Plight of the Colony

Factors Leading to Colony Collapse and Bee Demise

http://upload.wikimedia.org/wikipedia/commons/a/a1/Apis_mellifera_carnica_worker_hive_entrance_3.jpg

Beekeeping

- Egyptian practice
  - *Circa* 2400 BCE
    - Images in tombs
  - *Apis mellifera*

http://pcela.rs/Egyptian_Beekeeping_1.htm
http://upload.wikimedia.org/wikipedia/commons/9/99/Apis_mellifera_flying.jpg

Present

- Reliance upon bees
  - Demand bee products
    - Wax, honey, royal jelly
  - Agricultural role
    - 33% of food

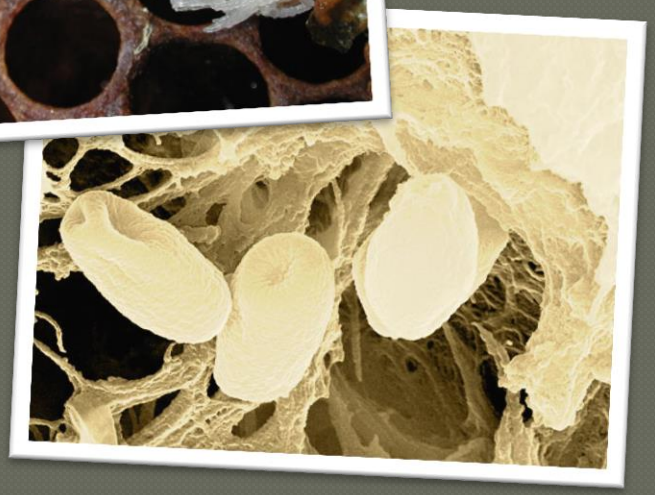
http://www.thesustainablespot.com/wp-content/uploads/2013/02/Spanish_Honey.jpg
http://www.francesca-radcliffe.com/images/puglia/FR09_12.jpg

Colony Collapse Disorder

- Winter losses (USDA 2013)
  - pre 2005 – 5 to10%
  - 2006 to 2011 – 33%
  - 2011 to 2012 – 22%
  - 2012 to 2013 – 50%
- Features (vanEngelsdorp *et al.* 2009)
  - Rapid decline/disappearance
  - surplus brood
  - may initially seem healthy

Suggested Agents

- *Nosema ceranae*
  - Microsporidium
- *Varroa destructor*
  - Mite
  - Vector action
- Viral infections
  - Many forms
- Systemic pesticides
  - Bans
  - Mechanism



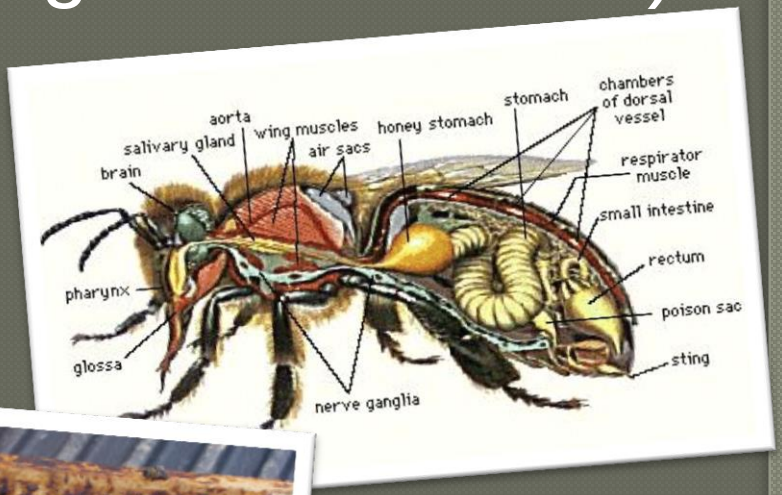
http://beespotter.mste.illinois.edu/topics/ccd/pupalmite_s.jpg http://wsm.wsu.edu/mag_images/big_brother/2010spring_bees5.jpg

Specific Question

What combination of *Nosema* infection, *Varroa* mites, viral infection, and systemic pesticides leads to symptoms of colony collapse disorder in *Apis mellifera*?

Nosema ceranae

- Effects of Nosemaosis (Highes *et al.* 2006)
  - Gut degeneration
    - Damages epithelium
    - Inhibits repair
  - 66% mortality after 6 days
- Propigation
  - Fecal-oral
  - Oral-oral



http://www.rhoneypots.com/bees/nosema2.jpg

Nosema ceranae

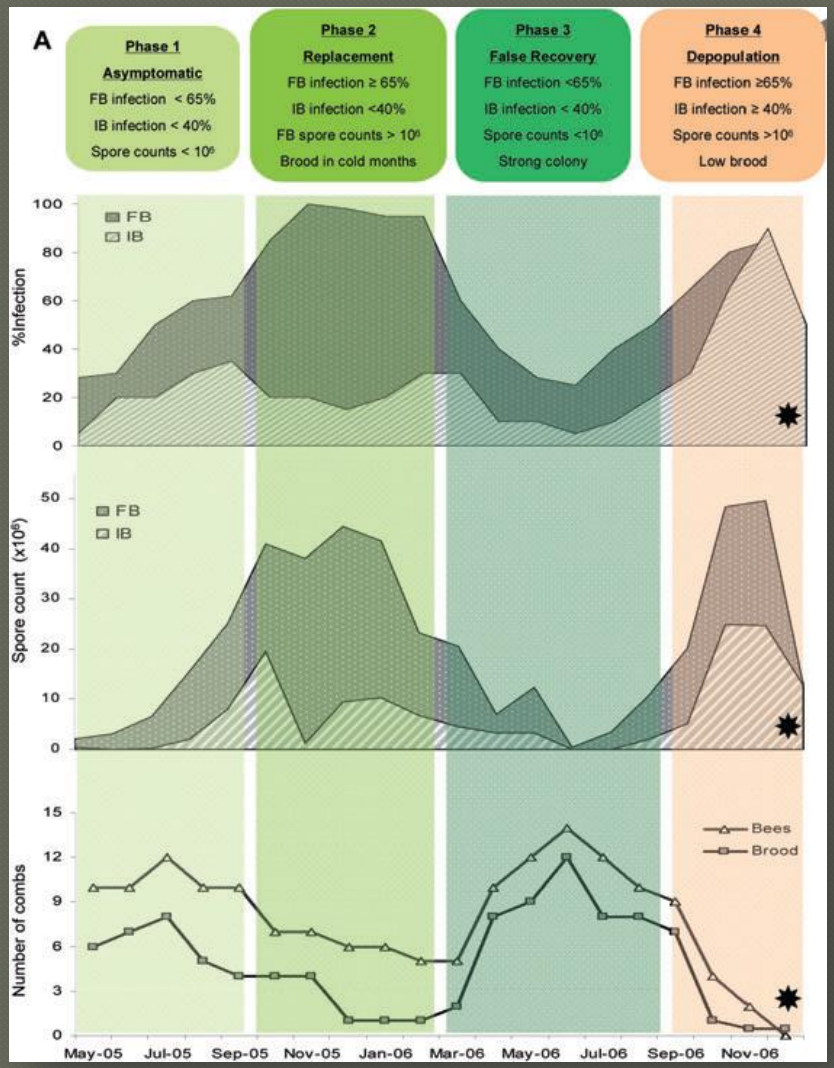
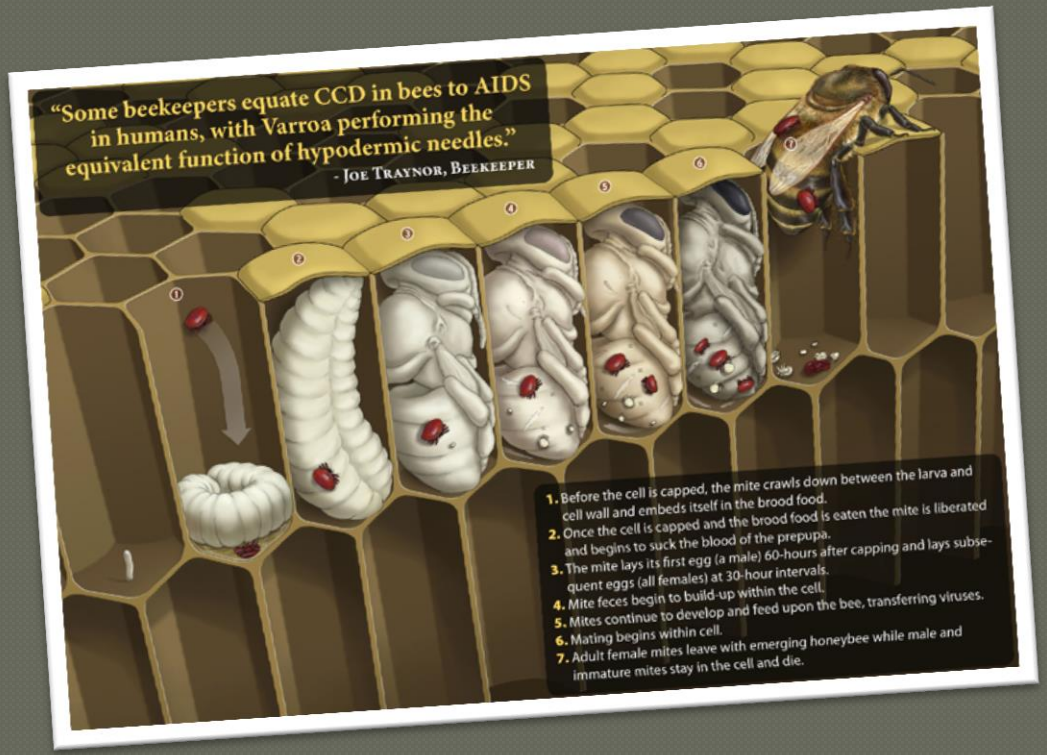


Figure 3. Clinical monitoring of *N. ceranae* natural infection.Dynamics of natural *N. ceranae* infection of a model colony and the phases of nosemosis. Percentage of *N. ceranae*-infected bees (*n* = 30), mean spore count (*n* = 30) and number of combs covered by brood or bees in the B255 colony.(Highes *et al.* 2008)

Varroa destructor

- Mechanism (Rosenkranz *et al*. 2009)
  - Life cycle
  - Vector
- Treatment
- Fatality
  - 2-3 years



http://tonylinka.com/assets/images/sci%20content/linka_varroaMite.jpg

Varroa destructor

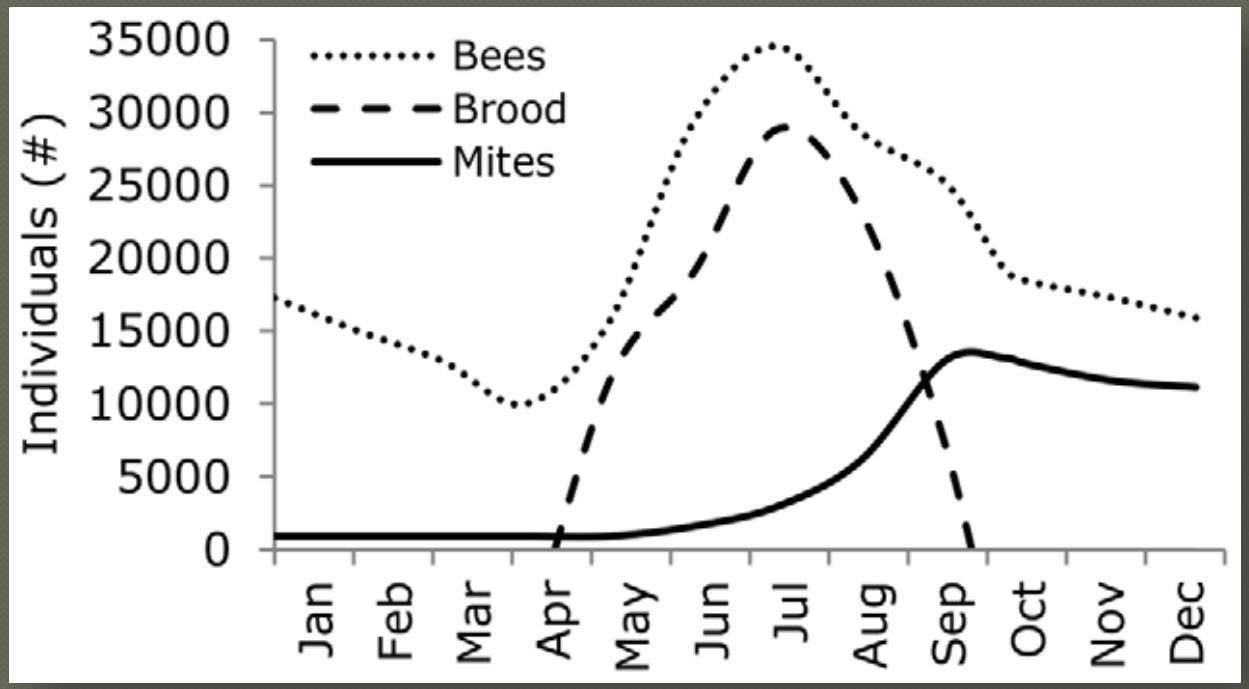


Figure 1. Colony development for adult bees, worker brood, and *Varroa destructor* mites. The daily number of individual adult bees (dotted line) and worker brood (striped line) was modeled over one year. The number of mites (solid line) was modeled as being the second year of mite infestation with a starting population of 100 mites in the first year. (van Dooremalen *et al.* 2012)

Systemic pesticides

- USDA regulation
  - Sub-lethality
    - USDA allowed: 0.7 to10 µg kg^{-1}(Whitehorn *et al.* 2012)
    - Negative effects:1 µg kg^{-1} (Bonmatin *et al.* 2005)
- Effects
  - Near 50% shorter larval lifespan (Wu *et al.* 2011)
  - Homing failure
  - Decreased queen dev.
- Bumblebees
  - Primary natural pollinator

http://www.dittonparishcouncil.gov.uk/images/Bombus_terrestris.jpg

Viral Infection

- APV Effects (Cox-Foster 2007)
  - Trembling
  - Progressive paralysis
- TRSV infection (Lian *et al.* 2014)
- Highly communicable (Runckel *et al.* 2011)
  - Effectively 100% infection
  - Can be passed to other species
- Significant co-occurance

Viral Infection

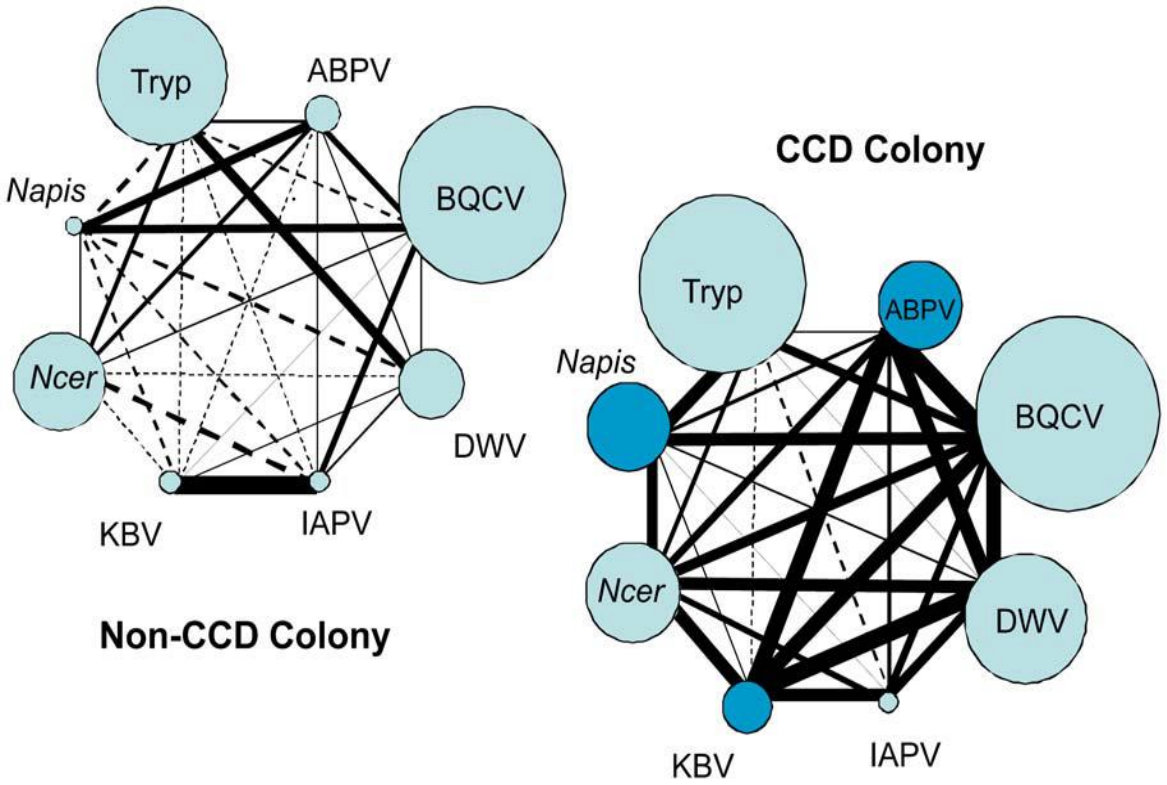


Figure 2. Graphical representation of pairwise correlations between pathogen abundance in CCD and non-CCD colonies. The thickness of lines is scaled to the Spearman's rho correlation coefficient for each pair. (Cornman *et al.* 2012)

Comorbidity

- No one factor to blame
  - *A. mellifera* pathology well understood
  - Indicated multiplicity of factors

http://www.sott.net/image/image/s4/82668/full/DEAD_BEES_0930_rdax_676x456.jpg

Nosemaosis + Neonics

- *N. ceranae* infected bees
  - Inevitable contact with systemic pesticides
- Hightened mortality (Vidau *et al.* 2011)

Varroa destructor

- Vector effect
  - Generally carry viruses
  - Varroosis may affect many systems (Le Conte *et al.* 2012)
- Collapse within 3 yr.(Rosenkranz *et al.* 2009)

Conclusion

What combination *Nosema* infection, *Varroa* mites, viral infection, and systemic pesticides leads to symptoms of colony collapse disorder in *Apis mellifera*?

- Infections may be delivered by *Varroa*
- Neonics cause homing failure/ death
- Neonic and *Nosema* effects are additive

Conclusion

- Should CCD be considered it’s own disease, or is it greater than it’s parts?
- Do these factors act together in a distinct way from understood pathology?

Broader Implications

- Natural species also effected
- Crippling agriculture
  - Price of almonds driven up this year
  - Hive rental price
    - Three-fold increase

http://beeinformed.org/wp-content/uploads/2012/02/IMG_0564.jpg

Broader Implications

- Chinese Apple/ Pear Plantations
  - Total extinction
  - Hand pollination

https://s3.amazonaws.com/cd.live/uploads/content/image/5193/main_picture_2.jpg
http://static.guim.co.uk/sys-images/Environment/Pix/columnists/2010/12/16/1292511763893/Pollination-in-China--far-006.jpg

Literature Cited

Bonmatin, J.M., Moineau, I., Charvet, R., Colin, M.E., Fleche, C., Bengsch, E.R. 2005. Behaviour of Imidaclioprid in Fields. Toxicity for Honey Bees. *Env. Chem.* 483-494.

Cornman, R.S., Tarpy, D.R., Chen, Y., Jeffreys, L., Lopez, D., Pettis, J., vanEngelsdorp, D., Evans, J.D. 2012. Pathogen Webs in Collapsing Honey Bee Colonies. *PLoS ONE* 7(8): e43562

Cox-Foster, D. 2007. Colony Collapse Disorder and Israeli Acute Paralysis Virus. *Georgia Bee Letter.* 18(3):1-13

Ciarlo, T.J., Mullin, C.A., Frazier, J.L., Schmehl, D.R. 2012. Learning Impairment in Honey Bees Caused by Agricultural Spray Adjuvants. *PLoS ONE.* 7(7): e40848

Hamdi, C., Ballo, A., Essanaa, J., Crotti, E., Gonella, E., Raddadi, N., Ricci, I., Boudabous, A., Borin, S., Manino, A., Bandi, C., Alma, A., Daffonchi, D., Cherif, A. 2010. Gut Microbiome dysbiosis and honeybee health. *J. Appl. Entomol.* 135(2011):524-533

Higes, M., Marti-Hernandez, R., Botias, C., Balion, G.B., Gonzalez-Porto, A.V., Barrios, L., Jesus del Nozal, M., Bernal, J.L., Jimenez, J.J., Palencia, P.C., Meana, A. 2008. How natural infection by *Nosema ceranae* causes honeybee colony collapse. *Env. Microbio.* 10(10):2659-2669

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Literature Cited

Rosenkrans, P., Aumeir, P., Ziegelmann, B. 2009. Biology and control of *Varroa destructor. Journ Invert Path.* 103(2010): 97-119

[USDA] United States Department of Agriculture. 2013. Honeybees and Colony Collapse Disorder. <http://www.ars.usda.gov/News/docs.htm?docid=15572>

van Dooremalen, C., Gerritsen, L., Cornelissen, B., van der Steen, J.J.M., van Langevelde, F., Blacquiere, T. 2012. Winter Survival of Individual Honey Bees and Honeybee Colonies Depends on Level of *Varroa destructor* Infestation. *PLoS ONE* 7(4): e36285

vanEngelsdorp D, Evans JD, Saegerman C, Mullin C, Haubruge E, et al. 2009. Colony Collapse Disorder: A Descriptive Study. *PLoS ONE* 4(8): e6481.

Vidau, C., Diogon, M., Aufauvre, J., Fontbonne, R., Vigue`s, B. 2011. Exposure to Sublethal Doses of Fipronil and Thiacloprid Highly Increases Mortality of Honeybees Previously Infected by *Nosema ceranae*. *PLoS ONE* 6(6): e21550.

Whitehorn, P.R., O'Connor, S., Wackers, F.L., Goulson, D. 2012. Neonicotinoid Pesticide Reduces Bumble Bee Colony Growth and Queen Production. *Science.* 336(6079):351-352

Wu, J.Y., Anelli, C.M., Sheppard, W.S. 2011. Sub-Lethal Effects of Pesticide Residues in Brood Comb on Worker Honey Bee (*Apis mellifera*) Development and Longevity. *PLoS ONE* 6(2): e14720

Question & Answer

http://www.agweb.com/assets/1/6/USDA-fields.jpg