The design of a beautiful weapon

[*resolving the paradox of the weakening combatant*]

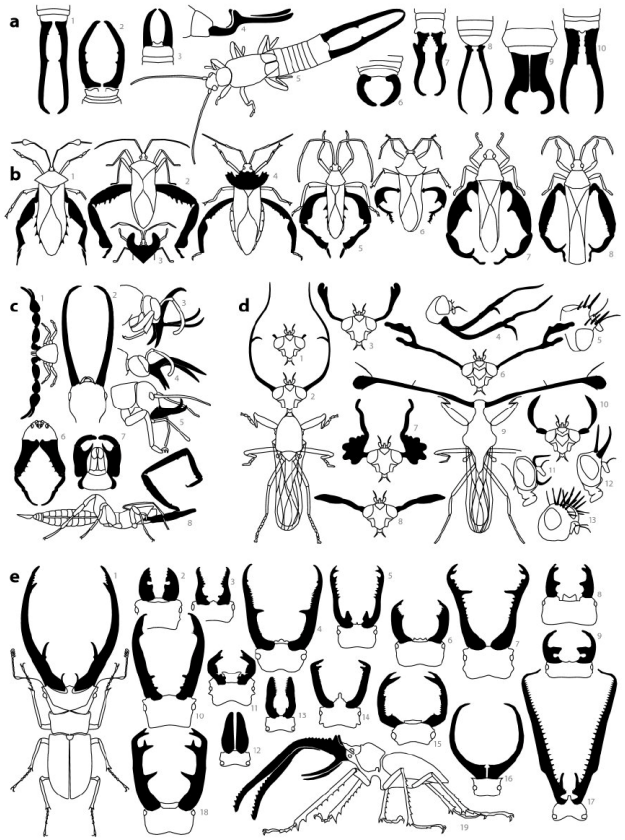
Stefan Dennenmoser

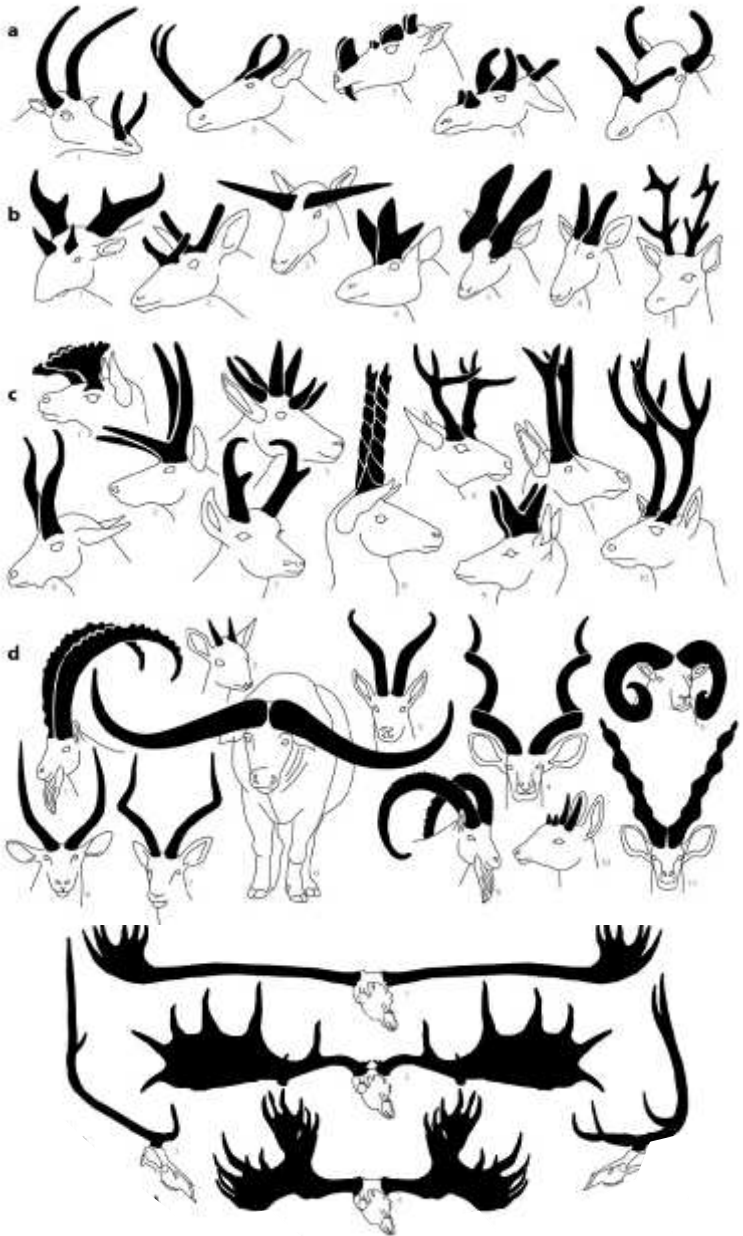
Francesca Gherardi Memorial Award

University of Florence (May 12, 2016)

Smithsonian

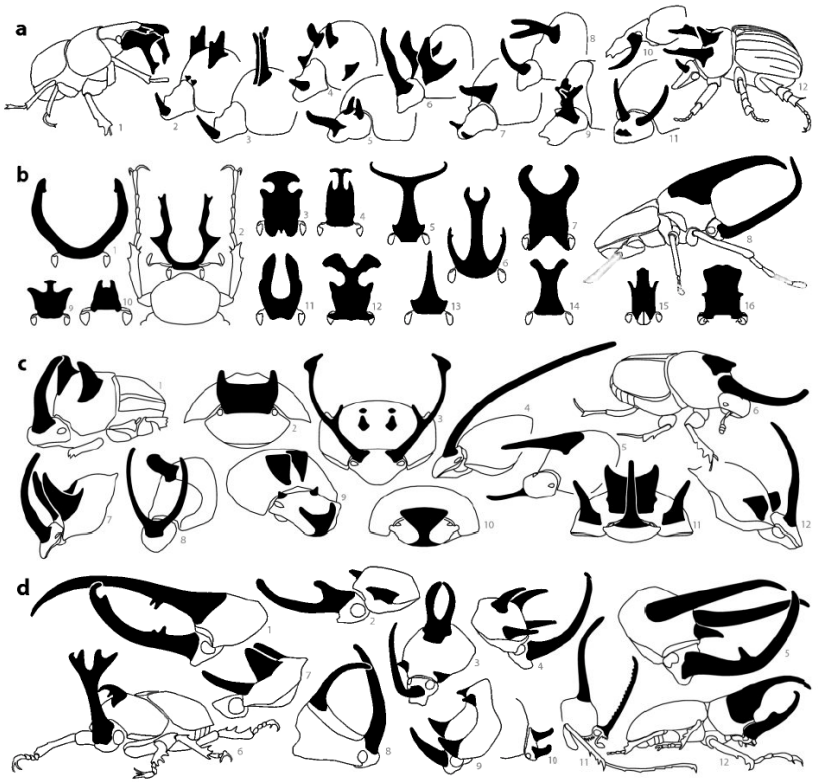
Animal weapons are highly diverse

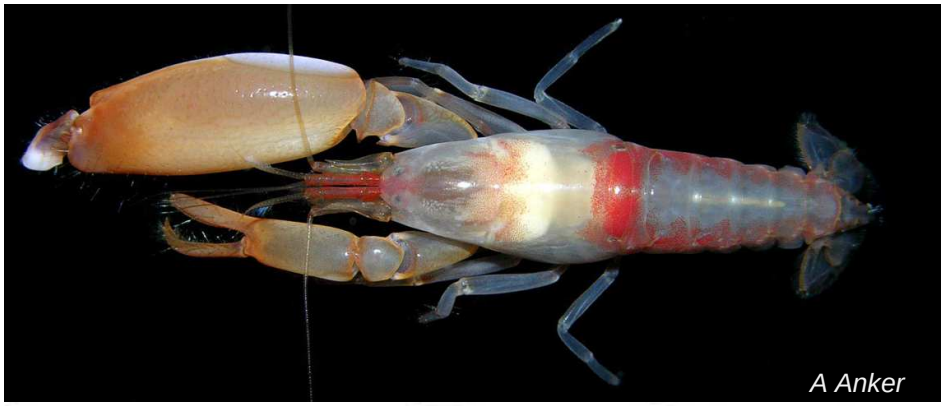


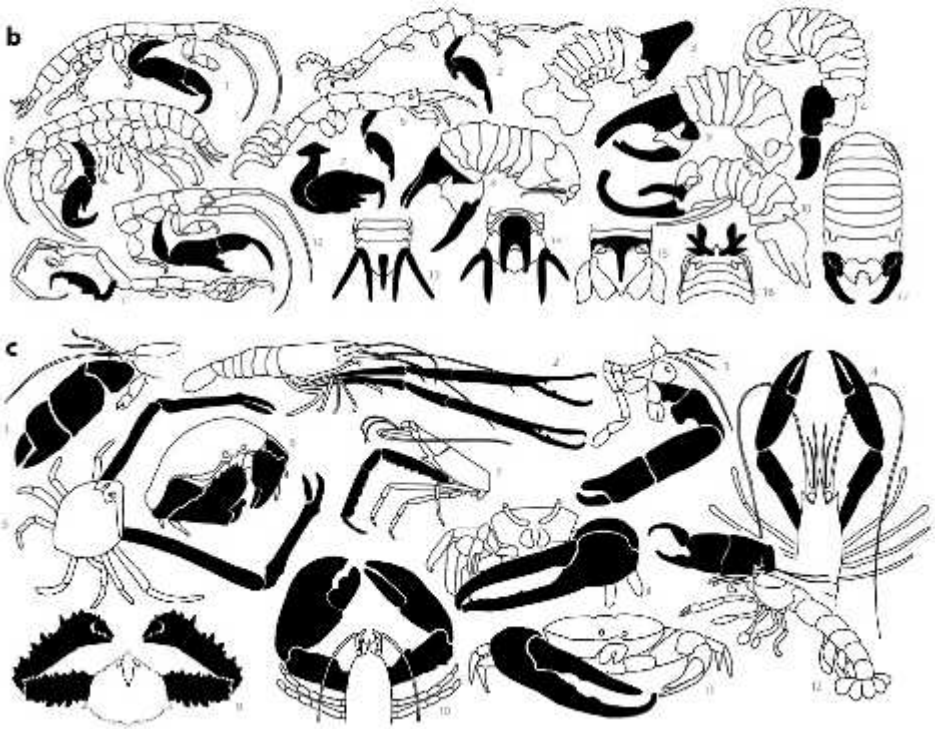


Emlen 2008

Animal weapons are highly diverse







Emlen 2008

Exaggerated growth is common

Emlen et al. 2012

Compensatory traits

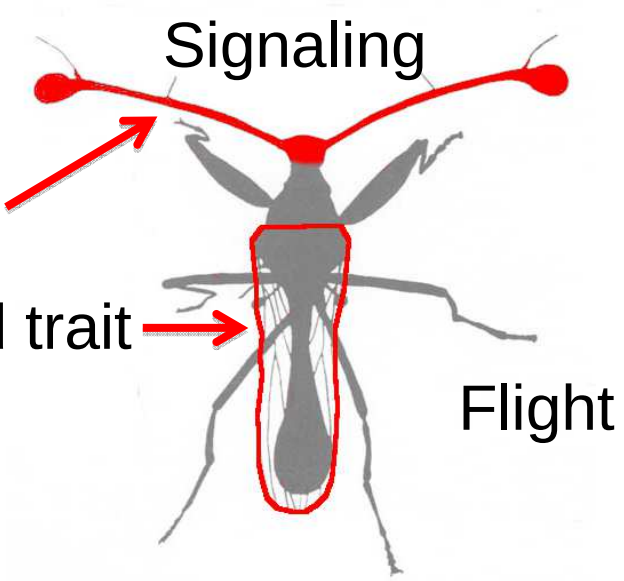
Tomkins et al. 2005, Husak and Swallow 2011

Selectional conflict in multi-functional traits?

Conflict among structures

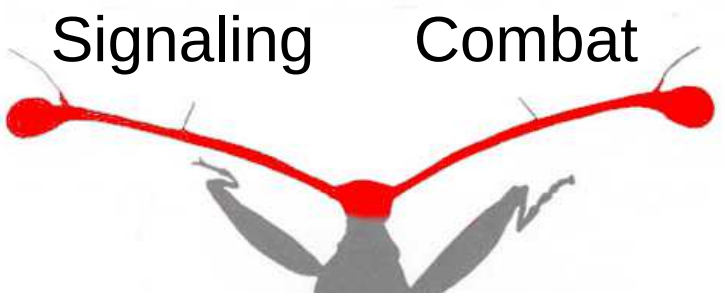
Reduce costs of exaggerated trait

Enhance performance of conflicted trait



Conflict within structures

Different functions may perform best at different trait expressions



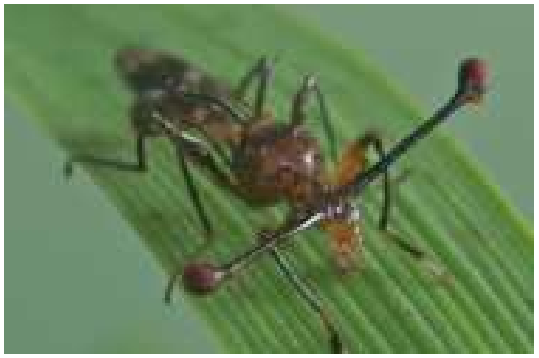
… change trait design?

Selectional conflict in multi-functional traits?

Hunt et al. (2009):

Assessed multi-functional traits in 51 species (mostly body size and signaling structures)

Male competition and female choice aligned: 82%



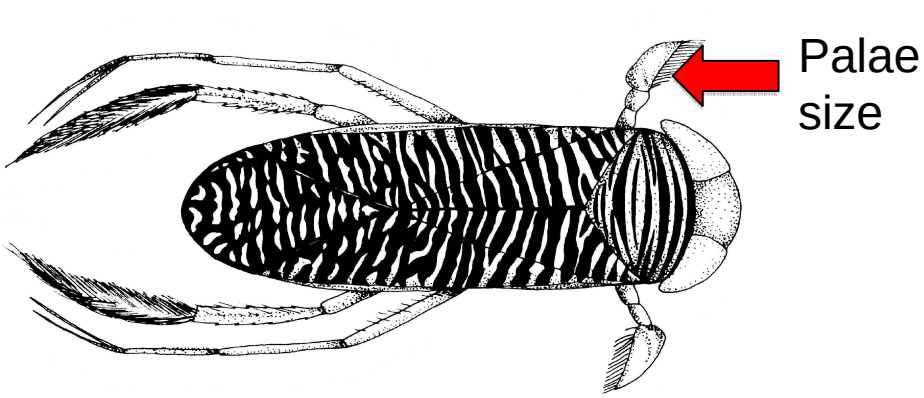
No Conflict..

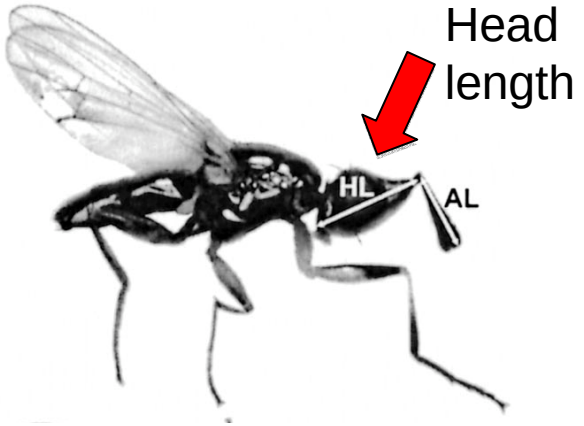
Selectional conflict in multi-functional traits?

Hunt et al. (2009):

Assessed multi-functional traits in 51 species (mostly body size and signaling structures)

Male competition and female choice opposed: 18%





Selectional Conflict!

Candolin et al. 2004, Bonduriansky and Rowe 2003

Compensation for opposed sexual selection on multi-functional traits?

Male Fiddler Crab‘s Major Claw

Mate attraction

Claw waving display
(e.g., McLain and Pratt 2007)

Weapon

Male-male combat
(e.g., Levinton and Allen 2005)

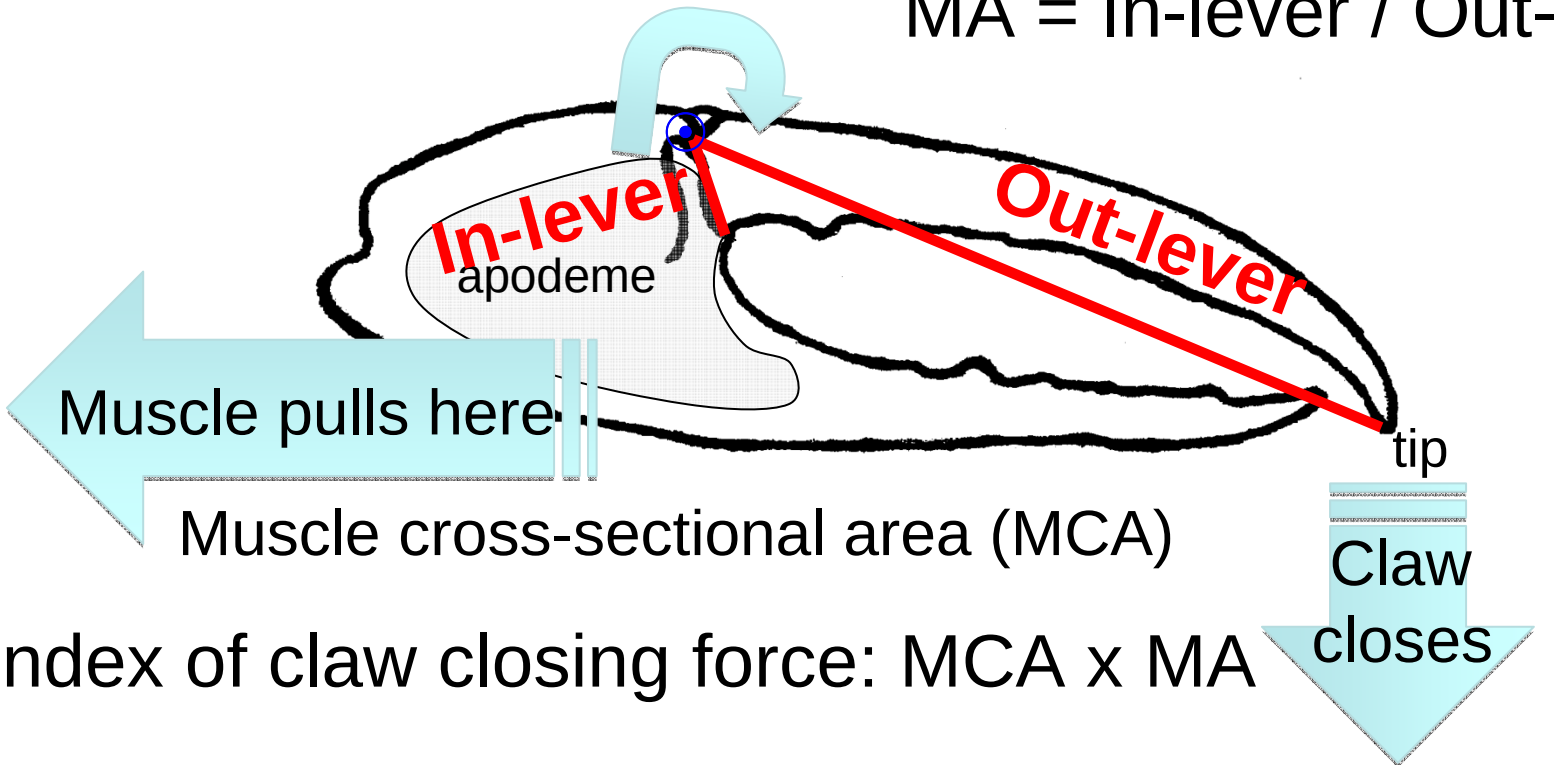
Paradox of the weakening combatant

Levinton and Allen (2005)

As claws grow and get longer fingers, they get relatively weaker because mechanical advantage decreases.

Claw as a lever system:

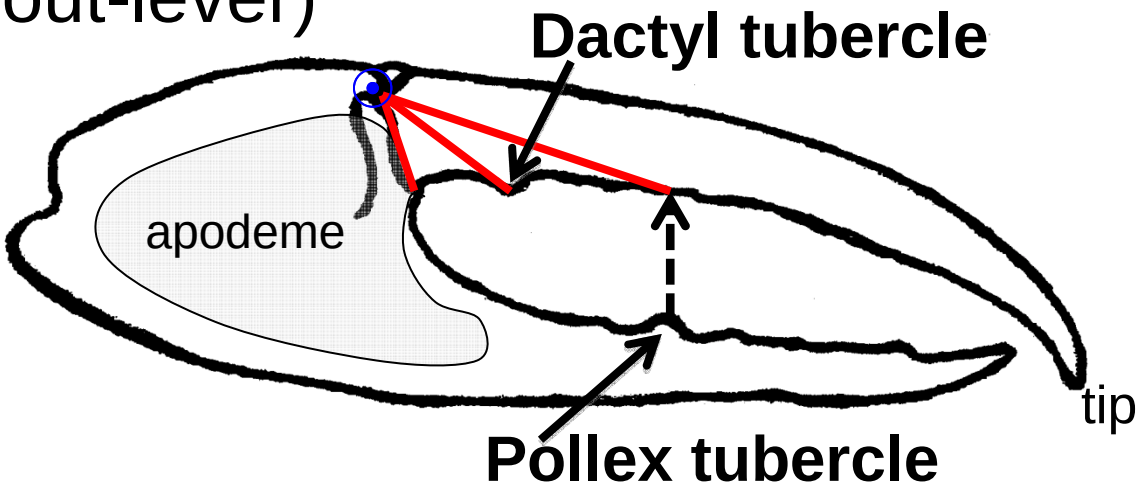
MA = In-lever / Out-lever



Index of claw closing force: MCA x MA

A possible two-part solution

1) **Crabs deliver force at tubercles instead at claw tip:**
   Better MA (shorter out-lever)



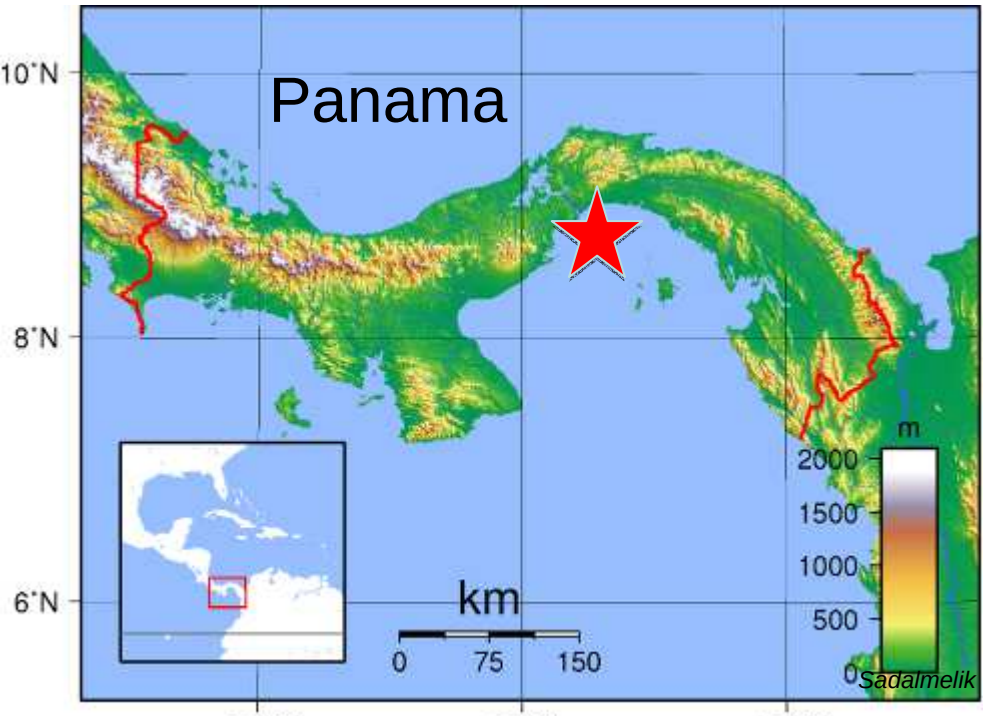
2) **Slower loss of MA at tubercles during growth**:

   Tubercles could maintain their position close to pivot

   Preserves MA of shorter claws

Dennenmoser and Christy 2013

Study area and species



Smithsonian Tropical Research Institute

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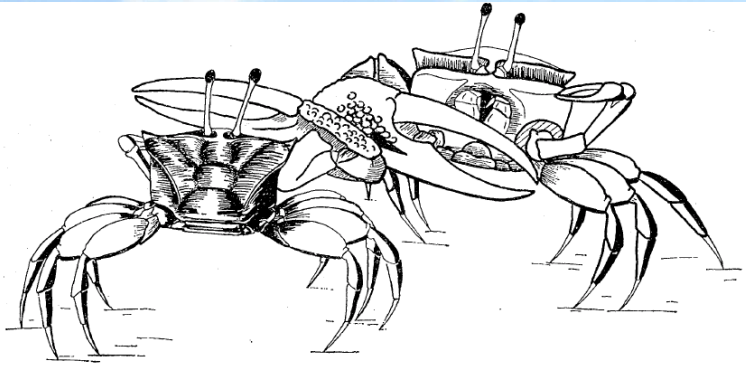
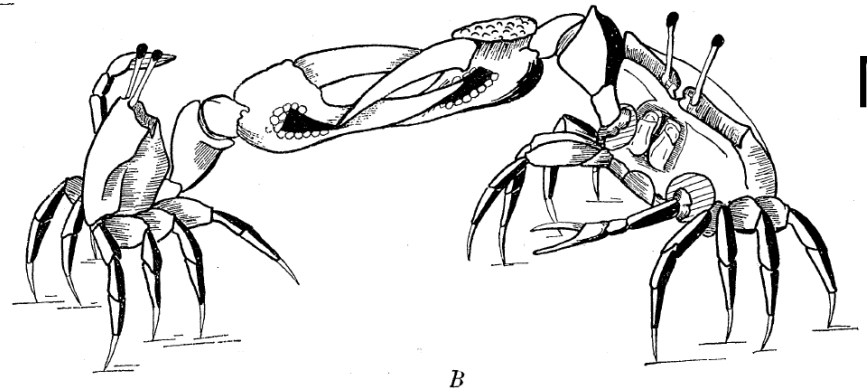
Uca terpsichores

Uca beebei

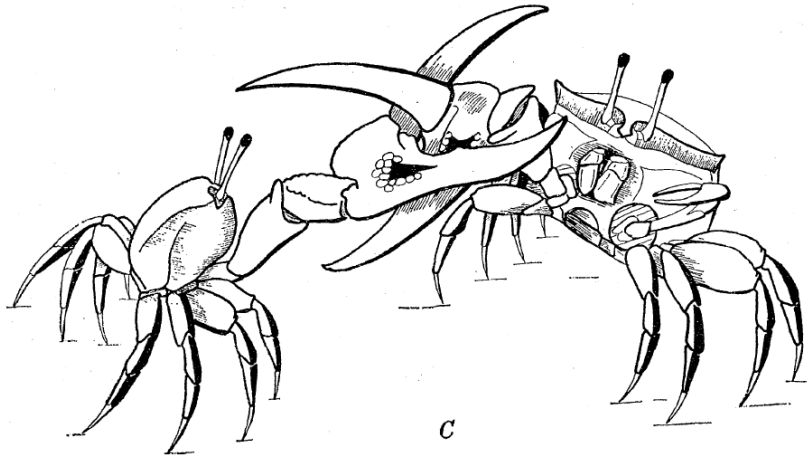
Part I: How do fiddler crabs fight?



A



B



C

Low Intensity

Manus push

Medium Intensity

Dactyl slide

High Intensity

Fully Interlaced claws

Crane 1966; Hyatt and Salmon 1978

Part I: How do fiddler crabs fight?

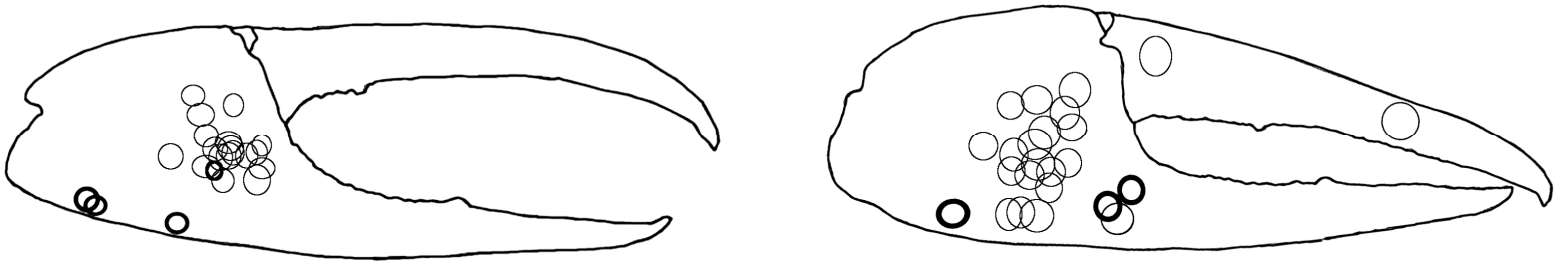
https://www.youtube.com/watch?v=hvsfNOtUfNA

Part I: Gripping force: delivered by tubercles

Uca terpsichores
22 recorded fights
18x dactyl tubercle
4x pollex tubercle

Uca beebei
24 recorded fights
21x dactyl tubercle
3x pollex tubercle

Contact points of tubercles:

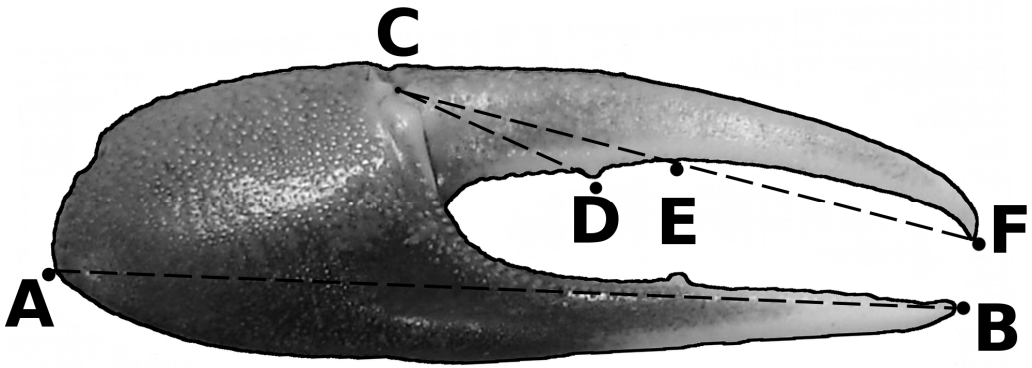


Crabs deliver force at tubercles instead at claw tip

Part 2: Slower loss of MA at tubercles?

Collected claws in the field (94x *U.terpsichores*; 121x *U.beebei*)

Measurements:



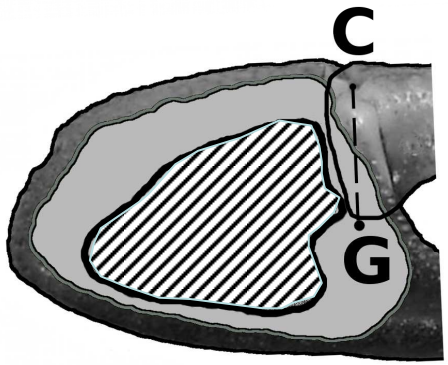
Out-lever lengths:

Dactyl tubercle (C-D)

Pollex tubercle (C-E)

Claw tip (C-F)

Claw Length (A-B)

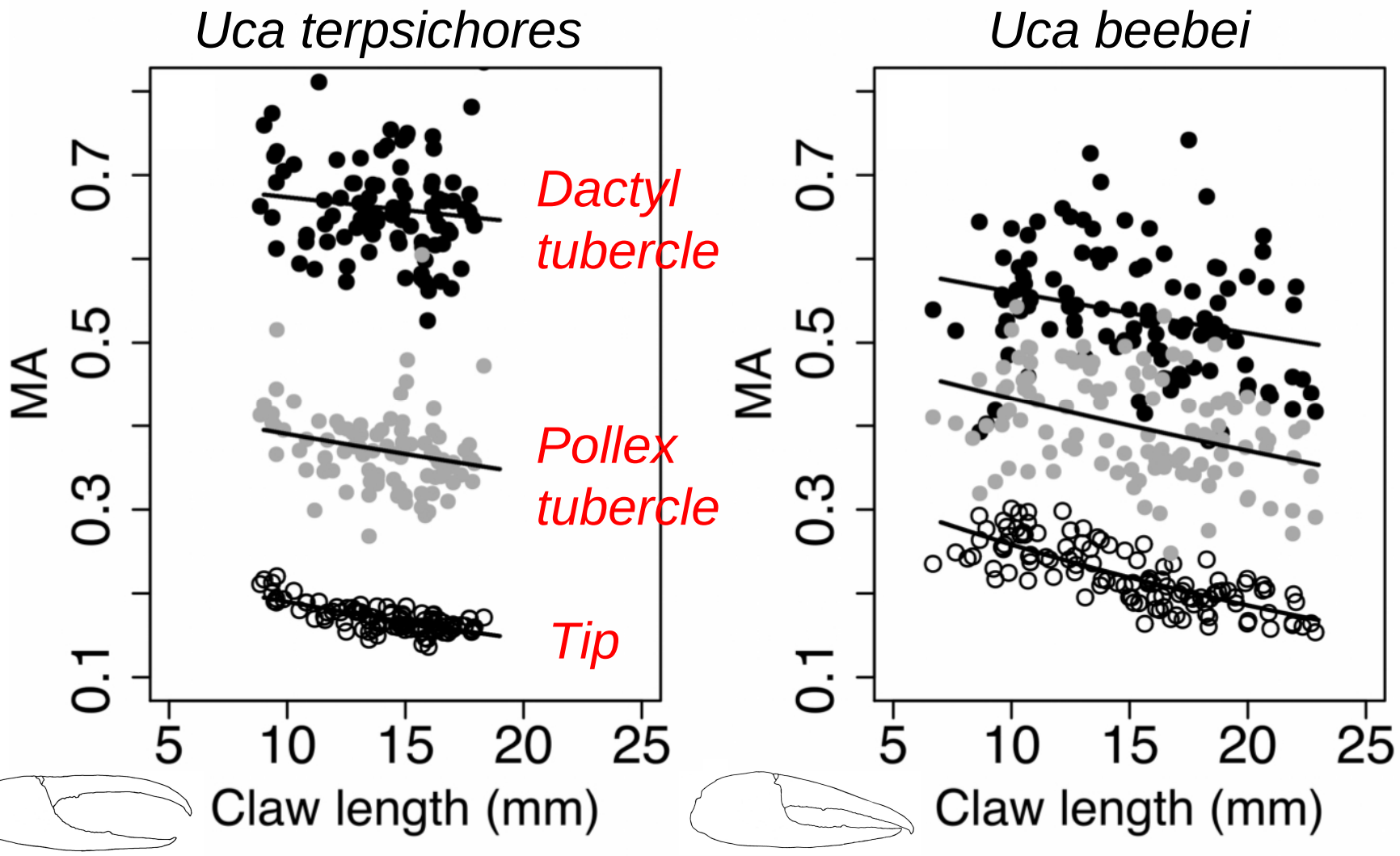


In-lever length: Dactyl height (C-G)

Apodeme area (~muscle cross sectional area)

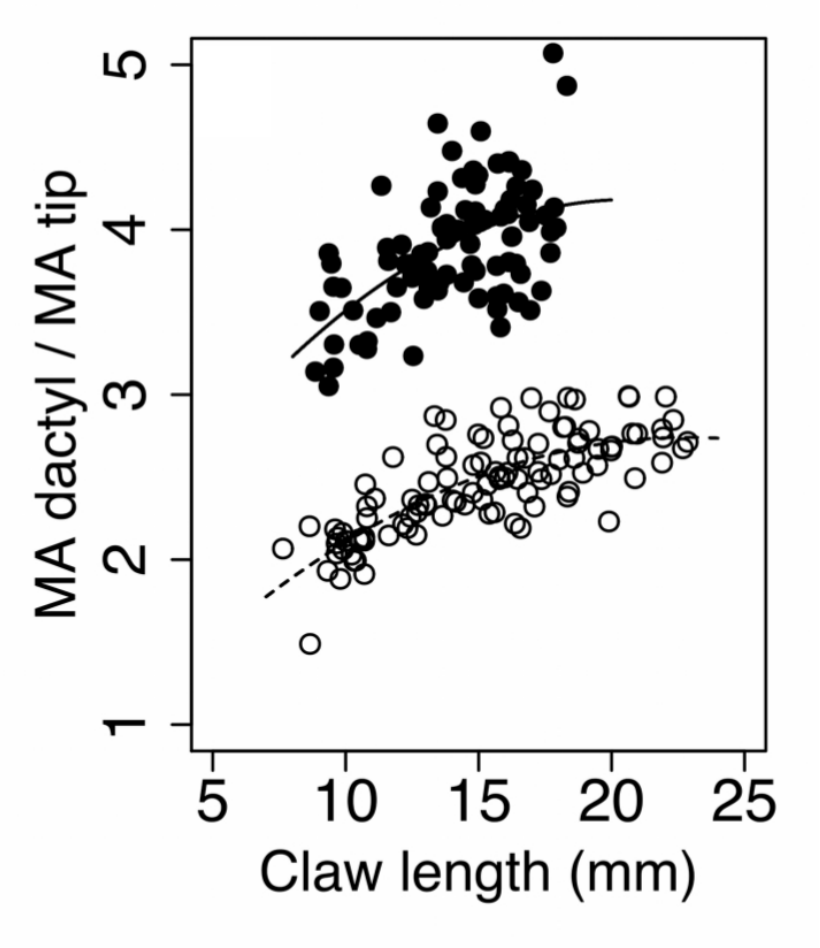
Loss of MA: lower at tubercles

Tubercles stay relatively close to the pivot as the claw grows



MA compensation at dactyl tubercle

Compensation increases with claw length



Uca terpsichores

Uca beebei

No paradox but a beautiful weapon

Mate attraction
Long, conspicious claw

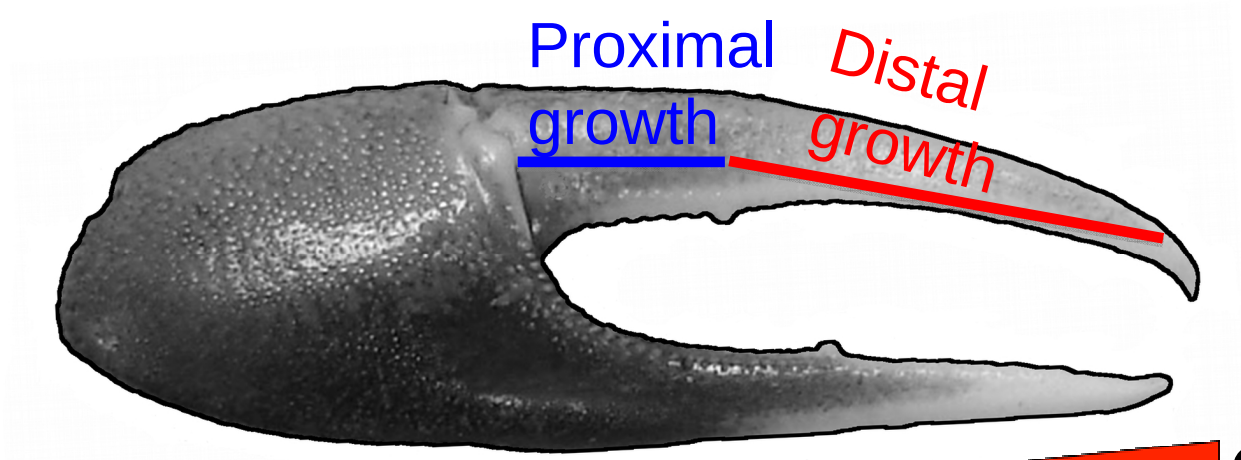
Weapon
Strong gripping force

Low MA *vs.* High MA

Tubercles

Compensatory trait: Use of tubercles to deliver gripping force

High MA is maintained during growth



Growth gradient?

Animal weapon diversity

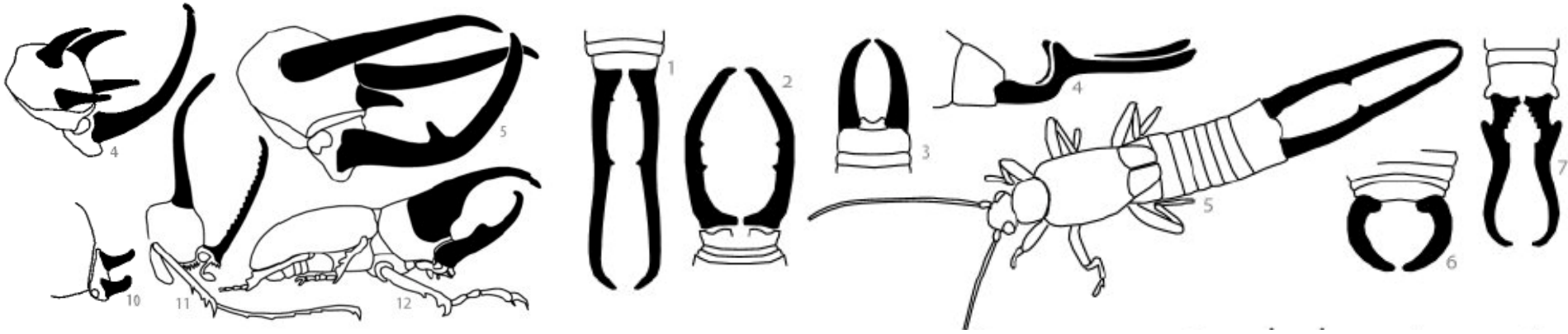
Exaggerated size (female choice; male-male combat)

Fighting style matters (e.g., levering, pinching, gripping)

Functional conflicts through opposed selective forces

Elongated structures *vs.* mechanical advantage
(signaling, levering) (gripping, pinching)

Compensation features can be integrated in weapon design



Thank you to Francesca Gherardi for many great inspirations!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Behav Ecol Sociobiol (2006) 59: 500–510
DOI 10.1007/s00265-005-0074-z

ORIGINAL ARTICLE

Francesca Gherardi

Fighting behavior in hermit crabs: the combined effect of resource-holding potential and resource value in *Pagurus longicarpus*

biology letters

Biol. Lett. (2008) **4**, 163–165
doi:10.1098/rsbl.2007.0590
Published online 12 February 2008

Animal behaviour

Evidence of female cryptic choice in crayfish

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Thank you!

The Gherardi Family
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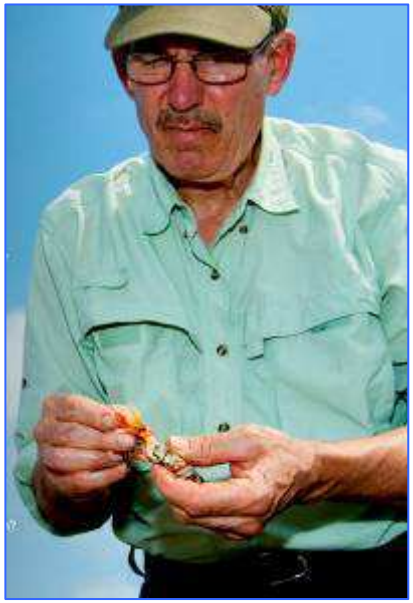
Field assistance: Taewon Kim



… questions?