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Learning objectives

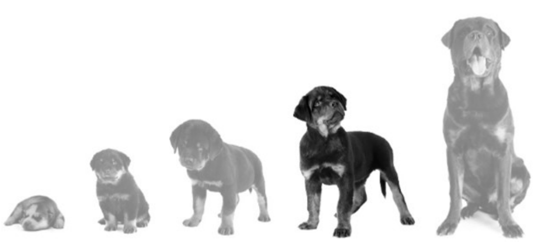
- Outline canine developmental stages
- Identify influences on adolescent & adult behavior
- List common adolescent behavior patterns
- Identify and understand adolescent brain changes
- Track developmental changes through adolescence
- Discuss evolutionary advantages of adolescence
- Pull it all together…

- Neonatal – birth to 13 days
- Transitional – 13 days to 3 weeks
- Socialization – 3 weeks to 12-16 weeks
- Juvenile – 12-16 weeks until sexual maturity
- Adult - Sexual maturity onward

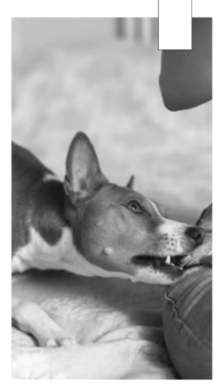
- *Where does adolescence fit?*
  - What is a canine "teenager"?
  - Poorly defined age range

Windows of influence

- Genetic factors
- Prenatal effects
- Neonatal period
- Primary socialization
- Ongoing learning
  - Adolescence to adulthood



- Increased independence, "stubborn"
- Decreased responsiveness to trained cues/prompts
- High energy (ongoing)
- Increased impulsivity
- Onset of territoriality?



- Gender specific behaviors (male/testosterone)
  - Urine marking (social signaling, communication)
  - Leg lifting (physical posture change)
  - Mounting (multiple motivations)
  - Roaming (motivated by reproductive drive?)
- Influenced by castration?
  - Prevention
  - Intervention

- Exacerbation of existing patterns
  - Housesoiling
  - Destructive chewing
  - Excessive barking
  - Separation anxiety
  - Reactivity
  - Compulsive disorder
  - Fear based behaviors

Human and Animal Factors Related to the Relinquishment of Dogs and Cats in 12 Selected Animal Shelters in the United States

M. D. Salman
College of Veterinary Medicine and Biomedical Sciences
Colorado State University

TABLE 2
Characteristics of Animals Surrendered to 12 U.S. Shelters (1995–1996)

	Dogs		Cats	
Characteristics	*Number*	*%*	*Number*	*%*
Age				
Unreported	143	6.6	242	15.5
0–5 months	191	8.8	126	8.1
5 months–3 years	1,023	47.4	629	40.3
3–8 years	409	18.9	352	22.5
>8 years	394	18.2	212	13.6

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Characteristics of Relinquished Dogs and Their Owners at 14 Rehoming Centers in the United Kingdom

Gillian Diesel, David Brodbelt, and Dirk U. Pfeiffer
The Royal Veterinary College, University of London, Hatfield, United Kingdom

TABLE 1
Descriptive Results of Dog Characteristics for Those Dogs Relinquished to Dogs Trust During 2005

		Dogs Not Obtained From Dogs Trust			
Variable Name	*Variable Categories*	*Dogs Obtained Privately (%)*	*Dogs Obtained From Kennels Other Than Dogs Trust (%)*	*Dogs Originally Obtained From Dogs Trust*	*All Dogs (%)*
Total number of dogs		1,217	396	1,193	2,806
Sex	Male	660 (54.2)	231 (58.3)	704 (59.0)	1,595 (56.8)
	Female	557 (45.8)	165 (41.7)	489 (41.0)	1,211 (43.2)
Crossbreed	Crossbred	827 (68.0)	346 (87.4)	1,047 (87.8)	2,220 (79.1)
	Purebred	390 (32.0)	50 (12.6)	146 (12.2)	586 (20.9)
Size	Small (<10 kg)	360 (29.6)	59 (14.9)	210 (17.6)	629 (22.4)
	Medium (10–30 kg)	638 (52.4)	274 (69.2)	769 (64.5)	1,681 (59.9)
	Large (>30 kg)	218 (17.9)	63 (15.9)	214 (17.9)	495 (17.6)
	Unknown	1 (0.1)	0	0	1 (0.1)
Age	<0.5 years	227 (18.7)	20 (5.1)	151 (12.6)	398 (14.2)
	0.5–<1 year	257 (21.1)	29 (7.3)	330 (27.7)	616 (21.9)
	1–<3 years	311 (25.5)	77 (19.5)	424 (35.5)	812 (28.9)
	3–<6 years	209 (17.2)	123 (31.1)	198 (16.6)	530 (18.9)
	6–<10	169 (13.9)	113 (28.6)	76 (6.4)	358 (12.8)
	≥10	44 (3.6)	33 (8.3)	14 (1.2)	91 (3.2)
	Unknown	0	1 (0.1)	0	1 (0.1)

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ALMOST
NOTHING

Current Biology 24, 574–578, March 3, 2014 http://dx.doi.org/10.1016/j.cub.2014.01.058

Voice-Sensitive Regions in the Dog and Human Brain Are Revealed by Comparative fMRI

Attila Andics,[1,*] Márta Gácsi,[1] Tamás Faragó,[1] Anna Kis,[2,3] and Ádám Miklósi[1,2]
[1]MTA-ELTE Comparative Ethology Research Group, Pázmány Péter sétány 1/C, 1117 Budapest, Hungary
[2]Department of Ethology, Eötvös Loránd University, Pázmány Péter sétány 1/C, 1117 Budapest, Hungary
[3]Research Centre for Natural Sciences, Institute of Cognitive Neuroscience and Psychology, Hungarian Academy of Sciences, Magyar tudósok körútja 2, 1117 Budapest, Hungary

To reveal possible functional analogies be[…] nonprimate auditory brain regions, this s[…] comparative investigation of dogs and hu[…] gated (1) whether in dogs, similarly to human[…] regions (voice areas) would respond strong[…] vocalizations than to either heterospecific[…] nonvocal sounds and (2) whether dogs are […] in the cortical processing of emotional cues[…]
To address these questions, we used a […]

- 11 fMRI trained dogs
- 22 human subjects
- Presented with identical vocal and non-vocal stimuli
- Sensitivity to emotional valence cues engaged similarly located regions in both species
- Identified functionally analogous voice sensitive cortical regions

Current Biology 24, 574–578, March 3, 2014 ©2014 Elsevier Ltd All rights reserved http://dx.doi.org/10.1016/j.cub.2014.01.058

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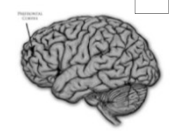
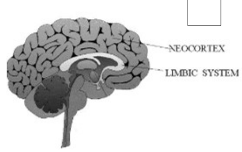
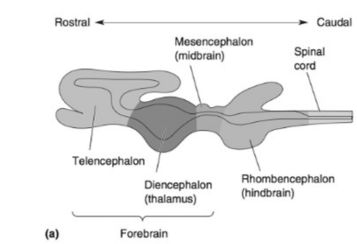
- Limit of information?
- Specific to one area of inquiry
  - Parallel/homologous development?
  - Ancient evolutionary origin?
  - More similar than different?
  - Depends on the comparison…



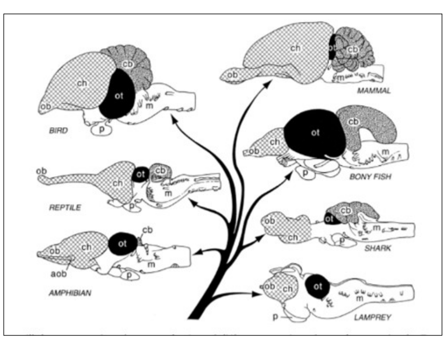
- Capacity for reasoning, forming concepts, information processing, cognitive regulation of emotional responses
- Activation is required for learning connections between behavior and consequences



- Activation occurs during times of danger or arousal
- Primes animal to respond with escape behavior or to avoidance conditioning
- Under normal conditions, necessary for survival



Diagrammatic sagittal view of a vertebrate brain showing the division into primary regions. Source: BCP Chapter. 7



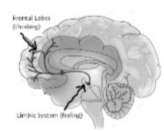
- Can we make comparisons from what we know of other species?
- Probably… but with awareness that our knowledge may change as additional research is conducted

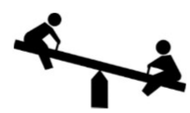
Switching species for a bit…

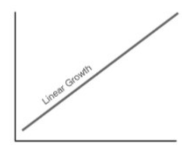
"Adolescence is a developmental period characterized by suboptimal decisions and actions that are associated with an increased incidence of unintentional injuries, violence, substance, abuse, unintended pregnancy, and sexually transmitted diseases"

~ Casey 2008

- One theory…
  - Cognitive development during adolescence is associated with progressively greater efficiency of cognitive control and affective modulation
  - Associated with increased activity in prefrontal cortex and diminished activity in other regions
  - Essentially stating that children learn to control their emotions as their PFC develops during adolescence
  - Suggests linear progression/development

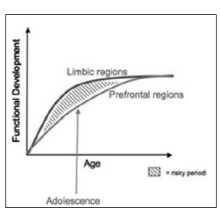






Thinking about this another way…

- If that's the case, we should see pattern of childhood → adolescence → adulthood
- And yet, see disproportionate *increase* in "risky" behavior during adolescence
- Data doesn't support straightforward linear progression!



- Ability to suppress thoughts/actions in favor of goal-directed ones
- Even in presence of short-term incentives
- Requires control of impulses or delay of gratification
- Impulsivity decreases with age across childhood and adolescence, associated with PFC development, linear pattern of change, and yet…

"Risky behavior"

- Risky choices (teens): driving after drinking, driving without seat belt, carrying weapons, using illegal substances, engaging in unprotected sex
- Risk taking is *greatest* during adolescence, more exaggerated than during childhood or adulthood
- Associated with increase in subcortical activation (nucleus accumbens, amygdala)

Brain regions

- Nucleus accumbens
  - Central role in reward circuit
  - Closely related to primitive regions (VTA) and the PFC
- Amygdala
  - Part of the limbic system
  - Role in processing of memory, decision making, emotional reactions

Imaging studies (human, MRI)

- Brain reaches ~90% of adult size by ~age 6
- Ongoing changes in gray/white matter throughout adolescence
- Gray matter volume –
  - Motor and sensory systems mature before higher order associative areas (integrative function)
  - PFC is one of the last areas to mature, supports differential pattern of development (not uniform throughout brain)
- White matter – relatively linear pattern throughout development and into adulthood (ongoing myelination of axons)

Imaging studies (human, MRI)

- Early puberty – overproduction of axons and synapses
- Dopamine receptor expression is highest in nucleus accumbens during early adolescence
- Later adolescence –
  - Rapid pruning in amygdala, nucleus accumbens, PFC
  - Earlier maturity in NA than PFC based on rates of pruning in each area

Relation between regions

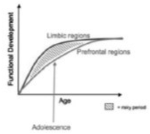
- Measure of cognitive control associated with development within PFC and basal ganglia
- SUBcortical areas show more significant changes during adolescence (does *not support* "impulse control" theory…)
- Can measure exaggerated response to reward with elevated NA activity *and* reduced PFC engagement (fMRI data)

Parallel changes (novelty seeking, risk taking) in rodents, non-human primates

Universal, valid animal model?

Semantics or… two different things?

- Differentiate “impulsive” from “risky”
- Consider both “top-down” control system
  - PFC, linear development of impulse control
- AND “bottom up” control system
  - Limbic, non-linear pattern of risky behavior
- Immature cognition of adolescence ~ impulsive (lacking cognitive control) *and* risky



Net impact for adolescent

- Time of increased emotional arousal and reactivity
- Value of + and – information may be exaggerated
- Heightened responsiveness to incentives, when emotional control is still immature

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Net impact for adolescent

- Adolescent behavior is more biased by functionally mature limbic regions, *before* full PFC control develops
- Accounts for “risky” behavior despite being able to reason and understand risks of behavior
- Higher incidence of affective disorder onset and addiction during this developmental period

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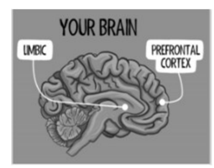
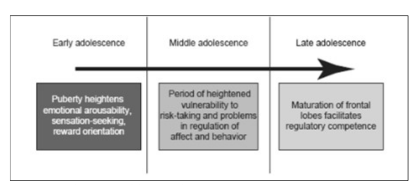
Adolescent in emotionally salient situation =

- Limbic response “wins” over PFC
- Individual may “know better” but salience of emotional context biases behavior in opposite direction of optimal action
- Heightened responsiveness to reward, lack of impulse control → seek immediate rather than long term gain



“Behavioral data have often made it appear that adolescents are poor decision-makers. This led initially to hypotheses that adolescents had poor cognitive skills relevant to decision-making or that information about consequences of risky behavior may have been unclear to them. In contrast to those accounts, however, there is substantial evidence that adolescents engage in dangerous activities *despite* knowing and understanding the risks involved.”

- In summary…during adolescence (compared to adulthood or childhood) immature PFC may not provide sufficient top-down control of robustly activated reward and affect processing regions
- WHY???



TRENDS in Cognitive Sciences Vol.9 No.2 February 2005

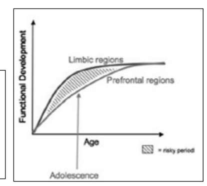
- Development of independence skills → increase the success of separating from protective influence of the family
- Independence seeking behaviors are consistent across species, increase in peer-directed social interactions, intensification in novelty seeking and risk taking behaviors
- Overlap of "adolescence" (loosely defined margins) with puberty (specific biological markers)

- NEED for engaging in high-risk behavior to leave family/home/group to find mate and reproduce

- NEED for engaging in high-risk behavior to leave family/home/group to find mate and reproduce
- Risky behavior occurs simultaneous with increase in sexual hormones, and seeking of sexual partners
- Increase in novelty seeking – in combination with mechanism for detecting cues of safety/danger (emotional reactivity increases vigilance and awareness of threat, to ensure survival)

- Impulsivity = immature PFC, linear maturity
- Risky = increase in NA in adolescents, relative to both children and adults
- Adolescent choices explained by the combination

FIGURE 3. The traditional explanation of adolescent behavior has been that it is due to the protracted development of the prefrontal cortex. Our model takes into consideration the development of the prefrontal cortex together with subcortical limbic regions (e.g., nucleus accumbens and amygdala) that have been implicated in risky choices and emotional reactivity.



- Onset of psychiatric disorder symptoms - due to greater than usual imbalance between brain regions?
- Individual variability in emotional reactivity and ability to modulate behaviors, predisposition of risk?
- Amygdala is essential for learning emotional significance of cues in environment
  - Evidence of dysregulation in anxious/depressed children and adults
  - Sustained amygdala activity correlated with trait anxiety
- At risk? Increased amygdala activity / less activity in PFC, exacerbated by normal developmental processes

- 8-12 yr old kids, incentive go-nogo task, measure of response inhibition
- Successful trials followed by feedback (neutral image, smiling face, monetary reward)
- Both social and monetary rewards yielded improvement in task performance (better inhibition scores), largest improvement for monetary reward group

Kohls, G., Peltzer, J., Herpetz-Dahlmann, B., & Konrad, K. (2009). Differential effects of social and non-social reward on response inhibition in children and adolescents. Developmental Science, 12 (4), 614–625.

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Thank you for your attention!