**Polistes paper wasps**

Cooperative breeding and communication

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**Paper wasp natural history**

- Primitively eusocial wasps
- Global distribution: >500 species in genus >5000 species in family (Vespidae)
- Little caste differentiation (i.e. queens and workers are very similar)
- Make nests out of wood pulp
- Wasps eat caterpillars and nectar.

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**Nest cycle**

Nests are initiated either by a single female or a group of cooperating females

Cooperative nests tend to have higher rates of survival

Reproduction is not evenly shared among foundresses

*Why do fertile foundresses cooperate to rear a nest?*
Why cooperate?

Multi-foundress nests tend to have:

(1) Higher rates of survival
(2) Higher per-capita rates of reproduction.

Why cooperate?

Dominants benefit from cooperation.

But why do subordinates cooperate?

Why cooperate?

3 reasons for subordinate cooperation in paper wasps

1. Low opportunity cost
2. Direct Benefits
3. Indirect Benefits

Compare the two options

Fitness when solitary
Fitness when subordinate
Compare the two options

Fitness when solitary
In many species single foundress nests always fail
In other species failure rates are similar for single or multiple foundress nests

Fitness when subordinate
Lower than dominant but often greater than zero

Why cooperate?

3 reasons for subordinate cooperation in paper wasps

1. Low opportunity cost
2. Direct Benefits
3. Indirect Benefits

Direct benefits of cooperation:
Subordinates in *P. dominulus* populations in Spain have elevated fitness relative to solitary individuals

Leadbeater et al 2011

Why cooperate?

3 reasons for subordinate cooperation in paper wasps

1. Low opportunity cost
2. Direct Benefits
3. Indirect Benefits
Indirect Benefits

\[ r \times b > c \]

- \( r \) = Relatedness to recipient
- \( b \) = Benefit to recipient
- \( c \) = Cost to actor

Fitness can be gained through acts that increase reproductive output of relatives

Hamilton's rule

Indirect Benefits – an example

Two wasps can either cooperate to rear a nest of found nests separately.

- If they found nests separately each wasp will have 10 offspring.
- If they cooperate, the dominance wasp will have 20 offspring and the subordinate will have 3 offspring.

If the two wasps are related by .5 should they cooperate?

What about if relatedness is .75?

Indirect Benefits?

<table>
<thead>
<tr>
<th>Species</th>
<th>Relatedness among co-foundresses</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>P. dominulus</em></td>
<td>39.5% Queller et al (2001)</td>
</tr>
<tr>
<td><em>P. fuscatus</em></td>
<td>50 ± 0.06 % Reeve et al (2000)</td>
</tr>
<tr>
<td><em>P. carolina</em></td>
<td>64 ± 0.06 % Seppa et al (2002)</td>
</tr>
<tr>
<td><em>P. bellicosus</em></td>
<td>67 ± 0.04 % Field et al (1998)</td>
</tr>
<tr>
<td><em>P. olivaceus</em></td>
<td>74 ± 0.03 % Kudin &amp; Tsuchida (2012)</td>
</tr>
</tbody>
</table>
Partitioning of reproduction among foundresses can be complicated!

Example from *P. carolina*

Variable color patterns are used to manage conflict among queens

*Polistes fuscatus*

“The North American *Polistes*, like those of other parts of the world, are quite variable in the extent, arrangement and shade of color markings. The extreme case is perhaps that of *P. fuscatus*, in which color seems to run riot and to defy any attempt at rational analysis.”

Bequaert (1940) *J NY Ent Soc*
Individual Recognition Experiment

Faces are special for humans

But specialization isn’t necessary….
Demonstrating cognitive specializations for face processing

1. Wasps learn to discriminate faces more quickly and accurately than other images

2. Normal faces are learned more quickly and accurately than manipulated faces

Sheehan & Tibbetts (2011) Science

P. fusca tus face learning

<table>
<thead>
<tr>
<th>Percent correct</th>
<th>Faces</th>
<th>Patterns</th>
<th>Caterpillars</th>
</tr>
</thead>
<tbody>
<tr>
<td>P. fusca tus face learning</td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
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</table>

P. fusca tus face learning

<table>
<thead>
<tr>
<th>Percent correct</th>
<th>Faces</th>
<th>Jumble</th>
<th>No Antenna</th>
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<tr>
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<td><img src="image3.png" alt="Image" /></td>
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</table>
Is specialization adaptive?

Specialized face learning should be associated with the evolution of facial recognition

*P. fuscatus*

Convergent evolution of specialized face processing between wasps and primates

Sheehan & Tibbetts (2011) *Science*

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Is specialization adaptive?

Species lacking IR should lack specializations for face learning

*P. fuscatus*  
*P. metricus*

No IR  
Close relative

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### P. metricus face learning

<table>
<thead>
<tr>
<th></th>
<th>Percent correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Faces</td>
<td>P &lt; 0.002</td>
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<tr>
<td>Patterns</td>
<td>P &lt; 0.007</td>
</tr>
<tr>
<td>Caterpillars</td>
<td></td>
</tr>
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</table>

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### P. fuscat us learns both species’ faces better

<table>
<thead>
<tr>
<th></th>
<th>Percent correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>P. fuscatus</td>
<td>P &lt; 0.0001</td>
</tr>
<tr>
<td>P. metricus</td>
<td>P &lt; 0.002</td>
</tr>
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</table>

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Adaptive specialization for face learning

Convergent evolution between wasps and primates
Different optical and neural structures

Divergence between two closely related paper wasps
Sympatric, very similar ecology

Sheehan & Tibbetts (2011) Science

Conflict management

How to demonstrate a quality signal

• Correlation between trait and condition
• Correlation between trait and fitness
• Manipulative experiment needed to show that proposed trait is actually conveying information
Experiment to show signaling function

Paint faces of two wasps with the same initial signal to be either low or high signals.

Let a focal wasp choose which individual it is more willing to challenge.

Video...

Guard challenged for food

Do the wasps know their own face?

Behavior and facial pattern are correlated.

What allows for a correlation?

Condition dependence
Signals and behavior are both condition dependent
Better nutrition = better fighter = stronger signal

Tibbetts & Curtis 2007

<table>
<thead>
<tr>
<th>P. fuscatus</th>
<th>P. dominulus</th>
</tr>
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<tbody>
<tr>
<td>Individual Recognition</td>
<td>Quality signal</td>
</tr>
<tr>
<td>- Nametag</td>
<td>- Karate belt</td>
</tr>
<tr>
<td>- Many variable color patterns</td>
<td>- One variable color pattern</td>
</tr>
<tr>
<td>- Remember individuals</td>
<td>- Useful in interactions with unfamiliar individuals</td>
</tr>
<tr>
<td>- Requires interaction</td>
<td>- Condition dependent</td>
</tr>
<tr>
<td>- Cognitively complex</td>
<td>- Cognitively simpler</td>
</tr>
</tbody>
</table>

Tibbetts & Curtis 2007