overview

What is synchrony?
What is synchrony?

- Populations that oscillate in space so they go up and down together? (or exactly 180 degrees out of phase?) Or different populations at the same location?
- Nerves that fire together?
- Circadian rhythms?
- ?
• Synchronous oscillatory activity is a universal phenomenon that occurs in biological systems ranging from the level of intracellular dynamics to population dynamics across thousands of kilometers.

• The study of synchrony from a mathematical standpoint has had a very long history going back at least as far as Huygens in the 1600's. However, there are still many unanswered questions involving synchronization that are of central biological importance.
The dynamics of synchrony has significant biological implications across a range of fields

- spatiotemporal dynamics of childhood diseases
- In ecology, the absence of spatial synchrony is often thought to play an important role in persistence of species.
- In neural systems, synchrony plays a role in the coordination of locomotion and respiration, in the dynamics of diseases such as Parkinson’s and epilepsy, and in sensory processing and cognition.
- Synchronous oscillations in systems of coupled oscillators are also prevalent in the fields of circadian rhythms, intracellular dynamics, as well as various areas of physics and chemistry and engineering.
- The importance of synchrony in these wide range of fields has led to large bodies of literature on synchrony that have surprisingly little cross-referencing. So a goal here is to increase communication.
Examples of synchrony in nature

- Predator-prey cycles across space (hare and lynx in Canada)—table and figure from Stenseth et al., PNAS 2004
Examples of synchrony in nature

- Synchronized species – voles and other small mammals
- Data for western Finland from Huitu et al. Ecography 2003
Examples of synchrony in nature

- Masting – one example from a New Zealand tree, Norton and Kelly 1998 Functional Ecology

\[ r = -0.49, \ P < 0.01 \] (log transformed). \( n = 31 \).

Fig. 2. Total seedfall (sound plus unfilled seeds) in rimu (\textit{Dacrydium cupressinum}) over 33 years at a site near Haririhi, West Coast, South Island New Zealand (February to May total seedfall m\(^{-2}\)) and Hokitika summer (December–February) temperature. The seedfall value for 1970 (*) is extrapolated from data at a nearby site (see text). (a) Seedfall, linear scale. (b) Seedfall, log base 10 (x + 1) scale. (c) Summer temperature.
Examples of synchrony in nature

- Insect outbreaks – Williams and Liebhold Ecology 2000

Fig. 2. Time series of detectable defoliation by eastern spruce budworm in 160 × 160 km cells in eastern North America over the 44-yr period from 1945 to 1988. The large cell at the lower right provides a key.
Time series of total weekly measles notifications for 60 towns and cities in England and Wales, for the period 1944 to 1994; the vertical blue line represents the onset of mass vaccination around 1968. (Levin, Grenfell, Hastings, Perelson, Science 1997)

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Geographical extent of synchrony</th>
<th>References</th>
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<tbody>
<tr>
<td>Protista: ciliophora</td>
<td>10–500 cm (microcosm)</td>
<td>Holyoak &amp; Lawler 1996</td>
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<tr>
<td>Fungal plant pathogen</td>
<td>0.5–3 km</td>
<td>Thrall et al. 2001</td>
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<td>Viral human pathogen</td>
<td>1–1000 km</td>
<td>Bolker &amp; Grenfell 1996, Rohani et al. 1999, Viboud et al. 2004</td>
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<td>Insect detritivores</td>
<td>5–20 m</td>
<td>Tobin &amp; Bjørnstad 2003</td>
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<tr>
<td>Fish</td>
<td>10–500 km</td>
<td>Fromentin et al. 2000; Myers et al. 1995, 1997; Ranta et al. 1995a</td>
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<tr>
<td>Amphibians</td>
<td>0.2–100 km</td>
<td>Trenham et al. 2001, 2003</td>
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<td>Mammals</td>
<td>10–1000 km</td>
<td>Bjørnstad et al. 1999b; Christiansen 1983; Elton &amp; Nicholson 1942; Grenfell et al. 1998; Ims &amp; Andreassen 2000; Mackin-Rogalska &amp; Nabaglo 1990; Moran 1953b; Post &amp; Forchhammer 2002; Ranta et al. 1995a,b, 1997a,b, 1998; Small et al. 1993; Smith 1983; Swanson &amp; Johnson 1999</td>
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<tr>
<td>Mollusks</td>
<td>2–30 km</td>
<td>Burrows et al. 2002</td>
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Much of the mathematical theory on synchronization makes assumptions that may or may not fit the biological system

• For example, one theoretical framework to study synchronization assumes that input due to coupling is pulsatile and the system quickly returns to its normal periodic cycle before subsequent input arrives.

• Another framework assumes that coupling is weak (i.e. intrinsic dynamics dominate the effects of weak coupling).

• While most theories can be extended to include heterogeneity and noise, they are assumed to be sufficiently weak.
With out of phase dynamics, predator and prey maintain reasonably high levels.
With out of phase dynamics, predator and prey maintain reasonably high levels, but when synchrony finally occurs the population crashes.
And spatial arrangement matters
Structure affects dynamics

- More regular on top
- Less regular on bottom
- Less regular more stable because it has more clusters
Goals

- Look for cross-fertilization
- Identify gaps in the theory
- Look for possible approaches to fill the gaps
Goals

• “Write” a review paper
• Generate new ideas
  – To study measures of synchrony
  – To determine new approaches for dynamics of synchrony
    • Heterogeneity, stochasticity, and more
• Foster future collaboration
  – Working groups at NIMBioS
  – Other ways