# MA4M9-15 Mathematics of Neuronal Networks

## 26/27

**Department**
Warwick Mathematics Institute
**Level**
Undergraduate Level 4
**Module leader**
Magnus Richardson
**Credit value**
15
**Module duration**
10 weeks
**Assessment**
Multiple
**Study location**
University of Warwick main campus, Coventry

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## Description

## Introductory description

This module introduces the mathematics developed to understand how natural computation might emerge in neuronal tissue and how this has inspired and is inspired by artificial neuronal networks.

Module web page

## Module aims

The module will cover:

- mathematical models of the computational units of natural neuronal networks: stochastic synapses and neurons.
- how detailed synaptic and neuronal models can be simplified and combined to describe activity at the level of coupled networks.
- how these detailed models can be further simplfied to develop abstract models of networks that can store patterns or learn from example.

## Outline syllabus

This is an indicative module outline only to give an indication of the sort of topics that may be covered. Actual sessions held may differ.

Experimentally verified mathematical models of synapses and neurons will first be developed with a particular emphasis on their noisy dynamics. These components, described in terms of stochastic differential equations, will be coupled to provide a probabilistic Fokker-Planck-based description of emergent phenomena at the population and network levels. Further abstractions of neurons and their synaptic weights will also be introduced to understand how patterns might be stored in attractor networks or learned in feedforward networks. These mathematical insights into natural and artificial neuronal networks will allow for a critical evaluation of whether currently proposed architectures reflect cognitive activity in the brain as we currently understand it.

## Learning outcomes

By the end of the module, students should be able to:

- build testable mathematical models of physiological objects such as synapses and neurons.
- understand basic stochastic differential equations and develop probabilistic descriptions of their dynamics.
- understand how emergent phenomena in networks arise from the characteristics of their coupled lower-level components.
- construct abstract, artificial neuronal networks that can learn to recall or classify patterned inputs.

## Indicative reading list

[Reading lists can be found in Talis]

## Interdisciplinary

This module covers the mathematics/biophysics of neuronal networks with a link to artificial neuronal networks and so spans multiple departmental disciplines.

## Subject specific skills

The module will teach you:

- how to build mathematical models of stochastic synapses and neurons .
- how to construct and solve basic stochastic differential equations.
- how to model the input-output transformation of neurons as a function of their physiology.
- how to mathematically predict the emergent states of coupled networks of neurons.
- how abstract models of neurons are used to construct artificial attractor and feedforward neuronal networks.

## Transferable skills

The transferable skills taught are:

- the ability to construct testable mathematical models of real-world systems.
- understanding of stochastic differential equations and their construction.
- how artificial neuronal networks learn input patterns.

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## Study

## Study time

| Type | Required |
| --- | --- |
| Lectures | 30 sessions of 1 hour (27%) |
| Tutorials | 10 sessions of 1 hour (9%) |
| Private study | 70 hours (64%) |
| Total | 110 hours |

## Private study description

Students are expected to work through the lecture notes, prepare for the tutorials and prepare for and sit the exam.

## Costs

No further costs have been identified for this module.

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## Assessment

You must pass all assessment components to pass the module.

### Assessment group B

| | Weighting | Study time | Eligible for self-certification |
| --- | --- | --- | --- |
| Centrally-timetabled examination (On-campus)<br>Centrally timetabled written exam. | 100% | 40 hours | No |

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- Answerbook Gold (24 page)

### Assessment group R

| | Weighting | Study time | Eligible for self-certification |
|---|---|---|---|
| In-person Examination - Resit | 100% | | No |
| Centrally timetabled written exam. | | | |

- Answerbook Gold (24 page)

**Feedback on assessment**

Students will have access to previous exams for preparation and have feedback from the lecturer.

Past exam papers for MA4M9

## Availability

## Courses

This module is Optional for:

- Year 1 of TMAA-G1PE Master of Advanced Study in Mathematical Sciences
- Year 1 of TMAA-G1PD Postgraduate Taught Interdisciplinary Mathematics (Diploma plus MSc)
- Year 1 of TMAA-G1P0 Postgraduate Taught Mathematics
- TMAA-G1PC Postgraduate Taught Mathematics (Diploma plus MSc)
  - Year 1 of G1PC Mathematics (Diploma plus MSc)
  - Year 2 of G1PC Mathematics (Diploma plus MSc)

This module is Core option list F for:

- Year 4 of UMAA-GV19 Undergraduate Mathematics and Philosophy with Specialism in Logic and Foundations

This module is Option list A for:

- Year 4 of UPXA-FG31 Undergraduate Mathematics and Physics (MMathPhys)
- Year 4 of USTA-G1G3 Undergraduate Mathematics and Statistics (BSc MMathStat)
- Year 5 of USTA-G1G4 Undergraduate Mathematics and Statistics (BSc MMathStat) (with Intercalated Year)

This module is Option list B for:

- Year 2 of TMAA-G1PD Postgraduate Taught Interdisciplinary Mathematics (Diploma plus MSc)
- Year 4 of UCSA-G4G3 Undergraduate Discrete Mathematics
- Year 5 of UCSA-G4G4 Undergraduate Discrete Mathematics (with Intercalated Year)

This module is Option list C for:

- UMAA-G105 Undergraduate Master of Mathematics (with Intercalated Year)
  - Year 4 of G105 Mathematics (MMath) with Intercalated Year
  - Year 5 of G105 Mathematics (MMath) with Intercalated Year
- UMAA-G103 Undergraduate Mathematics (MMath)
  - Year 3 of G103 Mathematics (MMath)
  - Year 4 of G103 Mathematics (MMath)
- Year 4 of UMAA-G107 Undergraduate Mathematics (MMath) with Study Abroad
- Year 4 of UMAA-G106 Undergraduate Mathematics (MMath) with Study in Europe