CANCER AND LIFE HISTORY THEORY

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CAVEATS AND CONSTRAINTS

- I am an PhD Evolutionary Psychologist, not an MD Physician:
  - And I don't even play one on TV!
- Given those constraints, I will attempt to derive general principles from Life History Theory that might specifically relate to the other talks in this session on the subject of *Cooperation, Conflict, and Co-evolution:*
  - Drawing explicit analogies from psychosocial phenomena addressed in my own program of research on Human Life History Strategy

CANCER AND LIFE HISTORY: WHAT IS THE RELATION?

- Williams, Miller, Harper, & Wiersma (2010) have provided both comparative and experimental evidence in birds that the rate of *cell metabolism* is directly related to the rate of *cell division*
- Controlling for body weight, tropical bird species have *lower metabolic rates* than do temperate bird species
- Controlling for body weight, tropical bird species have *longer life spans* than do temperate bird species

CANCER AND LIFE HISTORY: WHAT IS THE RELATION?

- Cell-cultured Dermal fibroblasts derived from tropical birds have *slower rates of growth* than do such cells from birds of temperate species:
  - Consistent with the hypothesis that these cells have a slower metabolism
- Conversely, cell-cultured dermal fibroblasts derived from tropical birds *resist chemical agents* that induce oxidative and non-oxidative stress better than do such cells from birds of temperate species:
  - Consistent with the hypothesis that birds that live longer invest more in self-maintenance, such as in the antioxidant properties of cells

CANCER AND LIFE HISTORY: WHAT IS THE RELATION?

- Joyce and Pollard (2009) have provided experimental evidence that the *microenvironment* in which tumors develop play a major role in modulating the metastatic capacity of most cancers:
  - The formation of metastases has many rate-limiting steps, and certain *microenvironmental cues* are important moderating influences at each and every one of these rate-limiting steps

CANCER AND LIFE HISTORY: WHAT IS THE RELATION?

- The implication is that the different microenvironments within the body in which tumors develop may systematically select for different allocations of bioenergetic and material resources towards:
  - Faster metabolism, growth, and proliferation
  - Self-maintenance, resistance, and survival

CANCER AND LIFE HISTORY: WHAT IS THE RELATION?

- Elser, Kyle, Smith, & Nagy (2007) proposed the *Growth Rate Hypothesis* (GRH), in which a tumor growing in the body can be considered a complex ecological and evolutionary system
- The protein synthesis demands of accelerated cell proliferation in tumors produce elevated phosphorus demands, due to increased allocations to phosphorus-rich nucleic acids such as ribosomal RNA
- This suggests the preferential but differential allocation of resources in tumor tissues towards the *numerical proliferation* as opposed to the *individual survival* of cancer cells

CANCER AND LIFE HISTORY: WHAT IS THE RELATION?

- This bioenergetic tradeoff is analogous to those respectively characterizing *r-selection* (favoring allocations towards propagule proliferation) and *K-selection* (favoring allocations towards propagule survival)
- This theoretical prediction was tested by examining the different allocations made by cancer cells developing in different parts of the body
- The biochemical compositions of cancer tissues were examined and compared in the Liver, Kidney, Colon, and Lung

CANCER AND LIFE HISTORY: WHAT IS THE RELATION?

- Unstable local conditions in the *Lung* and *Colon* impose high levels of external mortality on tumor cells, producing long-term selection favoring transformed (*r-selected*) cells with increased rates of cell division:
  - These tumor tissues are *more* enriched in phosphorus and nucleic acids, as predicted by the *GRH*
- Stable local conditions in the *Liver* and *Kidney* may instead predominantly favor transformed (*K-selected*) cells with lower rates of cell mortality, such as a reduction in apoptosis:
  - These tumor tissues are *less* enriched in phosphorus and nucleic acids, as predicted by the *GRH*

SO WHAT ELSE CAN WE LEARN FROM LIFE HISTORY THEORY?

- The conditions for the evolution and development of fast and slow life history strategies have been extensively studied:
  - Reviewed in Ellis, Figueredo, Brumbach, & Schlomer (2009)
- Many of these ecological conditions have strong implications, both directly and indirectly, for the dynamics of *Cooperation, Conflict, and Co-evolution:*
  - So let's review the basic mechanisms...

LIFE HISTORY STRATEGY IS ABOUT RESOURCE ALLOCATION

- Somatic Effort:
  - Bioenergetic and material resources devoted to continued survival of individual organism
- Reproductive Effort:
  - Bioenergetic and material resources devoted to production of new organisms as vehicles for survival of individual's genes

REPRODUCTIVE EFFORT

- Mating Effort:
  - Bioenergetic and material resources devoted to obtaining and retaining sexual partners
- Parental/Nepotistic Effort:
  - Bioenergetic and material resources devoted to enhancing survival of any offspring produced by self or kin

FAST AND *SLOW* LIFE HISTORY STRATEGIES

- *Fast ("r-Selected")* Life History Strategies allocate resources preferentially to:
  - Reproductive Effort over Somatic Effort
  - Mating Effort over Parental/Nepotistic Effort
  - Emphasize the *production* of new propagules over the *survival* of existing ones (whether self or offspring)

FAST AND *SLOW* LIFE HISTORY STRATEGIES

- *Slow ("K-Selected")* Life History Strategies allocate resources preferentially to:
  - Somatic Effort over Reproductive Effort
  - Parental/Nepotistic Effort over Mating Effort
  - Emphasize the *survival* of propagules (whether self or offspring) over the *production* of new ones

SLOW ("K-SELECTED") LIFE HISTORY STRATEGY

- As compared to *Fast* Life History Strategists, *Slow* Life History Strategists should therefore:
  - Manifest benefits of allocations in greater phenotypic quality and survivorship of propagules (whether cells or organisms)
  - Manifest greater individual viability on indicators of general health, developmental stability, and behavioral function

RABBITS AND ELEPHANTS: DIFFERENT LIFE HISTORIES

- **Rabbits** (*Fast Life History Strategy*):
  - Rapid sexual development
  - High fertility
  - Little parental care per offspring
  - High infant mortality
  - Adults are relatively short-lived

Female Rabbits:

“abandon their young in burrows immediately after birth and return to feed them for only about two minutes daily during their first 25 days. After this brief bout of ‘drive-by’ parenting, young rabbits are left to fend for themselves.”

RABBITS AND ELEPHANTS: DIFFERENT LIFE HISTORIES

- **Elephants** (*Slow Life History Strategy*):
  - Very slow and delayed sexual development
  - Produce few babies at a time
  - High parental care per offspring
  - Very low infant mortality
  - Adults are very long-lived

Female elephants:

“are pregnant for 21 months. they feed their child milk for up to 6 yrs”

“stay with their birth family for life while males live with the group until reaching puberty, between the age of nine and fifteen.”

THE EVOLUTION OF LIFE HISTORY STRATEGIES

- Fast Life History Strategies are naturally selected in unstable, unpredictable environments:
  - Sources of mortality predominantly *extrinsic,* and hence uncontrollable by genetically-influenced developmental processes
  - Leading to highly variable population densities and reinforcing this selective effect

THE EVOLUTION OF LIFE HISTORY STRATEGIES

- Slow Life History Strategies are naturally selected in stable, predictable environments:
  - Sources of mortality predominantly intrinsic, and hence controllable by genetically-influenced (and hence evolvable) developmental processes
  - Leading to highly stable population densities and reinforcing this selective effect

MULTIPLE LEVELS OF SELECTION FOR LIFE HISTORY

- A Hierarchical Cascade of Consequences:
  - *Natural* Selective Pressures generate both *Individual* and *Social* Sequelae
  - Producing *Social* Selective Pressures that generate *Sexual* Sequelae
  - Producing *Sexual* Selective Pressures that generate further *Sexual* Sequelae

SOCIAL SELECTION FOR FAST LIFE HISTORY STRATEGIES

- Unstable, unpredictable, and uncontrollable social relationships, under which individuals (both self and others) tend to evolve and develop:
  - Insecure attachment to kith and kin
  - Opportunistic and exploitative interpersonal styles
  - Low kin-selected altruism
  - Low parental and nepotistic effort
  - High social defection
  - High social antagonism
  - High social aggression
  - Generally selfish orientation to social partners

SOCIAL SELECTION FOR FAST LIFE HISTORY STRATEGIES

- These Socially Selected Sequelae are jointly due to:
  - The severely limited time horizon available for social, nepotistic, and parental relations due to the adverse natural selective pressures specified
  - The self-reinforcing nature of these effects (as in the Pianka, 1970, theory of *r*- and *K*-selection) due to the adverse social selective pressures in environments where the majority of conspecifics are also pursuing fast life history and short-term social strategies

SOCIAL SELECTION FOR SLOW LIFE HISTORY STRATEGIES

- Stable, predictable, and controllable social relationships, under which individuals (both self and others) tend to evolve and develop:
  - Secure attachment to kith and kin
  - Mutually and reciprocally rewarding interpersonal styles
  - High kin-selected altruism
  - High parental and nepotistic effort
  - High social reciprocity
  - High social mutualism
  - Generally altruistic orientation to social partners

SOCIAL SELECTION FOR SLOW LIFE HISTORY STRATEGIES

- These Socially Selected Sequelae are jointly due to:
  - The more distant and foreseeable time horizon available for social, nepotistic, and parental relations due to the relatively safe and favorable natural selective pressures specified
  - The self-reinforcing nature of these effects (as in the Pianka, 1970, theory of *r*- and *K*-selection) due to the relatively safe and favorable social selective pressures in environments where the majority of conspecifics are also pursuing slow life history and long-term social strategies

SEXUAL SELECTION FOR FAST LIFE HISTORY STRATEGIES

- Unstable, unpredictable, and uncontrollable sexual relationships, under which individuals (both self and others) tend to evolve and develop:
  - Insecure attachment to sexual partners
  - Higher mating effort in the service of multiple short-term pairings, whether simultaneous or serial or both
  - Opportunistic and exploitative sexual relations, including deceptive and coercive sexuality
  - High cross-sexual defection
  - High cross-sexual antagonism, including low cross-sexual cooperation and coparenting
  - High cross-sexual aggression, including “intimate partner violence”
  - Generally selfish orientation to sexual partners

SEXUAL SELECTION FOR FAST LIFE HISTORY STRATEGIES

- These Sexually Selected Sequelae are jointly due to:
  - The severely limited time horizon available for sexual relationships due to the adverse natural and social selective pressures specified
  - The self-reinforcing nature of these effects (as in the Pianka, 1970, theory of r- and K-selection) due to the adverse social and sexual selective pressures in environments where the majority of conspecifics are also pursuing fast life history and short-term social and sexual strategies

SEXUAL SELECTION FOR SLOW LIFE HISTORY STRATEGIES

- Stable, predictable, and controllable sexual relationships, under which individuals (both self and others) tend to evolve and develop:
  - Secure attachment to *romantic* partners, not just *sexual* partners
  - Lower mating effort in the service of a reduced number of long-term pairings, perhaps not perfectly monogamous
  - Mutually and reciprocally rewarding sexual relations
  - Strong and committed cross-sexual bonds
  - High cross-sexual reciprocity
  - High cross-sexual mutualism, including cross-sexual cooperation and coparenting
  - Low cross-sexual antagonism
  - Generally altruistic orientation to sexual partners

SEXUAL SELECTION FOR SLOW LIFE HISTORY STRATEGIES

- These Sexually Selected Sequelae are jointly due to:
  - The more distant and foreseeable time horizon available for sexual relationships due to the relatively safe and favorable natural and social selective pressures specified
  - The self-reinforcing nature of these effects (as in the Pianka, 1970, theory of r- and k-selection) due to the safe and favorable social and sexual selective pressures in environments where the majority of conspecifics are also pursuing slow life history and short-term social and sexual strategies

SO WHAT CAN CANCER RESEARCH LEARN FROM LIFE HISTORY THEORY?

- The ecological conditions for the evolution and development of fast and slow life history strategies have strong implications for the dynamics of *Cooperation, Conflict, and Co-evolution:*
  - The generative *Natural* Selective Pressures constrain and shape the *Social* Selective Pressures, which, in turn, constrain and shape the *Sexual* Selective Pressures that drive both Evolution and Development

SO WHAT CAN CANCER RESEARCH LEARN FROM LIFE HISTORY THEORY?

- The implications of all these theoretical considerations for the evolution and development of cancer tissues have yet to be worked out
- The implications for the prevention or treatment of cancer is an even more distant objective

SO WHAT CAN CANCER RESEARCH LEARN FROM LIFE HISTORY THEORY?

- Nevertheless, we may now reasonably ask:
  - What is a *malignant* tumor, other than a *fast* life history *(r-selected)* cancer tissue?
  - What is a *benign* tumor, other than a *slow* life history *(K-selected)* cancer tissue?
- If we can understand the *microenvironmental cues* triggering the developmental switches involved in a tumor evolving or developing into a *malignant* or *benign* one, that may be half the battle!