

Report and Proposal on the APPLIED MATH MAJOR PROGRAM at The Ohio State University

DRAFT VERSION

The Undergraduate Subcommittee
for the Applied Math Major, 2002

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1 The Status-Quo:

One of the initial motivations that led to the departmental undergraduate committee of 2001/2002 to reconsider and examine the curriculum for the math major program was to find ways to make it more attractive to either more or better students (or both) and find out if and how the effectiveness of the program in regard to success of graduates in their later endeavors can be improved. Presently the department allows within the math major program students to elect the “Applied Option”, besides the “Pure Option”, and the “Combinatorics Option”. There is also a Major in Mathematical Sciences on the books, which is also slanted towards applied mathematics, emphasizing also CIS and Stats courses. In this report we focus on the Applied Option within the regular Math Major. Here a few facts, questions, and problems that spurred the following discussion.

1.1 Marginal Student Numbers:

The students numbers in the regular pure math track tend to be reasonable. The quality of students there is rather mixed. Some with genuine interest in pure mathematics but also many that elect this major since they cannot fulfill GPA requirements of, e.g., the Engineering and CIS Departments (Sadly, they fall short of GPA’s often because of their weak performance in math courses).

Enrollment in the current Applied Math track and the Mathematical Sciences track are basically inexistent. There are perhaps 2 to 3 students graduating from these tracks per year.

1.2 Unequal Credit Hours:

Perhaps one of the most severe reasons for having nearly no enrollment in the current Applied Math program is that the total number of required credit hours substantially exceeds the total number of credit hours of the pure math option (by about 10-15 cr.). Particularly students for whom math is a second choice are unlikely to be attracted by such prospects.

Nevertheless, moderately increased requirements on the number of credit hours appear to be acceptable to students in other programs like Engineering. The difference is likely that these programs provide more professional perspective, better focus on educational goals, and, generally, enjoy better visibility and reputation.

For the applied math option there is little incentive or appeal in this way that would attract students willing to accept higher course and work loads.

As background information below the latest GEC requirements at Ohio State:

1. 191 cr total hours must be non-remedial.
2. min of 176 cr in A& S.
3. min of 60 cr in A& S upper division courses.
4. max of 80 cr (non 100-level) in a single area.
5. Drop-a-GEC gets req's cr's down to 80-100.

<u>GEC</u>	85-105
Writing Skills	10
Quantitative Logical Skills	10
Natural Science	25
Social Science	15
Arts and Humanities	25
Foreign Language	00-20
<u>Major</u> (minimum)	40
<u>Free Elective</u>	15
<u>Survey</u>	01
<u>Elective</u>	00-50
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Minimum Total Hours	191

1.3 Low Visibility and Focus:

Generally students are not uninterested in programs of applied mathematics and routinely ask about such possibilities. Yet there doesn't appear to be much awareness either among students or, even, faculty that such programs exist at least on paper.

One factor that may inhibit the visibility/popularity of the Applied Program may well be the decision to emphasize breadth rather than focus and specialization. This decision was based on wishes of engineering industry that they like particularly versatile people with broad education.

This, however, tends to also have the effect that the program offers little direction for students in their career choices or personal identification with what they are studying. The program so universal it does not use the strengths of the department to be more visible and attractive over similar programs at other universities, and, in fact, over the own pure math program.

1.4 Flexibility and Choices:

The current specialization in the Applied Math Option are the "Analysis Track", the "Algebra Track", and the "Combinatorics Track". The students thus have choices in their fundamental pure math classes. The choices of more applied math classes, such as numerical math, probability and statistics, etc. are not flexible leading in part to the accumulation of credit hours.

The only application specific specialization is the “combinatorial” one, which presumably none has made use of in years.

Still there is at least occasional interest by students to combine math majors with rather specific applied sciences. These may not be in engineering sciences which appears to have been the main focus of application in the present program.

1.5 Pure Math Component:

In order to cover prerequisites in pure mathematics presently math majors of the applied option are expected to take the same courses as pure math majors. In order to alleviate the course load from pure classes they may elect to completely avoid the Analysis or Algebra lecture series. There are two questions that arise with this approach.

(i) Should applied math majors go through the same algebra and analysis courses as pure math majors? On the one hand any math students should be exposed to a rigorous working, preferably in the context of an area relevant to the major/track. On the other hand the present 547-549 Analysis sequence, for example, while probably adequate for students interested in pure math itself and teachers, spends much time carefully developing concepts not all of which may be necessary for an applied math students.

(ii) Is it reasonable to allow students to drop completely out of Analysis or Algebra? Should there not be a minimum of exposure in both of these pure/rigorous directions?

1.6 Assessment and Effectiveness

Assessing the performance of the math major program is a problem that not only pertains to the applied track. Right now there is very little information that the department receives from their math major in either track.

Assessment in the applied track should give a measure of effectiveness of preparation for other math classes, for classes in the elected specialization that need math, and the preparation for their career after college. The latter requires keeping track and soliciting feedback from alumni, but also talking to later employers and advisors. Presently there is not much if anything done in this direction.

2 Comparison and General Considerations:

2.1 Comparison Report:

In the fall of 2001 the Undergraduate Committee collected information about math major programs at about 15 “Benchmark Univeristy”. The report on the Applied Math Majors at these

universities is included. There are roughly four categories of programs:

- (0) *Inexistent programs.* [3/15] (obviously, no description needed)
- (1) *Applied Math Programs with NO Specific Area of Application* [8/15]: Distinguish themselves from Pure Math tracks by putting more emphasis on applied mathematics courses, such as statistics and probability, numerics, etc., in junior and senior years.
- (2) *Applied Math Programs WITH Specific Area of Application/Specialization* [6/15]: The possible specializations are quite different from department to department, ranging from natural sciences, engineering, life sciences, social and behavioral sciences and/or skill oriented specializations. The particular tracks are as diverse as to include, for example, meteorology, metallurgical engineering, genetics, forestry, modeling and control systems, etc. The individual programs often have quite specific course requirements both in math and in the area of application. The various designs can differ a lot even within one applied math major program sometimes involving quite complicated elective procedures, though most universities attempt to maintain a minimal common core program.
- (3) *Individualized Programs* [3/15]: Here students can design their own tracks towards a particular application. All universities offering this option also have regular applied math tracks in place that can serve as models. Typically the program is designed together with a faculty advisor and approved either by individual faculty or an undergraduate studies committee.
- (4) *Interdisciplinary Programs*: [3/15] These are programs that are designed and established in collaboration with other departments such as engineering, computer science or medical schools.

There are several overlaps for departments that, e.g., offer both an applied math track with and without specialization.

The current program at Ohio State is presumably best put into category (1). Only the “Combinatorics” track in the Applied Math Option might count towards type (2), but the enrollment there is pretty much zero for years. Due to the very low enrollment in the Applied Math Option one might in fact place Ohio State closer to (0). In the way of (3) it is in principle possible to work with advisors, faculty and the committee to follow individualized programs. Yet there is no formal procedure to do so in place and also no program that could serve as comparisons.

2.2 Targeting a Clientele & Choosing Educational Goals:

Any design and assessment is heavily dependent on which goals are set. The questions here are which students should the programs be designed for, what are they supposed to take from the program, where are they expected to go? Here an attempt to categorize students and their needs into three groups. This is obviously a simplification but should be of service in developing a direction:

- ♠ One group are students coming to Ohio State with ambivalent intentions and then electing mathematics as their major later in their studies. Their motivations are to get a somewhat marketable background in a hard science though they are not focussed in a particular career direction. The reason for choosing mathematics over other programs such as engineering and computer science can be anything from an appreciation of the universality and abstraction of the discipline to the low GPA requirements. They may enjoy mathematics but have no real intention to obtain higher degrees in math or do research in math.

The reasons to choose an applied math track over the pure math track are driven only to a very modest extent by any sort of career ambitions in applied mathematics. More likely motivations are to get a sort of “soft engineering” degree without being harassed by too many rigorous math requirements. The quality of this category of students is probably mostly modest. It is also unlikely that there are many out of state students in this category.

- ◇ Some student may have already an academic or similar research career in applied mathematics in mind when they elect such a track. Their general goal would, e.g., be preparation for an advanced degree in an (applied) mathematical science. Such determination is somewhat exceptional and the quality of such types of students is likely to be exceptional as well. They have an inherent interest in the more abstract aspects of mathematics itself. The reasons to choose an applied option will be hard to generalize and in many cases matters of refined individual tastes.

- ♣ Finally, there are student with more definite career ambitions but are not focussed on advanced academic degrees in a part of mathematics itself. Rather they seek, for example, research type positions in industry or plan to enter interdisciplinary graduate programs. They have a definite need for a stronger background in mathematics since the type of work they like to do has a strong theoretical component. Their interest, however, is not so much the mathematics itself. The area of application is of primary interest to them and the specific choice thus rather important. Such students may likely go out of state to find a mathematics program in their preferred area of application and special training. Though they don't really envision a mathematical career they are likely to be ambitious and sound quality students.

Students of category ♠ can presumably be counted as a secure source of applied math majors given the size of Ohio State and the number of other demanding technical programs. Beyond a reasonable amount of advertisement not much needs to be done to attract this clientele. However, a probable prerequisite to maintain this influx of students is that the requirements in the applied math tracks are kept at a rather modest level. The department would probably continue to fare OK if this group of students is the main target of the programs. It is, however, also clear that this such a strategy is about the least ambitious one. This group will probably also have to be given consideration in the start-up phase of a more ambitious program since it will take time for a program to built up a reputation that would attract students beyond the local ones.

Currently only few math majors attempt to go into a mathematics graduate program. Even fewer (basically none) in the applied math track attempt to enter an applied mathematics graduate program. It may not be realistic at this stage to expect that this will change dramatically with a new math major program. Thus students in ◇ will probably remain a rather small group for a long time. It also seems that most students choose an advanced degree in applied math only after entering a graduate program as an unspecialized mathematics graduate student with a broad and solid background in pure and rigorous mathematics. Thus it might be reasonable to direct ◇ students towards the pure math track. Nonetheless, any applied math program should have enough rigorous mathematics not to actually obstruct the continuation in a mathematics graduate program.

It is seems, however, possible that a broader group of students of type ♣ can be attracted to an applied math major program at Ohio State that is sufficiently well conceived and implemented. This will clearly involve more effort than to attract ♠ type students. If successful this could notably raise the standard of the program with good and ambitious ♣ students coming from different states to Ohio State in order to take advantage of unique opportunities that the program may offer. In a professional world that has become more and more complex there is increasing demand for more and more diverse and exotic combinations of skill sets. An applied math major program can cover those that involve special mathematical analytical skills that the department is well equipped to teach combined with applications that are well represented at Ohio State.

2.3 A Move towards Tracks and Specializations:

Here a list of arguments and consideration for a move to tracking an applied math major according to specific specializations.

- Specializations would allow the program to fill “*niches*” in theoretical professional training, and thereby become competitive with applied math programs at other, possibly higher ranked universities. If there are only a couple of universities in the nation offering a

particular mathematics specialization very good students from all over the country with such interests are more likely to elect to come to Ohio State.

- Such niches should draw from the particular strengths and opportunities already available at the department.
- The specializations should have a clear direction towards a quiver of employment opportunities, which should be defined before the design of a track. At the same time the program should be theoretical enough not to compete with professional schools or other departments, and clearly taking advantage of the mathematical side.
- Tracking according to specialization will make it much easier to generate a high visibility of the program given sufficient advertisement. The individual names of the programs and the more well defined career opportunities will let them stand out and ignite interest.
- Specialization also allows “streamlining” of the course requirements in the individual tracks. They may be adapted more precisely towards the needs of a smaller group of employers or graduate programs.
- It is advantageous to keep the number of track in the beginning phase of the program to only a few. Too many tracks in the beginning will multiply any problems that may arise in the implementation phase. Further too great of a the number of choices will disperse students and make it hard to fill classes. Finally, as the program develops from a few starting track it is possible to determine which other types of tracks and specializations are in demand much more accurately then imposing them right form the start. Here is an “individualized option” can play an instrumental role.
- Tracking has been done successfully at other benchmark universities, leading to quite lively and diverse applied math major programs. There is plenty of experience that one can draw from.

These arguments and consideration are in the background of the program outline given below.

2.4 About Depth and Breadth:

With limited number of available credit hours and also upper limits on what can be expected from the majority of students decisions need to be made how to gauge the appropriate level of the courses and how to allocate hours between the mathematical and applied aspects of the curriculum.

(A) LEVEL AND NUMBER OF CLASSES.

There are a couple of dependencies that one needs to keep in mind. One is that the higher the level of the offered classes and the higher the work load the fewer students will enroll that don't expect a worthwhile payoff in their professional careers or have not even developed ambitions in this direction. Thus there will be less ♠-type students.

On the flip side, the anticipation that a program will yield career payoff for more ♣-like students will depend on the reputation of the program, particularly among employers. Such a reputation is hard to work up with a soft program that offers that puts out students with weak training.

Thus some delicacy would have to be applied to gradually raise the level of courses en par with elevating the reputation if one wanted to establish a higher caliber program with higher marketability without deterring students that are between the ♣ and ♠ category in the initial phase.

(B) MATHEMATICS VS. APPLICATION.

A challenge of designing an applied math major program within a limitation of credit hours is to find a balance between the time invested learning a mathematical foundation and the time needed to penetrate into an area of specialization and application. Some decisions that need to be made in each track:

- (a) Is it desirable to have students see the mathematics they learned applied in the courses in the area of their application. In many fields of application, such as life sciences, considerable knowledge has to be accumulated before any non-trivial mathematics applications can be found. Thus if this is wanted more hours need to be allocated in there and, in turn, the total number of mathematics courses needs to be kept at a more manageable and efficient level.
- (b) Conversely, the purpose of entering area of specialization may be simply to acquire a certain amount of basic knowledge there parallel but by-and-large independently of the mathematics studies. In this case there is more flexibility to design the track more broadly and also to put more emphasis on the mathematics side.
- (c) In order to provide opportunities to see mathematics applied in a relevant context specific courses can be developed, such as ones in cryptology or biostatistics, either within the math department or together with the respective department/program of application.
- (d) The decision to which extend concrete applications of mathematics are taught will also depend on demands of future employers and the aspirations of the department.

3 Proposal and Suggestions:

Next the main features of the proposed math major program in applied mathematics are introduced and outlined.

3.1 Foregoing and Developing new Majors:

So far the applied math program is an “option” within the regular math major. For the beginning phases of the new program it is presumably sufficient to stay with current format and award only the general math major for a BS. This may be changed later once the programs have established themselves more solidly, and a separate applied math major can be considered. The urgency of introducing a separate major has to do with how much the mathematics requirements will differ from the pure math major and how much resistance in the department there is to give the same math major to students with, e.g., a different curriculum in analysis or other rigorous courses. If there exists an understanding that eventually there will be a separate applied math major after a transitional period this should be feasible with most faculty in the department.

Presently there exists also the “Mathematical Sciences Major”. This program has had nearly no enrollment in last few years. The idea to organize the new applied math program under this major and thereby circumvent the process of having a new major approved bears a number of problems. One is that this would cause confusion among students and make it harder to advertise a genuinely new program. Moreover, the math sciences major was approved under certain assumptions which may no longer apply to a new program, and could thus lead to inquiries from the college and university level.

Most agreed that a new applied math major should be installed under a new name going through the routine approval procedure. Sentiments also went towards abolishing the the current math sciences major due to the low enrollment and possible conflicts with a new major.

3.2 Curriculum Outline with Minimal Core:

The following describes the general skeleton of the curriculum that shall apply to every track universally. It starts with a Core that is common to all tracks and from there diverges depending on the particular track requirement. The credit hours are noted for each group of courses.

The *total number* of credit hours for the major comes out to be about **55 cr.** The justification is that this is the standard of **49-50 cr.** for a major plus **5-6 cr.** that can be obtained from the *Drop-A-GEC* Option. The program thus stays “competitive” with other majors.

I. Core Required Courses: [42-43 cr. = 15 GEC + 27-28 Major]

See Section 4.I. These courses are mandatory for all math majors in the applied option (or applied math majors) and fits the standard of minimal math requirements of the department and many other benchmark universities. It differs from the core requirements in the pure math track only in a computer course and at the “top end”, namely the sequences in abstract algebra and real analysis.

II. Required Courses, Optional Tracks: [12 cr]

See Section 4.II. This is a list of mathematics courses from which additional math requirement for the track are taken. For each track a specific subset of these courses is defined that which are mandatory for students going through that particular track. The subset is subject to the given limit on credit hours.

III. Elective Minor Courses: [15 cr]

See Section 4.III and Section 5. Here courses for the given area of application and specialization are give. Each tack itself may contain several flavors of specializations (e.g., Aeronautical Engineering in the Engineering Track, or EEOB-studies in the Biomath Track). For each such specialization a *template* of required courses is designed that fills out the credit hours. Students may take the templates literally as their course requirements once they choose a “flavor” but they can also serve as guidelines in designing an individualized curriculum through the individual studies option.

IV. Additional Course Choices:

See Section 4.IV. The section provides an opportunity for each track to list courses that are recommended additional choices either to go into more depth where needed, fill up university course requirements, or, with the adequate permission, substitute other required courses.

3.3 Installment of Several Tracks:

Below are the three areas of specialization and four tracks that were generally agreed up on as the ones that were best represented by the department, supported by other university programs, and provide marketable professional training.

A) Engineering/Physics Track

The current design of the applied option within the math major is geared primarily towards this area of application. There are well established ties with the engineering and physics department and both of these department enjoy high rankings. Some units are also forthcoming

in developing minors (such as in Electrical and Computer Engineering) and interdisciplinary programs (such as Ecological Engineering). This one should continue to be taken advantage of.

Professional opportunities arise in theoretical/modeling aspects of R& D in engineering firms, but also in physics and math/engineering interdisciplinary graduate programs.

B) Bio Math Track

The new *Mathematical Bioscience Institute* provides a unique opportunity and environment for a track relating mathematics to biological sciences. Several of the mathematics faculty are working in this area. In addition OSU has reputable colleges of biological sciences and psychology and a large medical school that would offer courses and other educational opportunities. Other universities that offer applied math majors in biomathematics are, e.g., U Scranton and U Michigan.

Career opportunities in industry become more and more numerous, including modeling, algorithms and data handling in genetics, nanotechnology and DNA topology, epidemiology and biostatistics, ecological system modeling, fluid dynamics of blood, behavior of organismal dynamical systems, theoretical neuroscience, evolution mapping, etc.. At the same time more and more universities offer graduate programs in biomathematics and similar interdisciplinary areas (U Texas, UCLA, NCSU).

C) Discrete Math Track

The discrete track is mainly motivated by the existing research and teaching activities that already exist within the math department. (This also led to the earlier attempts to install a “combinatorics” track). As such it is generally oriented closer to mathematics and courses of application will need to be provided mostly within the department.

Areas and courses represented in the department are applied logic, cryptology and coding theory, combinatorics, and computational group theory. Other projects for course offerings include game theory and mathematical modeling. In addition theoretical course offerings of CIS may be adequately incorporated into a discrete math major.

The National Security Agency is one of the largest employer of mathematicians and discrete mathematics, particularly cryptology, is the natural preparation. Obviously, there is likely to be interest also in larger computer companies with mathematically oriented research units. Also, modeling and game theory are clearly applicable in economics leading to employment in areas that rely on economic prediction, auction and market design, etc.. The track is also still so close to mathematics that it could even give adequate preparation to certain graduate studies in pure mathematics.

D) Individual Applied Track

The purpose of this track is provide an opportunity to develop further applied math programs with more diverse specializations. Students will work with faculty advisors to design their curriculum according the outlined skeleton and using the templates as guidelines for the level of expectations of the major.

Some decisions on the formal process of approval of a particular program still need to be made. That is, whether this needs to go through the undergraduate committee or whether the approval of designated faculty is enough.

In any case, one should, at some level, collect and assess the individual programs that are approved in order to gather “experimental data” and gauge demand for the future development of the applied math major.

3.4 Minimum GPA Requirements:

As mentioned before one needs to maintain a delicate balance setting the GPA requirements. While the program is still a part of the general math major this cannot be done independently from the pure math major.

In case a sufficient demand for this program is generated and it is organized under its own major the GPA requirement can be gradually increased. Slowly enough to maintain to maintain a minimal enrollment but quickly enough to be able to work up a reputation and make the major functional in its advanced courses.

3.5 Increased Advertisement, Communication, and Assessment:

In order to guarantee enrollment and thus the possibility to improve quality the applied math program needs to be thoroughly advertised. Particularly, career opportunities should be pointed out clearly. Similarly the wide range of options the program offers even with only 3-4 tracks. Such advertisement should go beyond university and state border since there are only few similar programs offered nationwide.

Furthermore, each program can benefit from communication with potential employers or graduate programs, both about their general demands as well as their experiences with our graduates. Specific endorsements of particular employers can be included at later stages in the advertisement. Relationships of this kind to industry and research institutions will possibly also lead to sponsorships and additional funding of the program.

4 The Core Scheme:

This section defines the specific course requirements that are common to all tracks. The general skeleton and grouping have been described in Section 3.2.

4.I. Required Courses (42-43 cr = 15 cr GEC + 27-28 cr Major):

In this block are the course requirements that pertain to **all** math majors that choose the applied option. Three of them, namely MATH 151, 152, and 153, with a total of 15 credit hours count towards GEC or Elective requirements, see Section 1.2. Five more, namely MATH 254, 415, 571, 572, and a programming course, totalling 19 credit hours, must be taken by all students independent of the track and count towards the major. Finally, in 4.I.E, students must take a number of pure math courses with a total of 8-9 credit hours, according to the rules specified for their particular track.

4.I.A) Calculus (20cr):

MATH 151, 152, 153, 254: “Calculus and Analytic Geometry I-IV” (5cr each)

*Note: MATH 151 and 152 counts twds GEC req's.
MATH 153 counts twds “Electives”
MATH 254 counts twds the Major*

4.I.B) Differential Equations (4cr):

MATH 415: “Ordinary and Partial Differential Equations” (4cr, Req's: MATH 254)

Note: MATH 255 should not be listed but accepted as a substitute on case-by-case basis.

4.I.C) Linear Algebra (6cr):

MATH 571, 572: “Linear Algebra for Applications” (each 3cr, Req's: MATH 254)

*Note: It is desirable to keep the “proof” component in this course.
Engineers should be either warned or directed to other courses.*

4.I.D) Computer Programming (4cr):

Choose one of the following courses:

ENGRAPH 167: “Problem Solving through Programming ...” (4cr, Req's: MATH 151)

Note: teaches C/Fortran

CIS 202: “Introduction to Programming ...” . (4cr, Req’s: MATH 151)

Note: teaches C/”baby C++”, not open to CIS majors

CIS 230: “Introduction to C++ Programming.” (4cr, Req’s: ENGRAPH 167 or CIS 202)

Note: CIS 221/222 teach “C++-resolve” and should NOT be advertised, but accepted as substitute on case-by-case basis.

4.I.E) Pure Math Requirement(8-9cr):

The minimal requirement in pure mathematics are to be chose from one of the following blocks. There are sometimes obvious preferences for each track, but the main purpose is to expose students to some piece of rigorous mathematics. The question about the design of an applied analysis sequence still needs to be settled:

- MATH 553, 554, (555): “Analysis for Applied Math I, II (III)” (each 4cr, Req’s: MATH 254)
(or MATH 345, 547, 548, (549): “Introduction to Analysis” (each 3cr, Req’s: MATH 254))

Note: See Section 8.1.1 below.

The MATH 553, 554, 555 sequence (or similar) does not exist presently and needs to be designed

- MATH 366: “Discrete Mathematical Structures I” (3cr, Req’s: MATH 152)
MATH 580, 581: “Algebra I-II” (each 3cr, Req’s: MATH 345 and 568)

Note: MATH 366 is taken here as a substitute MATH 345

The course req. for MATH 580 needs to be adapted

- Other “Proof”-Courses:

- MATH 345: “Foundations of Higher Mathematics” (3cr, Req’s: MATH 254)
- MATH 366: “Discrete Mathematical Structures I” (3cr, Req’s: MATH 152)
- MATH 566: “Discrete Mathematical Structures II” (3cr, Req’s: MATH 366)

- MATH 578: “Discrete Mathematical Models” (**5cr**, Req’s: MATH 530 or STAT 427 or equiv,
MATH 568, and CIS 221.)
- MATH 640: “Introductory Topology” (**3cr**, Req’s: MATH 254)

4.II Required Courses, Optional Tracks (12)

The following courses are additional mathematics requirements. Which can and which have to be chosen depends on the track. The following table should be somehow completed with, e.g.,

“M”=Mandatory

“C”=Counting towards Requirement

“O”=Optional

(I put in here my best guesses - the track specialists need to adjust this)

Track\ Block	A	B	C	D
Eng/Phys	O	M	O	M
Biomath	C	M	C	C
Discrete	C	O	M	C

4.II.A) Probability & Statistics (6-10 cr):

STAT 427, 428 “Intro. to Probability and Statistics for ... I, II” (**ea 3cr**, Req’s: MATH 254)
 STAT 520, 521: “Mathematical Statistics I, II” (**ea 5cr**, Req’s: MATH 254)

4.II.B) ODE & PDE (6cr):

MATH 556, 557: “Differential Equations I, II” (**ea 3cr**, Req’s: MATH 255, 572)

4.II.C) Discrete Mathematics (11cr):

MATH 530: “Probability” (**3cr**, Req’s: MATH 254)

Note: Maybe replaced by STAT 427 from II.A)

MATH 566: “Discrete Mathematical Structures II” (**3cr**, Req’s: MATH 366)

MATH 578: “Discrete Mathematical Models” (**5cr**, Req’s: MATH 530 or STAT 427 or equiv,
MATH 568, and CIS 221.)

4.II.D) Numerical Methods (3-5cr):

MATH 607: "Essentials of Numerical Analysis" (5cr, Req's: MATH 548 or 652)

Note: *Taught in the summer, "hands-on" computing, probably Matlab.*

CIS 541: "Elementary Numerical Methods" (3cr, Req's: CIS201 or 221 or ENGRAPH 167 or 200, and MATH 153)

Note: *Mostly for CIS and ECE students. Content unclear.*

AEROENG 581: "Numer. Methods in Aerospace Eng." (3cr, Req's: ENGRAPH 167, MATH 414, MATH 571)

Note: *Standard numerical analysis course using Matlab*

4.III Elective Minor Courses (15 cr)

The templates are found in Section 5. A student is expected to elect one of the flavors in order to gain depth in area of specialization. It is preferably avoided that students take only the first basic introductory classes from several course sequences rather than going through with one particular sequence.

4.IV Additional Course Choices

The listings are found in Section 6. several of these courses still need to be designed.

5 Minor Elective Courses for Tracks

The organization of the template follows the hierarchy

Track \Rightarrow Department \Rightarrow Flavor/Template.

For example, "A.3.c Chemical Engineering" is under Track=A. Eng/Ohys, Department=3.Engineering, Flavor=Chemical. There are still many holes and open questions that need to be addressed by the track specialists. As before I put them in Note- or Question-boxes

5.A) Engineering/Physics Track:

5.A.1) MATH MINOR PROGRAMS

a. Analysis Math Minor: MATH 345, 547-549 (13cr)

b. **Algebra Math Minor:** MATH 345, 580-582 (13cr)

c. **Combinatorics Math Minor:** MATH 345, 366, 566, 575 and/or 578. (13cr, 16cr)

Question: *How should we think about the “math minor” in phys/engineering ?*
Is this not replicating a pure math or discrete math track, with repeated requirements and not much in the way of phys/engineering ?
There is also redundancy with core requirements(?)

5.A.2) PHYSICS MINOR PROGRAMS

5.A.2.a) General Physics Minor:

PHYS 525: “Dynamical Models” (4cr, Req’s: PHYS 133, MATH 255 or eq.)

PHYS 555: “Fields and Waves I” (4cr, Req’s: PHYS 133, MATH 415, MATH 513, 551, or 416)

PHYS 656: “Fields and Waves II” (4cr, Req’s: PHYS 555)

PHYS 657: “Fields and Waves III” (4cr, Req’s: PHYS 656)

PHYS 664: “Theoretical Mechanics” (4cr, Req’s: PHYS 262, MATH 255, MATH 513 or 551)

Question: *Intro sequence PHYS 131-133 is required here - is that supposed to be counted as “GEC” or “general Elective”. If so a GEC/Elective-recommendation should be made.*
Also vector analysis MATH 513 or 551 is required here.

5.A.3) ENGINEERING MINOR PROGRAMS

5.A.3.a) Aeronautical & Astronautical Eng.:

AAE 200: “Introduction to Aerospace Engineering I” (5cr, Req’s: MATH 152, PHYS 131)

AAE 201: “Introduction to Aerospace Engineering II” (5cr, Req’s: AAE 200)

AAE 405: “Thermodynamics” (4cr, Req’s: AAE 201)

AAE 414: “Applic. of Diff. Equations in AAE” (2cr, Req’s: AAE 201, MATH 254, 414)

AAE 530: “One-Dimensional Gasdynamics” (4cr, Req’s: AAE 201, 405)

AAE 560: “Fundamentals of Aerodynamics” (4cr, Req’s: AAE 530, 414)

AAE 570: “Viscous Flow and Heat Transfer” (4cr, Req’s: AAE 560, 414)

Question: *PHYS 131 appears again as a prereq.*
I added AAE 414 myself since its a prereq. later. It needs to be concurrent with MATH 414 ?

5.A.3.b) Biomedical Engineering:

Question: ... = ? *Should this be deleted or filled up?*
How far is this already included in BioMath track?

5.A.3.c) Chemical Engineering:

- CHEMENG 200: "Process Calculations I" (3cr, Req's: CHEM 123, MATH 254, PHYS 131)
CHEMENG 201: "Process Calculations II" (3cr, Req's: CHEMENG 200, MATH 415, PHYS 132)
CHEMENG 520: "Transport Phenomena" (3cr, Req's: MATH 415)
CHEMENG 521: "Transport Phenomena II" (3cr, Req's: CHEMENG 420 or 520)
CHEMENG 522: "Transport Phenomena III" (3cr, Req's: CHEMENG 521)

Question: *Again PHYS 132 and CHEM 123 req's*

5.A.3.d) Environmental Science: ...

Question: ... = ? *Should this be deleted or filled up?*

5.A.3.e) CIS: ...

Question: ... = ? *Is this not covered by the Discrete Track?*

5.A.3.f) Electrical Engineering:

- EE 205 : "Circuit Analysis" (3cr, Req's: PHYS 133, ENGRAPH 167 or CIS 201 or 221, MATH 415)
EE 311 : "Electromagnetics I" (3cr, Req's: EE 204 or 205, MATH 415)
EE 312 : "Electromagnetics II" (3cr, Req's: EE 311)
EE 351 : "Systems I" (3cr, Req's: EE 205 or 305)
EE 352 : "Systems II" (3cr, Req's: EE 351, EE 301 or 305)
EE 551 : "Intro. to Feedback Control Systems" (3cr, Req's: EE 352)

Question: *Again PHYS 131-133*
also EE 352 has EE 301 or 305 as extra requirement.

Note: *An ECE Minor was proposed in Memo from 2/1/02 by G.J. Valco, asking if Math Majors would be interested. The draft has as required courses and labs EE 205, 301, 323, 261, 265, 206, 209. This sums to 18 cr.. It includes an additional 9 cr. of EE-Electives giving a total of 27cr. This seems a bit beyond our limitation of credit hours.*

5.A.3.g) Industrial, Welding & Systems Engineering:

- ME 400 ???? (5cr)

ME 410: "Statics" (4cr, Req's: PHYS 131, ENGRAPH 167 or CIS 201 or 202, MATH 254)

ME 430: "Dynamics" (4cr, Req's: ME 400 or 410)

CHEM 125, ECON 200, ME 430, MATH 415 and 568,

ISE 500: "Intro. to ISE" (3cr, Req's: PHYS 133, PSYCH 100, STAT 426 or 428, English 367)

Open to ind eng majors only.

ISE 509: "Statistical Process Control" (3cr, Req's: ISE 500, STAT 427 and 428)

ISE H517: "Applic. of Math. Model. to Materials Proc." (3cr, Req's: ME 500, MATH 415
ENGRAPH 167 or eq.)

ISE 521: "Operations Research I" (5cr, Req's: ISE 500, STAT 427 and 428)

ISE 522: "Operations Research II" (4cr, Req's: ISE 500, MATH 254, 415, and 568)

ISE 523: "Operations Research III" (4cr, Req's: ISE 522, MATH 254, 415, and 568)

Question: ME 400 doesn't seem to be on the books any more - I added ME 410 instead.
ISE 500 appears to be open only to ISE-majors. This course also has lots of prereq's.

5.A.3.h) Mechanical Engineering:

ME 400 ???? (5cr)

ME 410: "Statics" (4cr, Req's: PHYS 131, ENGRAPH 167 or CIS 201 or 202, MATH 254)

ME 430: "Dynamics" (4cr, Req's: ME H210 or 400 or 410)

ME 420: "Intro. Strength of Materials" (4cr, Req's: ME 410 or equiv.)

ME 440: ????

ME 500: "Engineering Thermal Sciences" (4cr, Req's: MATH 415, PHYS 132, CHEM 121)

Question: Both ME 400 and 440 don't appear to be on the books anymore.
There are PHYS 132 and CHEM 121 requirements.

5.B) BioMath Track:

The following people had either already helped me or assured me their help with the design of the biomath track.

Prof. Thomas Clanton (Physiology & Allied Medicine/Biophysics)

tclanton@pop.service.ohio-state.edu

Prof. Mitch Masters (EEOB)

wmmasters+@osu.edu

Prof. Randy Nelson (Psychology and Neuroscience)

rnelson@osu.edu

Prof. Brian Smith (Entomology and Psychology)

smith.210@osu.edu

Balbir Thomas (Ph.D. student Biology/Mathematics)

thomas.1037@osu.edu

Further web sites containing information about undergraduate biomath programs are the following:

<http://www.smb.org/teaching/>

<http://ifs.massey.ac.nz/papers/biomaths.htm>

<http://www.math.rutgers.edu/undergrad/undergrad.html>

(<http://www.math.rutgers.edu/majorb.html#interdis>)

http://www.scranton.edu/academics/ac_factsheet_biomathematics.shtml

<http://www.bio.upenn.edu/programs/undergraduate/concentrations/compbio.html>

http://www2.acs.ncsu.edu/reg_records/crs_cat/ST.html#ST771

<http://life.biology.mcmaster.ca/~brian/biomath.html>

<http://www.math.uiowa.edu/Undergrad/UGH2001.htm>

<http://www.math.ucla.edu/undergrad/majors/major.aplsci.medlife.html>

<http://www.ms.washington.edu/acms/bsdegree00/bls/>

<http://www.math.lsa.umich.edu/undergrad/math-sci.shtml>

http://www2.hmc.edu/www_common/biology/academics/biomath.html

From the comments of these people, information on these web sites, and the OSU course catalog I compiled the following templates. There are bound to be many inadequacies, gaps, and sheer nonsense. It is strongly advised to carefully comb through them!!

5.B.0) Core Elective:

Biology 113, 114 (or Biology H115, H116) (5 cr each)

Note: *Courses been mentioned by everyone and are prerequisites to about any other biology course*

Note: *The credit hours could be counted towards GEC reqs. or Electives rather than the Major*

Note: *Several courses also have 100-level chemistry and physics prereq's, but also they should be absorbed in GEC and Elective reqs'.*

Note: *An Introductory Biomath Course may be added here - see Section 8.B)*

5.B.1) BIOLOGICAL SCIENCES MINORS

5.B.1.a) Evolution, Ecology, and Organismal Biology:

Note: EEOB was mentioned by everyone as a very natural minor for a biomath track. Courses EEOB 410, 413, 617 and 714 were suggested by Masters and Clanton mentioned to me.

EEOB 413: "Introduction to Ecology" (**3(+2)cr**, Req's: 10 cr in BIO)

EEOB 617: "Theoretical Ecology" (**5cr**, Req's: EEOB 413)

EEOB 714: "Theoretical Ecology II" (**4(+2)cr**, Req's: EEOB 617)

EEOB 671: "Plant Population Ecology" (**5cr**, Req's: EEOB 413, MATH 151)

Additional/Alternate Courses

EEOB H413: "Introduction to Ecology" (**4cr**, Req's: 10 cr in BIO , MATH 151)

EEOB 410: "Animal Form and Function" (**3cr**, Req's: BIO 114 or H116, CHEM 122, MATH 148, PHYS 111 or 131)

EEOB 512: "Laboratory in Vertebrate Dissection" (**2cr**, Req's: EEOB 410)

EEOB 636: "Animal Biomechanics" (**5cr**, Req's: EEOB 410, 512)

EEOB 400: "Evolution" (**5cr**, Req's: BIO 114 or H116) (??)

5.B.1.b) Molecular Genetics:

*Note: Genetics was mentioned by Smith together with introductory courses.
MOLGEN 500 is apparently redundant when also taking MOLGEN 605/606. It seems it's better to drop MOLGEN 500 and add on one of the additional courses.
Courses seem to have non-trivial math reqs. and applications!*

BIOCHEM 511: "Intro. to Biological Chemistry" (**5cr**, Req's: CHEM 123 and 242 or 252)

MOLGEN 500: "General Genetics" (**5cr**, Req's: BIO 113, +5 cr's in BIO , CHEM 232 or 252)

MOLGEN 605: "Molecular Genetics I" (**3cr**, Req's: BIOCHEM 511, MATH 152)

MOLGEN 606: "Molecular Genetics II" (**3cr**, Req's: MOLGEN 605, Closed to students w/ credit for 500)

Additional/Alternate Courses

MOLGEN 650: "Analysis and Interpretation of Biological Data I" (**5cr**, Req's:)

MICROBIO H610: "Bioinformat. & Molec. Microbio." (**5cr**, Req's: MICROBIO 581 or MOLGEN 605 or BIOCHEM 511)

5.B.2) PSYCHOLOGY MINORS:

5.B.2.a) Neuroscience:

*Note: Regular Neuroscience courses seem to exist only on the graduate level at OSU.
Smith says Psychology offers sound courses in Psychobiology on undergraduate level.*

PSYCH 300: "Research in Psychology" (4cr, Req's: PSYCH 100)

PSYCH 313: "Intro. to Psychobiology" (3cr, Req's: PSYCH 300)

PSYCH 501: "Advanced Psychobiology" (Psychopathology) (4cr, Req's: PSYCH 313)

PSYCH 626: "Sensory Psychobiology" (3cr, Req's: PSYCH 501 or EEOB 532 or 632, or perm.)

Additional/Alternate Courses

PSYCH 513: "Intro. to Cognitive Neuroscience" (4cr, Req's: PSYCH 313)

EEOB 632: "Neurobiology" (3cr, Req's: 10 cr of biosci @ 500+ level) (????)

5.B.2.b) Quantitative/Mathematical Psychology:

Note: Looks like a nice sequence leading up to math modeling

PSYCH 321: "Quantit. & Statis. Methods in Psych." (4cr, Req's: PSYCH 100; and PSYCH 219
or 320 or STAT 145 or 245)

PSYCH 608: "Intro. to Math. Psychology" (3cr, Req's: PSYCH 221, or 321)

PSYCH 609: "Intro. Math. Models Experi. Psych." (4cr, Req's: PSYCH 608, and
PSYCH 221, or 321)

PSYCH 610: "Contemp. Math. Models/Theories Psych." (4cr, Req's: PSYCH 608, and
PSYCH 221, or 321)

5.B.3) STATISTICS MINORS:

5.B.3.a) BioStatistics:

*Note: Biostatistics sounds like an obvious track. However, I can't seem to get anything reasonable together.
So here just a list of course with the prereq's to choose from:*

STAT 620: "Statistical Theory I" (4cr, Req's: MATH 548 (real analysis))

STAT 621: "Statistical Theory II" (4cr, Req's: STAT 620)

STAT 622: "Statistical Theory III" (4cr, Req's: STAT 621)

BIOSTAT 865: "Analysis of Discrete Data" (3cr, Req's: STAT 622, 742, or perm)

STAT 528: "Data Analysis I" (3cr, Req's: *grd stdg*)
STAT 529: "Data Analysis II" (3cr, Req's: STAT 528)
STAT 530: "Data Analysis III" (3cr, Req's: STAT 529)
STAT 662: "Environmental Statistics" (3cr, Req's: STAT 530 or *equiv.*)

BIOSTAT H318: "Introduction to Biostatistics"
(5cr, Req's: MATH 153 or (H)162, for honors students majoring in *bio./med. sci.*)

STAT 722: "Theory of Probability" (4cr, Req's: MATH 653 (*real analysis*))

BIOSTAT 805: "Survival Analysis I" (3cr, Req's: STAT 722)

BIOSTAT 806: "Survival Analysis II" (3cr, Req's: BIOSTAT 805)

5.B.xx) More Bio Courses:

Note: *Below a few more courses that could have intersection with mathematics and could be integrated into a track.*

MICROBIO 522 Basic Immunology
MICROBIO 641 Quantum Mechanics and Biology
BIOCHEM 613-615, 721
Biomedical Engineering 600, 721
Chemical Engineering 765
Neuroscience (Graduate Program) 716, 723, 724.

5.C) Discrete Math Track:

5.C.1) MATH MINOR PROGRAMS (CORE SEQUENCES)

Note: *These add up to only 8-12 cr (<< 15 cr).
- perhaps some of the "additional" courses should be moved here in order to provide more structure. .
- is there a way to add non-MATH course as in other tracks?*

5.C.1.a) Analysis Math Minor:

MATH 547-549 (9cr): "Analysis"

Question: *I don't understand this minor. How does it differ from the core req's and in its role in an applied discrete track?*

5.C.1.b) Algebra/Number Theory Math Minor:

MATH 582: "Algebra III" (3cr, Req's: MATH 345 and 568)

MATH m : “Applied Algebra” Sequence_(?), (**5cr**)

Note: *To be designed ... see Section 8 below*

5.C.1.c) Logic and Computation Math Minor:

MATH $n - (n + 2)$: “Applied Logic Sequence” (**9 cr.**)

Note: *To be designed ... see Section 8 below*

5.C.1.d) Combinatorics Math Minor:

MATH 575: “Combinatorial Mathematics and Graph Theory” (**5cr**, *Req’s: MATH 568*)

Note: *very low number of credit hours ... perhaps move MATH 578 here?*

6 Additional Courses for Tracks

6.A) Physics Engineering Track:

- MATH 345: “Foundations of higher mathematics” (**4cr.**)
- MATH 513: “Vector Analysis for Engineers” (**3cr.**)
- MATH 514: “Complex Variables for Engineers” (**3cr.**)
- MATH 606: “Introduction to the Numerical Solution of PDE’s” (**3cr.**)
- AERO ENG 615: “Introduction to Computational Aerodynamics” (**3cr.**)
- MECH ENG 707: “Numerical Methods in Particle Diffusion, Heat Transfer and Radiation Transport” (**3cr.**)

6.B) BioMath Track:

- Project Type Courses in BioMath (see Section 8)
- A selection of the “Additional/Alternate Courses”

6.C) Discrete Math Track:

Math Courses:

- MATH 578: “Discrete Mathematical Models”
- MATH zzz: “Mathematical Coding Theory” (Dijen’s course, for details see Section 8)
- MATH 635(?): “Game Theory” (to be designed, for details see Section 8)
- MATH 514 or 552: “Complex Variables”
- Probability: STAT 427-428, STAT 520-521 or MATH 530

<p><i>Note: These are already in the “II. Required Courses, Optional Tracks” Section</i></p>
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CIS Courses:

- Numerical Analysis: CIS 541 (**3cr**), CIS 640 or MATH 606-607
- Theory of Computation: CIS 625 (**3cr**)
- Algorithms and Data Structures: CIS 680 (**3cr**)
- Basic Theory of Programming: CIS 221-222 (**8cr**)

7 Guidelines for Free Design Track

????

8 Courses still in Need of Design and Development

8.1 Core Courses:

8.1.1 Analysis Sequence:

There is controversy and dismay about the adequacy of the introductory analysis sequence MATH 345, 547, 548, 549 for the applied math options. Here are some of the criticisms that were expressed:

- * “Asking four quarters of analysis from an applied math major is a lot”.
- * “The sequence is painfully slow. E.g., integrals are not introduced until MATH 549”.
- * “The material tends to be rather bland and lacking motivation/application”.
- * “A course introducing students for the first time to proofs should have recitations”.

There is a general sentiment that it would be better to design an independent analysis sequence. Some of the goals of a new design are the following:

- The sequence should be preferably only two quarters long, and certainly no more than three quarters. The total credit hours should be in the 8-9 cr range.
- Recitations would be very valuable, particularly for a faster paced proof-oriented course.
- Since it will be listed in the “I.D Pure Math” section of requirements, the sequence should introduce proof writing. It is up for debate whether that needs to be done in a separate preparatory course, like the present MATH 345, or if this can be accomplished through introductory chapters, e.g., about set theory, number systems, and point set topology, in an Analysis I course.

Arguments for a MATH 345-like design are that students in the analysis oriented tracks are exposed to a piece of discrete math, while their other courses are continuous math. Arguments for learning the proof writing within the analysis courses are that proof are practiced on the relevant mathematics avoiding redundancy in the curriculum.

- The basics of $\epsilon\delta$ -arguments should be taught. A more practical view toward dealing with confidence/stability issues in applied and numerical problems would be appropriate.
- A few basic examples in the direction of differential equations and Fourier analysis would help to make the course more attractive.

As starting points for a design one could use the current H190, H191 sequence that is presently regarded as a substitute for the MATH 345, 547-549 sequence. Instead of Spivak the textbook of Walter Rudin was mentioned as a possibility. The following list of topics was proposed for a concise syllabus:

1. Some Set Theory (Intro. to Rigorous Proof, geom. thinking)
2. Short Intro to \mathbb{R} . (Rigorous Proof)
3. Topology on \mathbb{R} . (Open, closed, compact, connected sets, state results on \mathbb{R}^n)

4. Continuous functions on \mathbb{R} .
5. Convergence of Sequences in \mathbb{R} and \mathbb{C} .
6. Convergence of Sequences of functions. (ptws., unif.)
7. Convergence of Series (basic tests, power series, Fourier Series(if time))
8. Differentiation of functions $\mathbb{R} \rightarrow \mathbb{R}$. (briefly state results on $\mathbb{R}^n \rightarrow \mathbb{R}^m$)
9. Integration (Riemann-Stieltjes, Lebesgue (if time))

8.1.2 ODE & PDE:

MATH 556/557 doesn't seem to have been running in recent times.

The course thus needs some revitalization and review of the syllabus.

To be observed in the review is that the course should not duplicate MATH 715/716 but rather be taught with a views towards applications (e.g., dynamical systems).

8.1.3 Basic Pure/Discrete Courses:

The regular higher pure math courses in algebra and topology might turn out to be too advanced to be realistic for applied math majors.

Some special additional courses to fulfill the core pure math reqs' could be thought of.

8.A) Physics Engineering Track:

Question: *Are there possibilities for project oriented courses also in Engineering and Discrete Tracks ??*

8.B) BioMath Track:

8.B.1) Intro to Bio Mathematics:

A general Introductory course that can be added to the "Biology Core Elective" in Section 5.B.0):

(David Terman)

8.B.2) Project Oriented Courses:

Suggested by David Terman.

One or two courses particularly designed to study mathematics applications to biology in a project oriented format.

8.C) Discrete Math Track:

8.C.1) Coding Theory Course:

Proposer: Dijen Ray-Chaudhuri.

Credit: One quarter. (3-5 cr.)

Possible number: MATH 576. H576 is for "Number Theory through History"

Title: Mathematical Coding Theory (with elements of Cryptography)

Dijen: "This will be a particularly attractive topic for many students in my opinion. Students of the 'Pure Tract' also could be interested in such a course as an elective course. If there is interest a Honors version could also be offered. There are several books at a suitable level:

1. Raymond Hill, A First Course in Coding Theory, Oxford Applied Mathematics and Computing Science Series, Clarendon Press, Oxford ISBN 0 19 853803 0.
2. Vera Pless, Introduction to The Theory of Error-Correcting Codes , A Wiley-Interscience Publication, John Wiley and Sons, ISBN 0-471-08684-39 (This is a little more difficult book, it will be suitable for the Honors track. Some sections are accessible.)
3. Albrecht Beutelspacher, Cryptology, The Mathematical Association of America. ISBN 0-88385-504-6 4.

Some sections of Doug Stinson's book on Cryptography are usable."

8.C.2) Applied Logic Course:

A 3 quarter course, 3 cr each quarter.

Tim Carlson taught this before.

Topics are:

Logic Programming, type theory, modal and dynamics logics, logics for program verification, complexity theory.

8.C.3) Applied Algebra Course:

One quarter course, 3-5 cr

Tim Carlson, Akos Seress.

Topics are:

Factoring, pseudo-random numbers, finite Fourier transform, arithmetic complexity of operations, coding theory and automata.

8.C.4) Game Theory Course:

<i>Note: An outline would be helpful</i>
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9 Sample Schedule:

This one is for Discrete Math (Tim Carlson)

<i>Note: Same should be provided for other tracks</i>
