
- Effective Communication. PhD graduates of Microbiology should be able to effectively communicate science through oral and written presentations to both scientific and general audiences.

II. Required materials:

This class is focused around key concepts in Microbial Ecology & Evolution, fields which are continually evolving. Therefore, and as a graduate-level course, we will read primary literature rather than a text book. Readings will be posted on **Carmen**. **You will be expected to access this site regularly in order to prepare for class.** It is your responsibility to turn on your notifications in Carmen so you receive alerts or emails when Announcements are made or assignments are posted.

III. Grading:

(note that the points values of the individual rubrics do *not* reflect the weighting of these graded components)

- A. 20% Weekly write-ups
- B. 10% Peer evaluation of weekly write-ups
- C. 10% Discussion leadership
- D. 40% Presentations (20% for first presentation, 20% for second)
- E. 5% Peer evaluation of presentations
- F. 10% In-class participation in discussions
- G. 5% Learning objectives write-ups

Primary literature discussions are the heart of this course. To support these discussions, there may be mini-lectures by the professors, presentations by students, and at-home viewing and reading assignments, to introduce foundational concepts and methods.

We will read 1-3 papers each week, and some weeks we will view videos or short supplementary writing to support the weekly topic.

A. Weekly write-ups: to synthesize the information in the assigned paper(s), and to practice your scientific writing skills, each week you will produce a short piece of writing with the following structure:

- 1 paragraph summarizing each of the paper(s) (i.e. 1 paragraph per paper). What was the key Q it was addressing and why is it important? What was their experimental design and approach? And what were there key findings?
- A short list of the “muddiest points” – what questions do you have about the paper(s).
- A short list of “axes of connection” to other research or concepts – how does this paper(s) relate to other papers or ideas covered in this course, in your own research, or in other classes, or elsewhere (including mainstream media)?

You will turn these write-ups in on Carmen, and bring 1 printed copy to class.

Weekly Write-ups rubric:

Criteria	Rating			Points (19)
Key Qs stated & concisely contextualized	3: clearly stated goals of all assigned papers and gave quick context	1: mentioned a single goal without context	0: did not describe goals of any of the papers.	/ 3
Experimental approach	3: clearly identified the essential experimental approach of the papers at a summary-level (ie not every step of protocols)	1: just lists some of methods or tools used, without overarching approach.	0: did not describe approach	/ 3
Findings	3: concisely articulated the key findings of the paper	1: states a single finding	0: did not describe findings	/ 3
Quality of writing	2: easy to read, clearly laid out	1: could follow, but there were some confusing sections.	0: poorly crafted, difficult to follow	/ 2
Spelling and grammar	2: no spelling and grammar errors	1: one error	0: more than one error	/ 2
Muddiest points	3: >2 questions identified clearly	1: a single question	0: none provided.	/ 3

Axes of connection	3: >1 axis of connection clearly defined	1: a poorly defined linkage to one other topic.	0: none provided	/ 3
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B. Peer evaluation of weekly write-ups: Assessing our colleagues' work is one of the best ways of improving our own. Each week you will assess a write-up from a different peer, using the same grading rubric as the instructors, and adding 1 sentence per criteria justifying your score. Feel free to add additional editorial comments on the documents, but these are not required nor do they add to your grade. Peer evaluations will be done at home, and are due the following week.

Peer evaluations rubric:

Criteria	Rating			Points (8)
Scored the rubric	1: filled in the rubric		0: did not complete	/ 1
Concisely justified each score.	7: Justified each score in a single clear sentence.	3: Only provided justifying sentences for a subset of the scores, and/or sentences did not actual relate to evaluate of criteria.	0: did not explain scores	/ 7

C. Discussion leadership. You will each sign up to be discussion leader one week, a different week than you are presenting. As discussion leader, you will lead the group through discussion of the papers and will be responsible for an added level of knowledge about the assigned papers (you do *not* need to know every last detail of the coding, statistical methods, etc, or have read all the papers these papers reference, but you do need to know the essential information of the focal discussion paper(s)).

The discussion you lead could include:

1. For the paper(s) themselves:
 - a. overall experimental design
 - b. discussion of methods (which, if they are challenging or less familiar, will likely have been *introduced* by that day's presenter in coordination with you), including the applicability of those methods for the Qs asked
 - c. sequential interpretation of figures as a group
 - d. key results
 - e. whether the results support the author's stated findings
 - f. what the outstanding Qs are about unclear parts of the paper (the 'muddiest points')
 - g. what the next research steps might be
2. For the week's theme / focal Q:
 - a. which previous papers in the semester also relate, and how
 - b. how the papers address the week's theme (what are the emerging principles, key take-homes)
 - c. how the papers fits into the field (some historical context may have been provided by that day's presenter, in coordination with you)
 - d. how the work relates to the various research engaged in by this class group.

Notably, discussion leadership should *not* comprise a lengthy presentation. While it might be necessary to show a few things on the screen, the focus should be squarely on leading a discussion of the papers, a pooling of our collective understanding of them and a collective distillation of the group's concerns about their validity, or insights into their importance, credibility, larger relevance, etc. We might go to the white/chalk board to sketch out experimental designs, or list insights, but these should arise from the group discussion not be prescribed by the leader (though you may have made your own lists of these in advance in order to steward the discussion most effectively and help ensure the group doesn't miss something essential).

It is OK as leader to call on your peers (or instructors) during the discussion especially when looking for insights from their particular areas of knowledge.

Discussion leadership rubric:

Criteria	Rating			Points (10)
	3: Prompted discussion with leading questions, kept 'top-down' description of material to essential background	1: Provided their own interpretations for the majority of the 'discussion' period, showed limited engagement of group	0: used a lecturing approach to cover the material	
Guidance rather than lecturing	3: Covered the key ideas of material (but note, it's OK if sometimes the discussion of a single paper is so engaged that you have less time for the other(s))	1: Skipped over key concepts of a paper (without being time constrained), or didn't give peers a chance to discuss their 'muddiest points'	0: Did not cover essentials of paper(s)	/ 3
Thoroughness of scope	3: Clear knowledge of essential details of paper(s)	1: Notable gaps in understanding of elements of paper(s)	0: Lack of understanding of paper(s)	/ 3
Knowledge of material	1: Minimal 'ums', encouraging tone and facial expressions to help promote discussion		0: No eye contact, flat tone of voice, many 'ums', etc.	/ 1
Style: Verbal & physical bearing and rapport with group				

D. Presentations. You will give 2 presentations during the semester. Presentations will be 15-20 minutes, with open question and discussion time afterwards.

A. You will sign up to present material related to the weekly topics. The goal of your presentation will be to deliver a primer on background to the assigned topic to your peers (this could include key terminology, methods, background/history, concepts). These will directly feed into improved paper discussions, but are distinct from the discussion leader's role of guiding the group through a discussion of the actual papers. You are required to meet with that week's discussion leader to coordinate and review your material. You are encouraged but not required to send the instructors your slides the week before your presentation to receive feedback.

B. The last day of class, everyone will present on a topic and associated paper of their choosing within the overarching theme of Microbial Ecology and Evolution.

Presentation rubric:

Criteria					Points (60)
Content	A	B	C/D	F	35
Organization	Organization clear from the start, & followed	Organization presented and mostly adhered to	Organization inconsistent	Disorganized	/ 8
Concept conveyance	Concepts are clearly conveyed, with succinct explanations, appropriate examples, and informative visual aids	Concepts presented but some are unclear	Concepts periodically murky; key concepts missing	No key concepts covered	/ 8
Accuracy	The information presented is correct	The information is mostly correct with only minor inaccuracies	One appreciable inaccurate	Rampant inaccuracies	/ 8
Referencing	Literature & knowledge sources referenced	Knowledge mostly referenced	Some important key ideas stated as 'known facts' without attribution	No referencing	/ 4
Timeliness	Talk fit within allotted timeframe	Talk was <2" over	Talk <5" over	Talk >5" over	/ 2
Q & A	Qs addressed with thought, some known answers, and engaged group brainstorming when answers not known	Qs addressed thoughtfully	Poor handling of Qs without known As	Qs addressed blankly	/ 5
Slides					15
Style	Slides uncluttered, easy to follow	Slides mostly clear	Difficult to follow, e.g. from excessive text, variable fonts, use of illegible tables	Slides impossible to follow	/ 10

Source attribution	Graphics consistently attributed to their source	Graphics almost always sourced.	Some graphics sourced.	No sources	/5
Speaking style					10
Physically	Professional bearing, no nail-biting, swaying, etc	A few fidgety moments	Periodic fidgets but generally stable	Excessive fidgety movement	/3
Verbally	(after the first 5"☺) Minimal 'ums', cogent verbiage, content matches slide content	Generally smooth delivery, a few rough spots	Periodically distracted; reads from notes	Frequently loses place; verbiage does not match slides	/5
Rapport	Maintains eye contact, "presence" in the space, facial expressions, use of laser pointer to help guide audience	Generally engaged with audience	Spends long periods with back to audience looking at slides; spends long periods looking down or out of window, or with eyes closed	No eye contact	/2

E. Peer evaluations of presentations. You will evaluate your peers' presentations using an in-class evaluation sheet based on the above rubric, and with time to write down comments about their performance. Full completion of the evaluation sheet, with comments, will earn full credit; partial completion partial credit; no completion will get zero credit.

F. Participation. Show up on time and prepared, and participate in class. Because these are discussions, **it is OK if you dislike speaking up with answers, or feel you know less than the rest of the class - you can still participate, by bringing your pithy questions to the group.**

	A	B	C/D	F
Preparation	Arrives on time fully prepared at every class session	Arrives mostly, if not fully, prepared (ongoing)	Inconsistent preparation	Rarely or never prepared
Participation	Plays an active role in discussions (ongoing)	Participates constructively in discussions (ongoing)	When prepared, participates constructively in discussions	Comments vague if given; frequently demonstrates lack of interest
Contribution to Class	Comments advance level and depth of dialogue (consistently)	Makes relevant comments based on assigned material (ongoing)	When prepared, relevant comments are based on assignments	Demonstrates a noticeable lack of interest

Courtesy of Jesse Kwiek; Adapted from The Teaching Professor, March 2005.

YOU WILL POSITIVELY AFFECT YOUR PARTICIPATION GRADE BY:

1. Becoming more active and/or making more effective comments that raise overall level of discussion.
2. Asking thoughtful questions that will enhance discussion and engage peers.
3. Listening carefully to, supporting, and engaging your peers in discussion.

YOU WILL NEGATIVELY AFFECT YOUR PARTICIPATION GRADE BY:

1. Not attending class (unexcused), or **arriving to class late.**
2. Using electronic devices (e.g. cell phone, iPad, computer, etc.) for personal, non-class related reasons.
3. Dominating class discussions, thereby restricting others' participation.
4. Making offensive, and/or disrespectful comments during discussions.

G. Learning objectives write-ups. At the beginning and end of the course you will be required to complete short writing assignments (no more than 1 page single-spaced) self-evaluating your strengths and weaknesses in each of the areas covered by the 4 course learning objectives, based on the 3 overarching themes. At the start of the course you will evaluate your knowledge coming in, describe how these knowledge and training areas fit into your longer term research and career goals, and the areas you are most excited to learn about, and identify your strategy/ies for succeeding in the course. We will read a summary of learning

styles to help frame this. At the end of the course, you will reflect on which areas you advanced your knowledge and in what ways, and what learning strategies worked for you.

Learning objectives write-ups (written for entry exercise; exit rubric will be simplified)

Criteria	Rating			Points (19)
Strengths & weaknesses	8: for each of the 4 learning objectives, articulated a clear self-assessment	4: only identified strengths or weaknesses, or only addressed a subset of objectives	0: did not self-assess.	/ 8
Longer-term context	3: identified how the course material fits into your overall training and professional goals	1: mentioned a goal but without contextualizing course material.	0: did not describe context	/ 3
Strategy	4: clearly articulated strategies you will use to achieve your learning goals in this course	2: identified a single strategy but did not link it to this course	0: did not describe strategy	/ 4
Quality of writing	2: easy to read, clearly laid out	1: could follow, but there were some confusing sections.	0: poorly crafted, difficult to follow	/ 2
Spelling and grammar	2: no spelling and grammar errors	1: one error	0: more than one error	/ 2

IV. Course Outline

Due to the dynamic nature of this class, this syllabus is subject to revision as the semester proceeds. Announcements will be made on Carmen. **Students are responsible for being aware of any changes.**

V. Academic integrity

It is the responsibility of the Committee on Academic Misconduct to investigate or establish procedures for the investigation of all reported cases of student academic misconduct. The term “academic misconduct” includes all forms of student academic misconduct wherever committed; illustrated by, but not limited to, cases of plagiarism and dishonest practices in connection with examinations. Instructors shall report all instances of alleged academic misconduct to the committee (Faculty Rule 3335-5-487). For additional information, see the Code of Student Conduct <http://studentaffairs.osu.edu/csc/>.

Title IX makes it clear that violence and harassment based on sex and gender are Civil Rights offenses subject to the same kinds of accountability and the same kinds of support applied to offenses against other protected categories (e.g., race). If you or someone you know has been sexually harassed or assaulted, you may find the appropriate resources at <http://titleix.osu.edu> or by contacting the Ohio State Title IX Coordinator, Kellie Brennan, at titleix@osu.edu.

VI. Communication

Students are responsible for announcements made in class, available on the course Carmen page or sent by e-mail. Late assignments will not be accepted without prearrangement with instructor. Assignment due dates will be explicitly noted and followed – turned in at the start of class or via Carmen at the assigned time.

VII. Disability Services

The University strives to make all learning experiences as accessible as possible. If you anticipate or experience academic barriers based on your disability (including mental health, chronic or temporary medical conditions), please let the instructors know immediately so that we can privately discuss options. To establish reasonable accommodations, we may request that you register with Student Life Disability Services. After registration, make arrangements with the instructor(s) as soon as possible to discuss your accommodations so that they may be implemented in a timely fashion. SLDS contact information: slds@osu.edu; 614-292-3307; slds.osu.edu; 098 Baker Hall, 113 W. 12th Avenue.

VIII. Suggestions for reading and writing

A. *Tips for reading a scientific data paper:*

- What was the goal of the study?
- What was the general approach?
- What was the actual experimental design – can you draw a flow chart of it?
- What specific methods did they use, both experimental and analytical?
- What does each of their figures mean? Each should tell you a central “piece” of the paper’s story. I often read figures through twice: once before reading the results – or sometimes even the paper! – and then a second time when I get to the places in the text where they’re referenced.
- What are the key results?
- Do these results support, or contradict, previous work?
- What are their take-home messages?

Tips for reading a scientific review paper:

- What is the topic being conveyed, and why is it worthy of a review?
- How long has the topic being reviewed been known about?
- Is it clear who the author(s) is – are they a leader in the topic?
- What are the key experiments, discoveries, or methods described for moving the topic forward?
- Does the review contribute any new analyses or offer any novel perspectives (either of which it will make clear are new and not just from other work; a common contribution is a new “synthesis” figure bringing together concepts within the topic they’re reviewing)?
- What is the point of each figure? Each should tell you a central “piece” of the paper’s story. I often read figures through twice: once before reading the results – or sometimes even the paper! – and then a second time when I get to the places in the text where they’re referenced.
- Does the reviewed topic fit in or contradict the previous conceptual framework?
- What are their take-home messages?

Tips for coherent writing:

- Make an outline first. It gets your ideas down and organized. Not starting with one can lead to a jumbled mix of concepts without clear logical flow.
- *Topic sentences* (e.g. see <http://www.writingcentre.uottawa.ca/hypergrammar/partopic.html>) are **key** to good writing.
- Use concise, direct language. Avoid run-on sentences.
- Always check your spelling and grammar.
- If you are unclear of what constitutes plagiarism, it is your responsibility to educate yourself; OSU has a resource for you, see the Code of Student Conduct <http://studentaffairs.osu.edu/csc/>

Citing your sources:

When information you provide in your writing is sufficiently novel and not your own, then sources must be cited in the text and a complete and correct bibliography (see example below) must follow. Your sources of information might include: (i) focal papers, (ii) textbook chapters (including section #) that provided any critical background information, (iii) web pages or additional sources of information.

To cite sources, you can numerically or “author year” provide the reference(s) when supporting your statements. For the example reference below, you might say and cite something in your essay like, “caves harbor phylogenetically distinct microbial lineages (Holmes et al 2001).” You clearly did not demonstrate this phylogenetic distinctness in cave microbes yourself, but the 2001 study did and that is where you gained the information.

Bibliographic citation example; feel free to use the citation format of any major journal.

Holmes, A.J., N.A. Tujula, M. Holley, A. Contos, J.M. James, P. Rogers, and M.R. Gillings. 2001. Phylogenetic structure of unusual aquatic microbial formations in Nullarbor caves, Australia. *Environmental Microbiology*. 3:256-264.

Week	Date	Focus Q and relevant topics	Readings (tentative, see Carmen for updates)
1	Jan 11	Why are we here (in this class)? (introductions, class format, syllabus & scheduling; how to read a paper; some big ecological Qs)	1. Antwis et al. 2017. Fifty important research questions in microbial ecology . <i>FEMS Microbial Ecology</i> . 5: fix044. 2. Lennon & Locey. 2017. Macroecology for microbiology . <i>Env. Microbiol. Reports</i> .
2	Jan 18	What should we count? (OTU/populations, species concepts, diversity)	1. OX Cordero, MF Polz. 2014 Explaining microbial genomic diversity in light of evolutionary ecology . <i>Nature Reviews in Microbiology</i> . 12: 263–273 2. Louca et al. 2018. Function and functional redundancy in microbial systems . <i>Nature Ecology & Evolution</i> . 2: 936-943. [need diversity primer? Consider ' Counting the uncountable ' or ' Species divergence and the measurement of microbial diversity ' or ' Diversity is the question, not the answer ' or online tutorial (here)]
3	Jan 25	How does taxonomy map to phylogeny? (phylogeny, taxonomy, Tree of Life)	1. LA Hug et al. 2016. A new view of the tree of life . <i>Nature Microbiology</i> 1: 16048. 2. Parks et al. 2018. A standardized bacterial taxonomy based on genome phylogeny substantially revises the tree of life . <i>Nature Biotech</i> . 36: 996-1004. [need phylogeny primer? Book (Phylogenetic Trees Made Easy) or tutorial (here)]
4	Feb 1	What does rare versus abundant mean? (diversity, rank abundance, cataloguing)	1. Thompson et al. 2017. A communal catalogue reveals Earth's multiscale microbial diversity . <i>Nature</i> . 551: 7681. 2. Banerjee et al. 2018. Keystone taxa as drivers of microbiome structure and functioning . <i>Nature Reviews Microbiology</i> 16: 567-576.
5	Feb 8	How do microbes change over space? (Patterns and drivers of microbial community structure)	1. Sunagawa et al. 2015. Structure and function of the global ocean microbiome . <i>Science</i> . 348:1261359. (*=co-first authors) 2. O'Brien et al. 2016. Spatial scale drives patterns in soil bacterial diversity . <i>Environ Microbiol</i> . 18:2039-51. [Need an ecological statistics primer? Consider ' Multivariate analyses in microbial ecology ' or ' The role of ecological theory in microbiology ']
6	Feb 15	How do microbes change over time? (scaling, networks, time series / chronosequences, MAGs)	1. Needham et al. 2017. Ecological dynamics and co-occurrence among marine phytoplankton, bacteria and myoviruses shows microdiversity matters . <i>ISMEJ</i> . 11: 1614-29. 2. Ottesen et al. 2014. Multispecies diel transcriptional oscillations in open ocean heterotrophic bacterial assemblages . <i>Science</i> . 345: 207-212.
7	Feb 22	What level of variation matters in nature? (population genetics applied to communities)	1. Schloissnig et al. 2013. Genomic variation landscape of the human gut microbiome . <i>Nature</i> . 493: 45-50. 2. Rocha. 2018. Neutral theory, Microbial practice: Challenges in bacterial population genetics . <i>Mol. Biol. Evol.</i> 35: 1338-47.
8	Mar 1	How do microbes impact ecosystems? (ecological models, activity measurements)	1. Guidi et al. 2016. Plankton networks driving carbon export in the oligotrophic ocean . <i>Nature</i> . 532:465-470. 2. Wieder et al. 2013. Global soil carbon projections are improved by modelling microbial processes . <i>Nature Climate Change</i> . 3: 909–912. 3. Starr et al. 2018. Stable isotope informed genome-resolved metagenomics reveals that Saccharibacteria utilize microbially-processed plant-derived carbon . <i>Microbiome</i> . 6:122.
9	Mar 8	No class! Happy spring break!	
10	Mar 15	Spring break	
11	Mar 22	How do microbes evolve in captivity? Guest discussion leader Alison Bennet (experimental evolution)	1. Good et al. 2017. The dynamics of molecular evolution over 60,000 generations . <i>Nature</i> 551: 45-50. 2. Zhang et al. 2018. Fungal networks shape dynamics of bacterial dispersal and community assembly in cheese rind microbiomes . <i>Nature Communications</i> . 9:336
12	Mar 29	How do microbial eukaryotes evolve? Guest discussion leader Matt Anderson (XYZ)	T.B.D. by guest lecturer
13	Apr 5	How do viruses fit in? (viral ecogenomics, microdiversity, biogeography)	1. Roux et al. 2016. Ecogenomics and potential biogeochemical impacts of globally abundant ocean viruses . <i>Nature</i> . 537: 689-693 2. T.B.D.
14	Apr 12	Is metabolic interconnectedness the rule? (metabolic handoffs, MAGs)	1. Hug & Co. 2018. It Takes a Village: Microbial Communities Thrive through Interactions and Metabolic Handoffs . <i>mSystems</i> . 2. Anantharaman et al. 2018. Thousands of microbial genomes shed light on interconnected biogeochemical processes in an aquifer system . <i>Nat. Comm</i> . 3. Woodcroft et al. 2018. Genome-centric view of carbon processing in thawing permafrost . <i>Nature</i> . 560: 49-54.
15	Apr 19	How do hosts + symbionts/parasites co-evolve? (holobionts, co-evolution)	1. Thompson. 2014. Microbes in the coral holobiont: partners through evolution, development, and ecological interactions . <i>Front Cell. Infect Microbiol</i> . 4: 176. 2. Scanlan. 2017. Bacteria-Bacteriophage Coevolution in the Human Gut: Implications for Microbial Diversity and Functionality . <i>Trends Microbiol</i> . 25:614-23
	Apr 22	Last day of spring semester classes	
	Apr 26	Final presentation in lieu of final exam	Each person presents for 15" + 5" Qs.