Seasonal Differences in Cell Proliferation in the Hippocampus and Septum of Food-Storing and Non-Storing Birds

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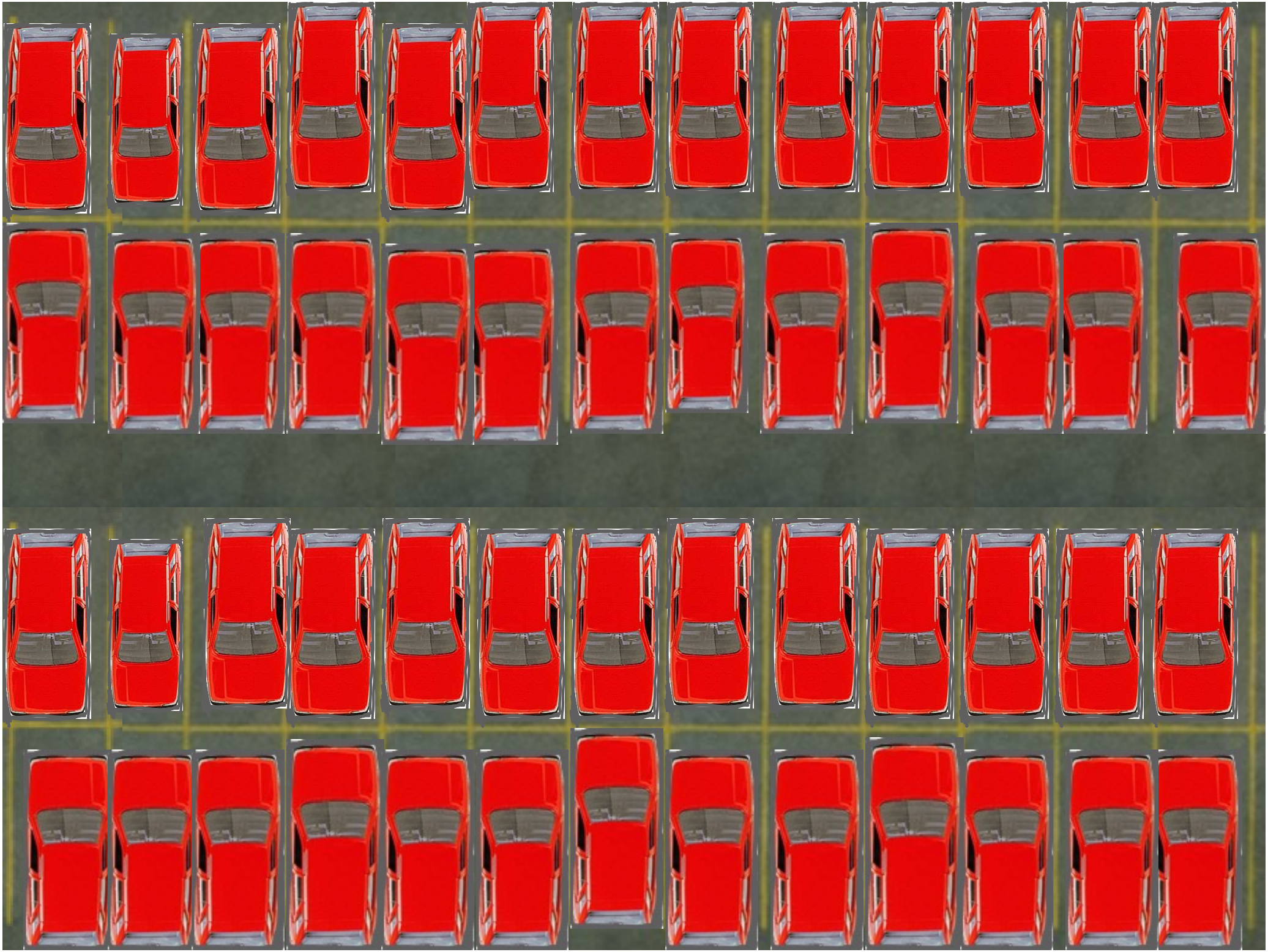


Avian Taxonomy

Emberizidae
(Juncos)

Parvorder *Paridae*
aka Parvids
(Chickadees)

Suborder *Passeri*
aka Passerine
(Song Birds)

Parvorder *Corvidae*
aka Corvids
(Crows & Jays)

Parvorder *Sittidae*
(Nuthatches)

Order *Passeriformes*
(Perching Birds)

Introduction

- Neurogenesis, the birth of new neurons, occurs in the adult avian and mammalian hippocampus (HP; Lee, Miyasato, & Clayton, 1998).
- The HP is important in learning and memory.
- Adult HP neurogenesis may play a role in the ability of food-storing birds to recall the location of stored caches.
- The survival value of HP-dependent recall for cache locations may have created an evolved specialization in the brain of these species (Hampton & Shettleworth, 1996).

Evidence for an Adaptive Specialization

1. Food-storing birds should have superior spatial memory capacity.

(Hampton & Shettleworth, 1996)

2. For food-storing birds, the HP should be involved in cache recovery.

(Sherry & Vaccarino, 1989)

3. For food-storing birds, there should be more cells in the HP during the fall.

(Smulders et al., 2000)

4. For food-storing birds, there should be more neurogenesis during the fall.

(Barnea & Nottebohm, 1994; Hoshooley & Sherry, 2004)

5. For non-storing birds, there should be no seasonal differences in neurogenesis.

(Hoshooley & Sherry, 2007)

Current Study

- Thus far: Memory capacity, total HP cell count, and HP neurogenesis.
- What happens in the Subventricular Zone (SVZ)?
- The current study sought to determine whether *cell proliferation* in the HP, Septum, and SVZ would provide further evidence for an evolved specialization in the brain of the food-storing chickadee.

  - Food-storing chickadees would be expected to have:

    (1) Higher rates of cell proliferation than non-storing juncos

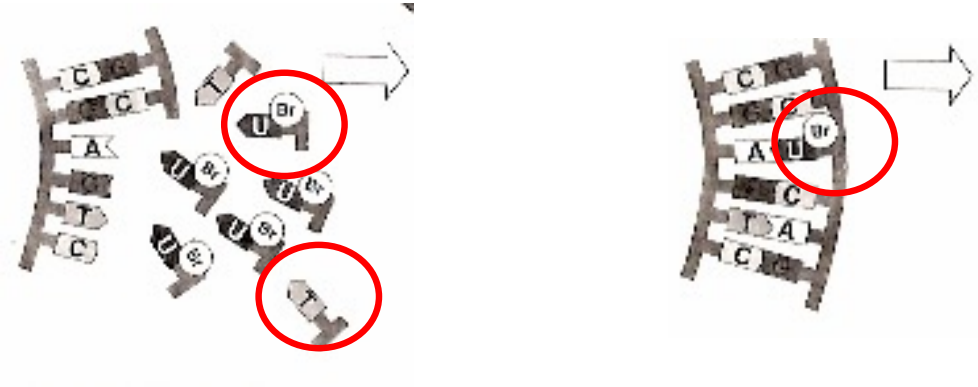
    (2) Higher rates of cell proliferation during the fall.

Methods

- Captured:
  - Adult food-storing black-capped chickadees (*Poecile atricapillus; n* = 17).
  - Adult non-storing dark-eyed juncos (*Junco hyemalis; n* = 16).
- During
  - Fall
  - Spring
- At two field sites in Maine:
  - The Coastal Studies Center in Orr's Island
  - Coleman Farm in Brunswick.

Methods

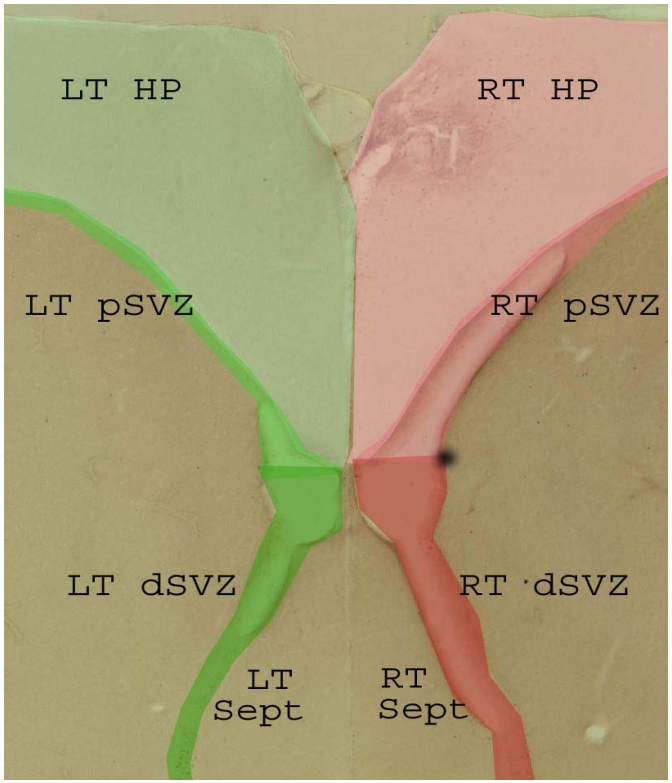
- 48 hrs after trapping, all birds received 1 injection of BrdU to label mitotic cells.



- On day 10 of captivity, all birds were perfused, brains were removed and cut, and tissue was processed using BrdU immunohistochemistry (IHC).

Methods

- BrdU-immunoreactive (BrdU-IR) cells were counted in the HP, proximal SVZ (pSVZ), distal SVZ (dSVZ), and Septum.



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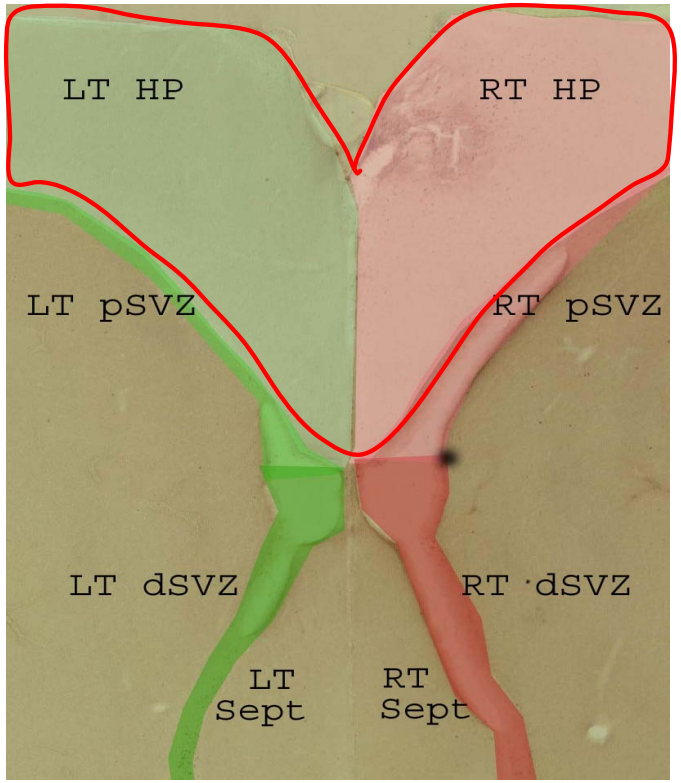

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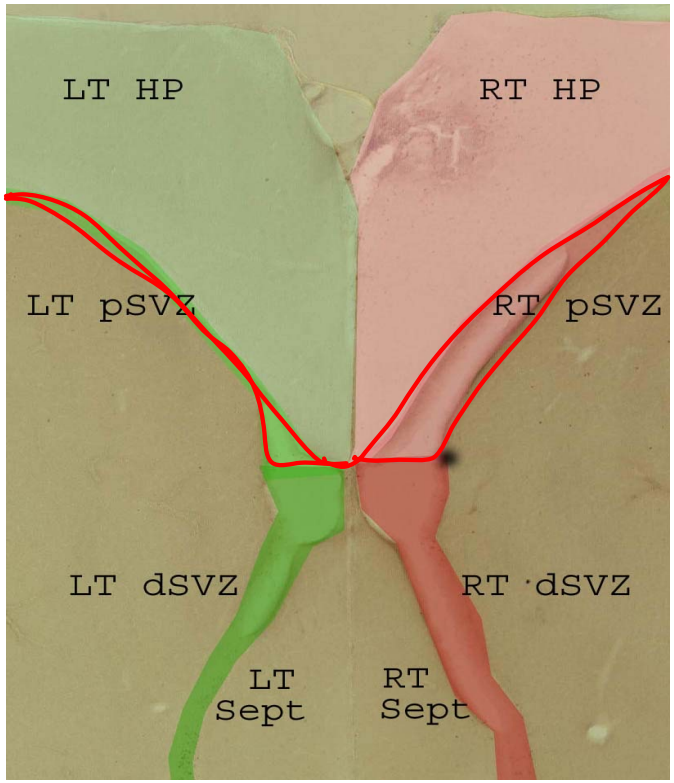

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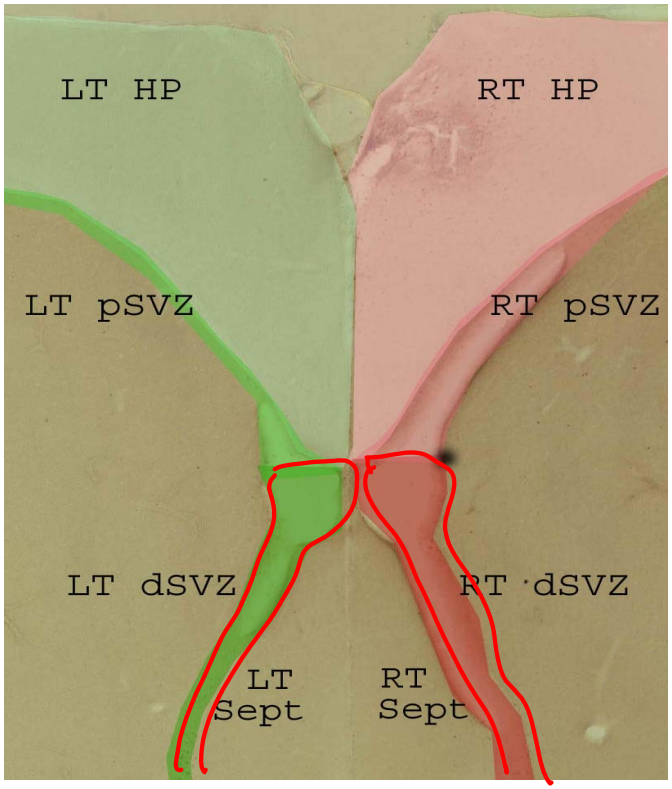

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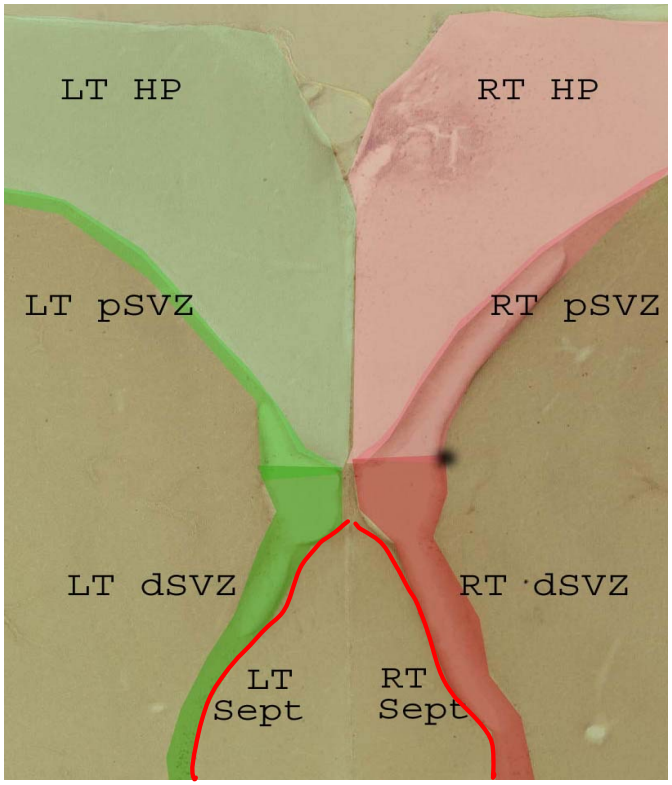

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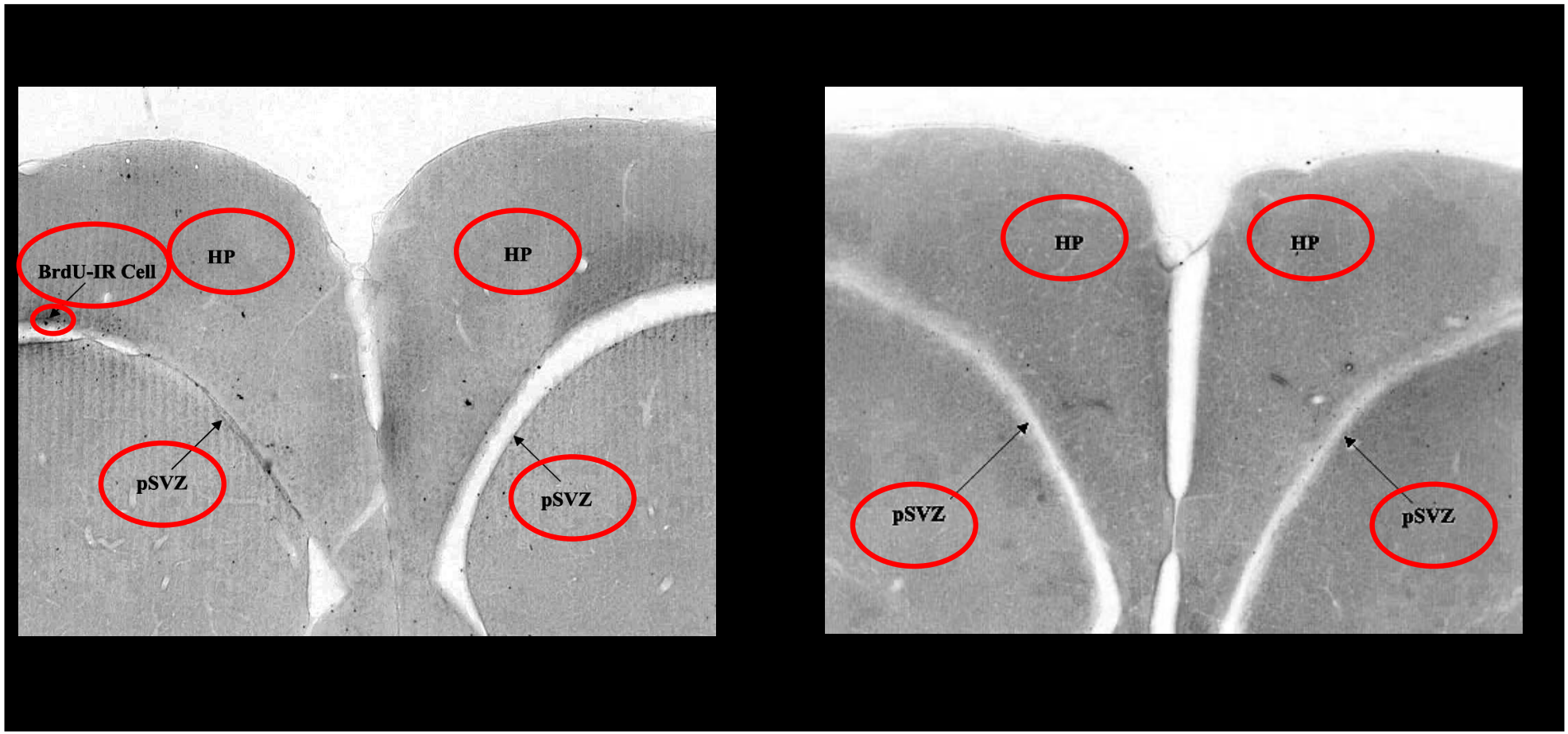
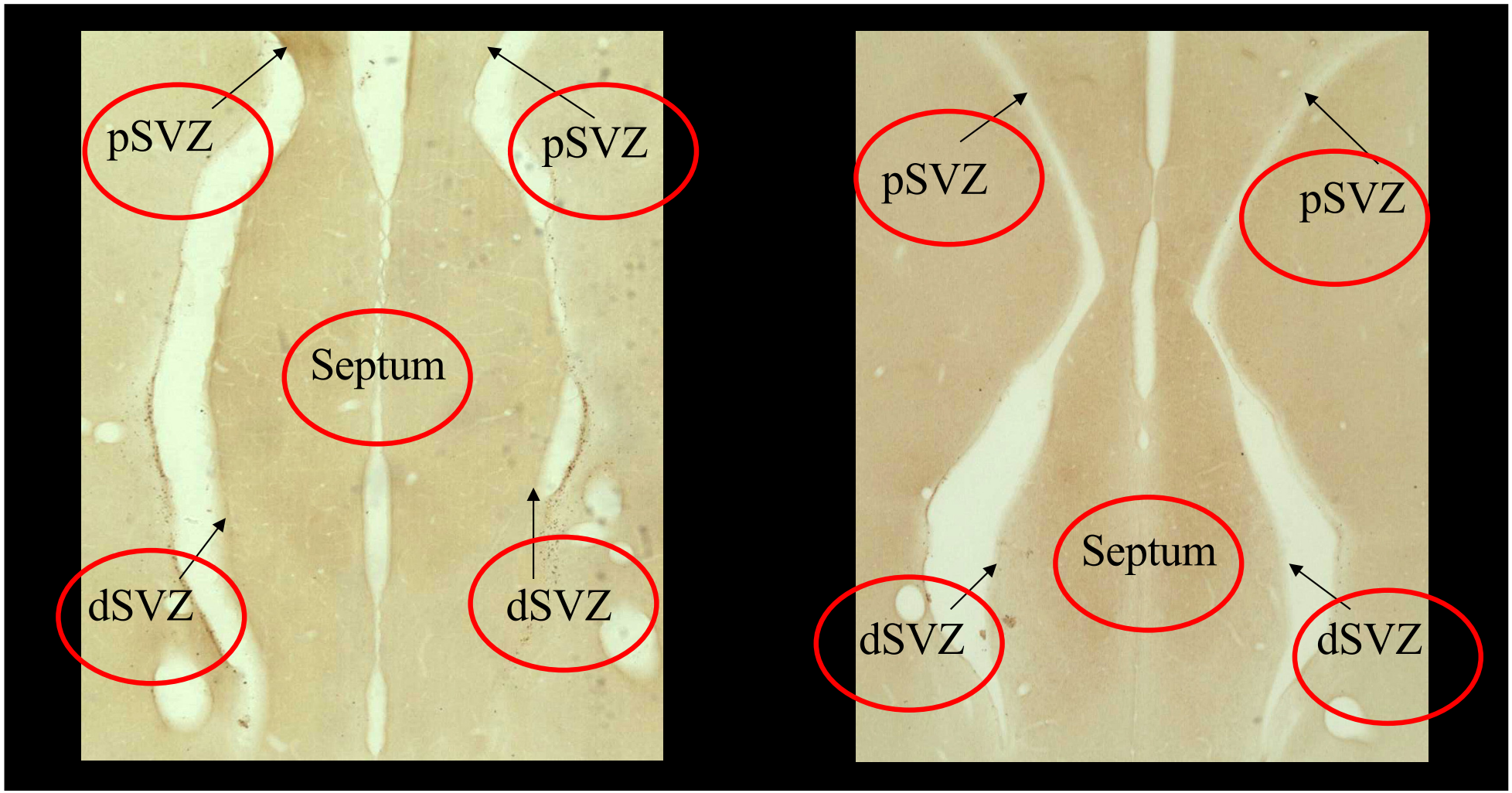


Black-capped chickadee

Dark-eyed junco

Methods



Black-capped chickadee

Dark-eyed junco

Statistical Analyses

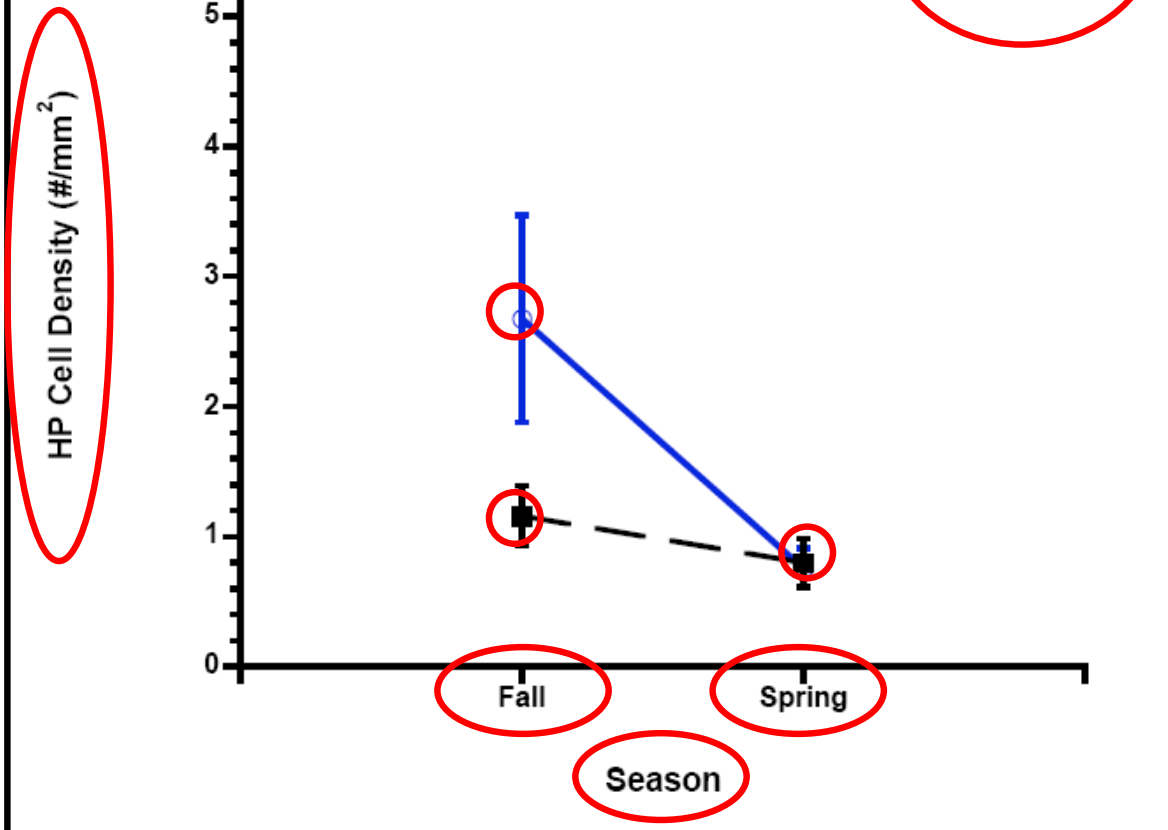
- IVs:
  - Species (chickadee, junco)
  - Season (fall, spring)

- DVs:
  - Density of BrdU-IR cells in the HP, pSVZ, dSVZ, or Septum

- 2x2 ANOVA: Main effects of species and season were analyzed.

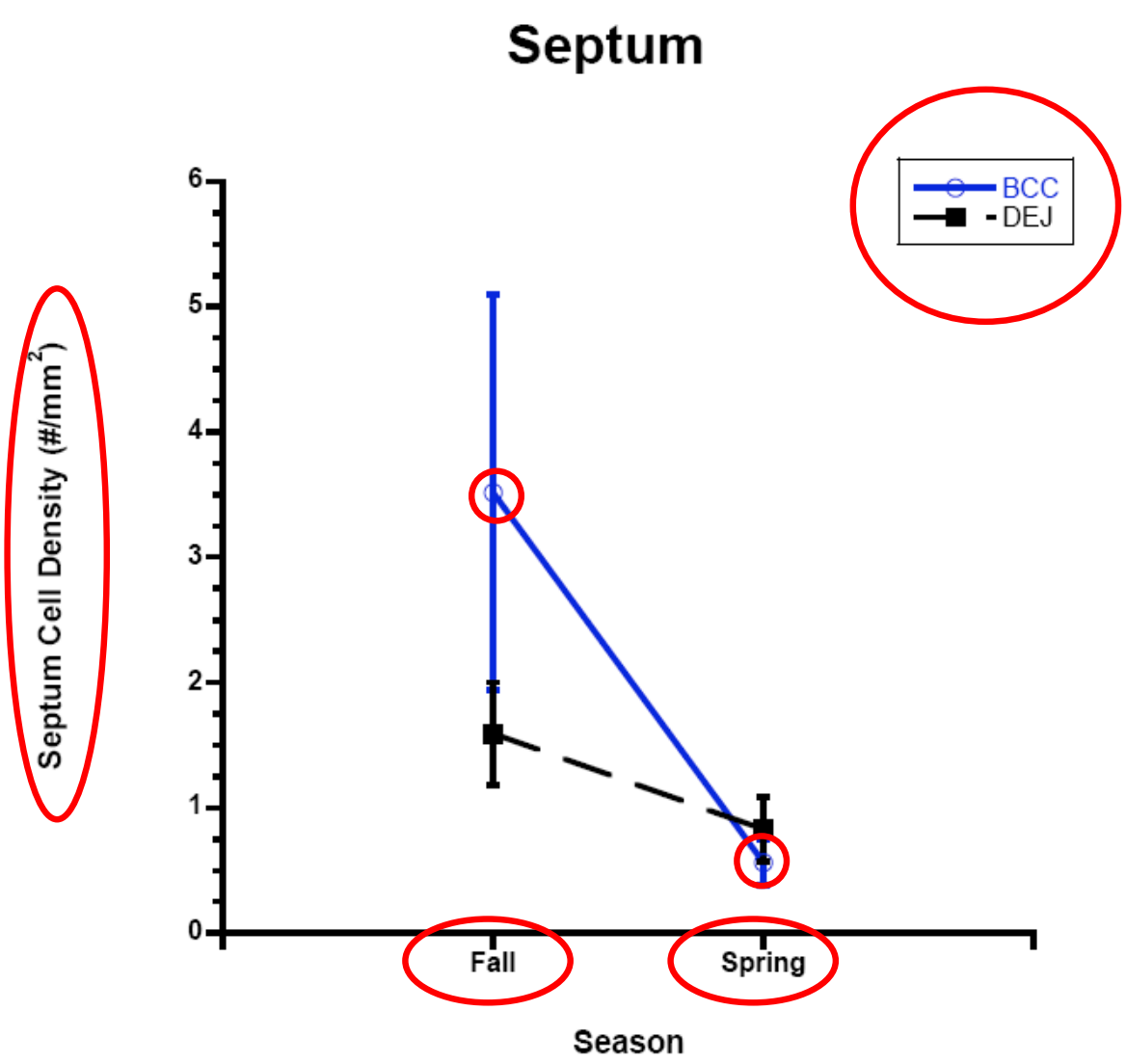
- Planned comparisons were performed on main effects.

Results



- Fall-caught chickadees had significantly more BrdU-IR cells in the HP compared to:
  - (1) Spring-caught chickadees
  - (2) Fall-caught juncos
  - (3) Spring-caught juncos

Results



- Fall-caught chickadees had significantly more BrdU-IR cells in the Septum than spring-caught chickadees.

- There were no differences between chickadees and juncos.

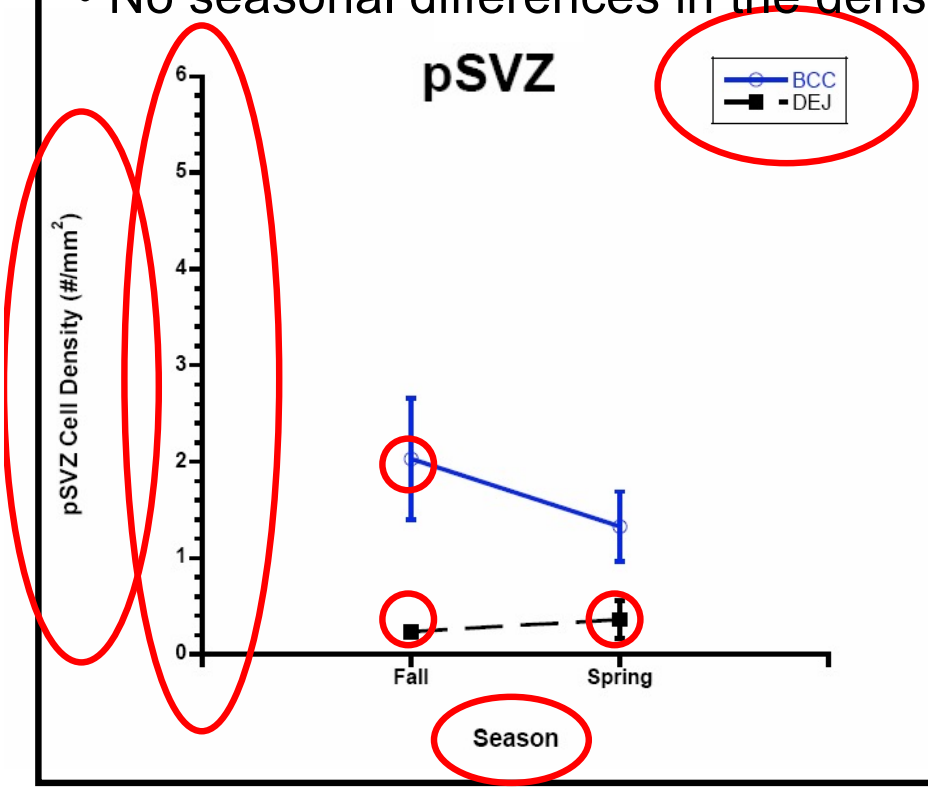
Results

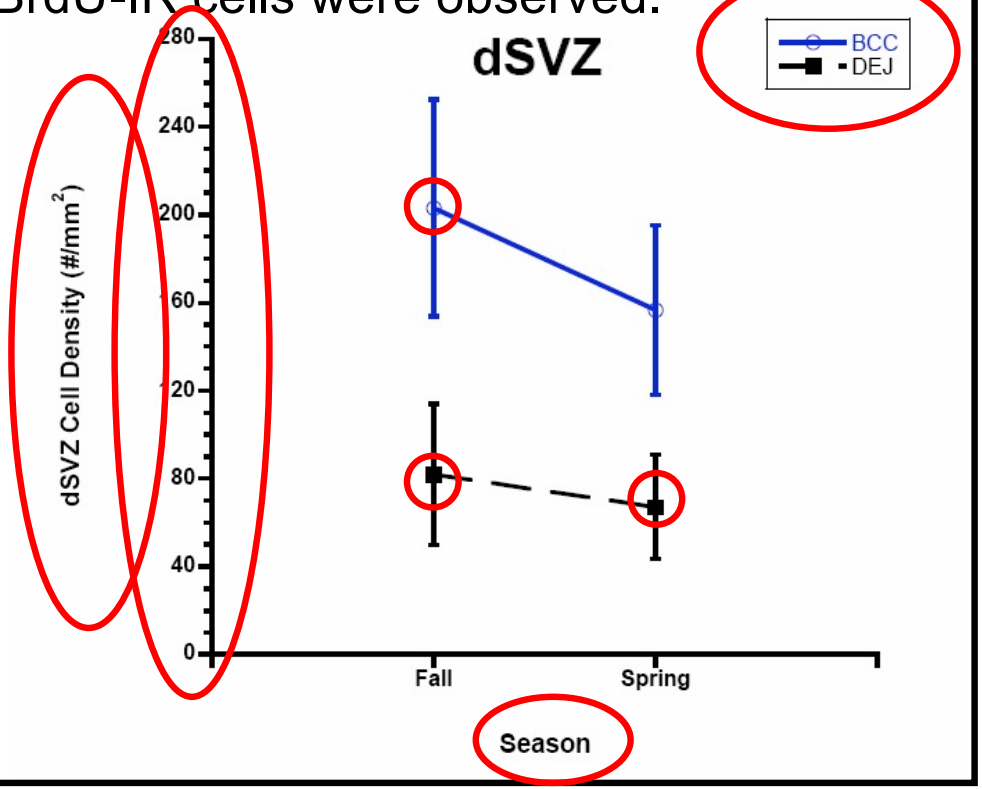
- Fall-caught chickadees had significantly more BrdU-IR cells in the pSVZ and dSVZ compared to:

  (1) Fall-caught juncos.

  (2) Spring-caught juncos.

- No seasonal differences in the density of BrdU-IR cells were observed.



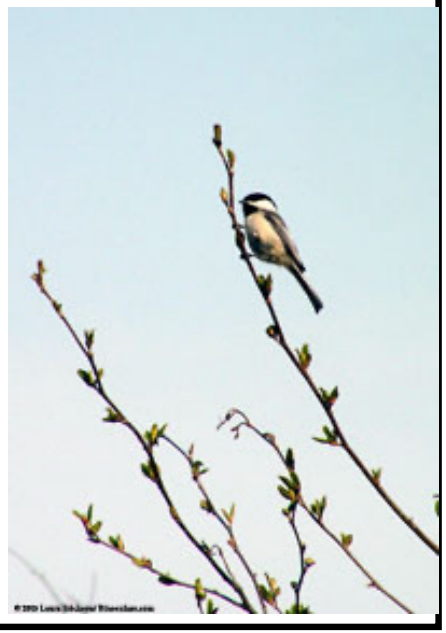


Conclusions

- Compared to non-storing juncos, food-storing chickadees had more newly born cells in the HP, and SVZ, indicating that these structures may have evolved a species-specific specialization.

- Compared to those caught in the spring, fall-caught chickadees had significantly more newly born cells in both the HP and Septum.

- In contrast, non-storing juncos showed no seasonal differences.



Conclusions

- Seasonal increases in the SVZ were not observed.

  - May be a species-specific specialization.

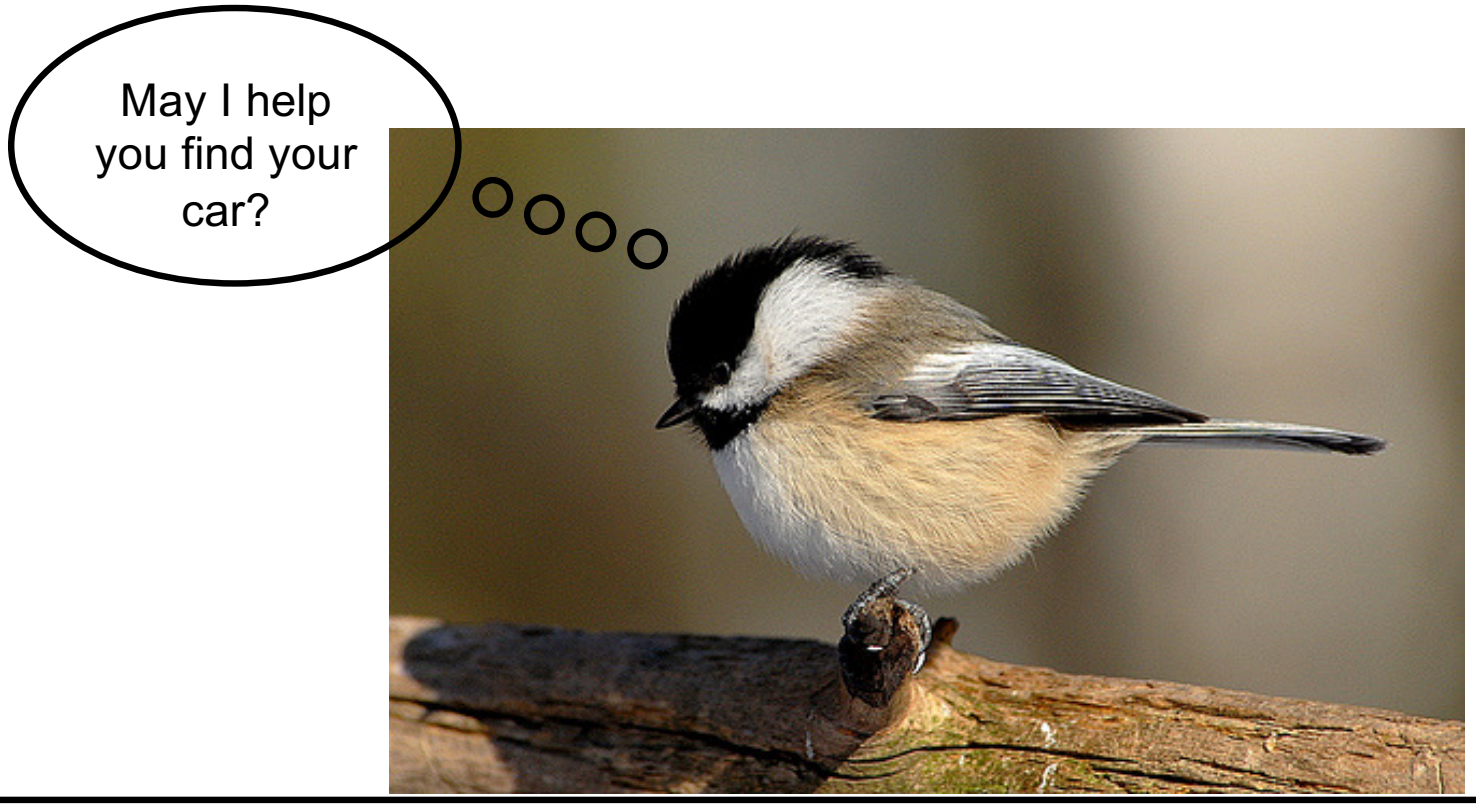
  - This specialization may not be related to food-storing

  - The process of cell division could be followed by migration out of the SVZ and into the HP much more rapidly in fall-caught chickadees

- Consistent with findings of enhanced neuronal recruitment in food-storing birds, as well as increased neuronal recruitment during the fall food-storing season.

Conclusions

- Taken together, results indicate that cell proliferation is enhanced in food-storers, especially during the fall, and may reflect a selective adaptation in the brain designed to meet the cognitive demands of food-storing.



Thanks To:

* Involved in this project

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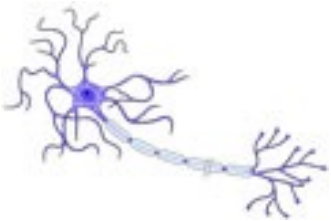
References



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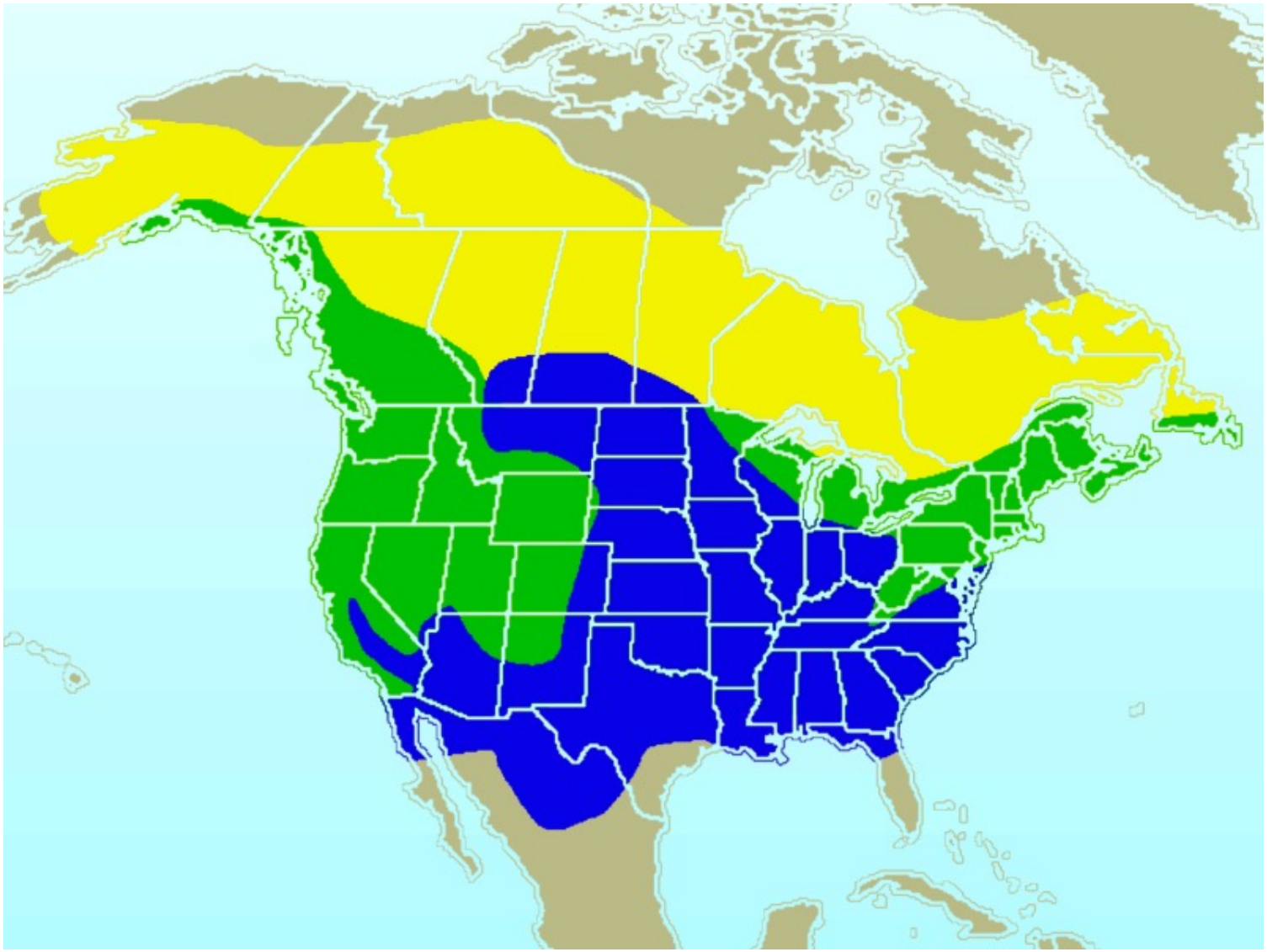
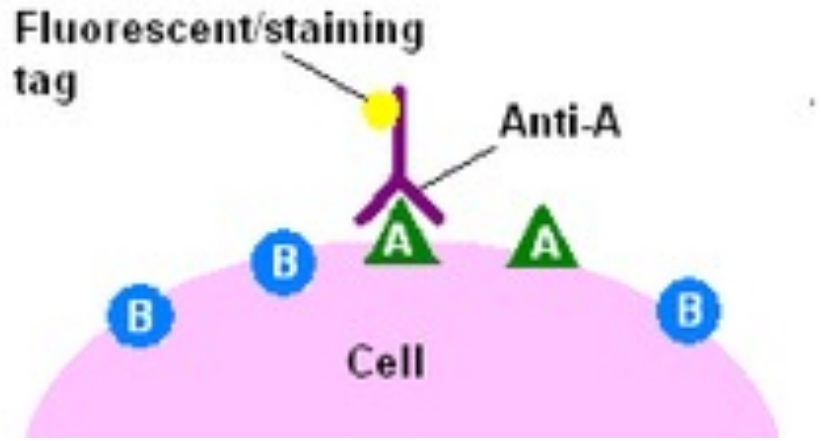
Black-Capped Chickadee Home Range

Dark-Eyed Junco Home Range



Immunohistochemistry

- If we inject BrdU at the time the cells are taking in thymidine, BrdU will be selectively taken up by these dividing (mitotic) cells instead of thymidine which is present in far less quantity. If we later apply antibodies synthesized to BrdU, since they are specific to BrdU not thymidine, they will identify and attach to BrdU wherever it is found.
- If we turn the BrdU antibody a noticeable color (using a chromagen, e.g., DAB which turns light brown), we can visualize this color label in the microscope and see all of the newly born cells which are now designated as being “BrdU-IR” (BrdU-immunoreactive.



Sex Differences

- Neither species are sexually dimorphic. Therefore, sex had to be determined postmortem.

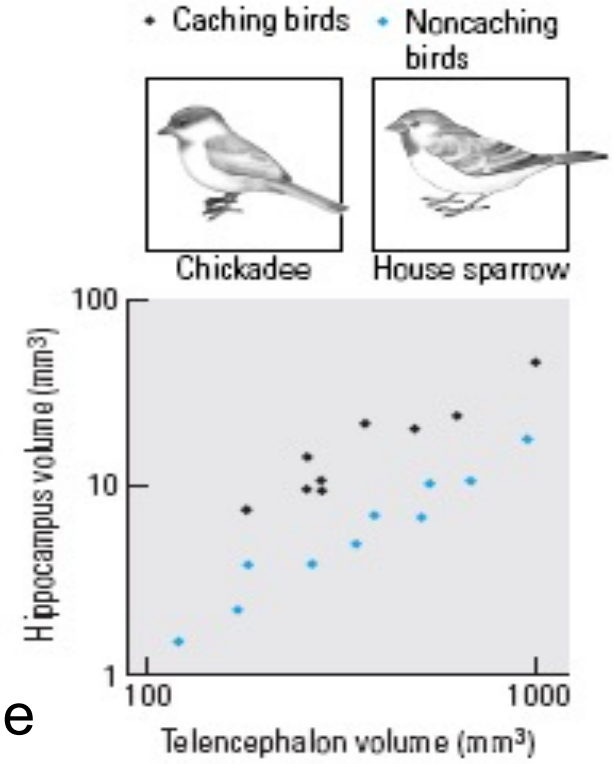
  - I'm still working on identifying sex in the spring-caught birds.

- We didn't catch any female dark-eyed juncos in the fall.

- Previous research indicates that the total HP cell count in black-capped chickadees did not differ between sexes (Smulders, Shiflett, Sperling, & DeVoogd, 2000).

HP Volumes

- We'd *expect* food-storing birds to have larger HP volumes than non-storing birds.
  - They do! (Sherry et al., 1989; Krebs et al., 1989)
- We'd *expect* food-storing birds to have larger HP volume during the fall.
  - Some report fall peaks (Smulders et al., 1995)
  - Some report spring peaks (Hoshooley & Sherry, 2007; Mitterling et al., 2007)
- We'd *expect* no seasonal changes in HP volume In non-storing birds.
  - Some report no seasonal changes (Hoshooley & Sherry, 2007)
  - Some report spring peaks (Mitterling, et al., 2007)



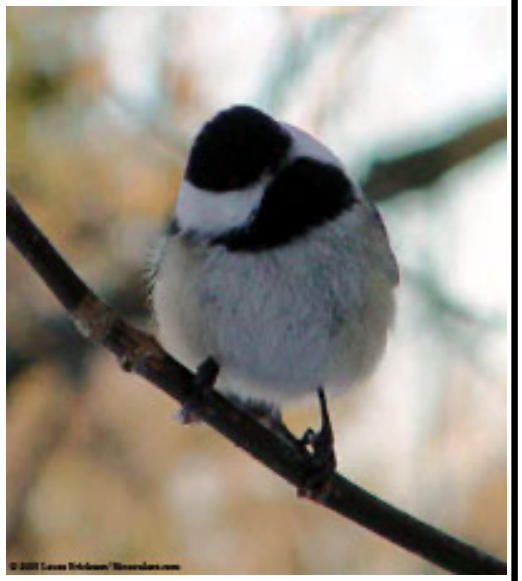
(Sherry et al., 1989)

Septum

- The HP shares reciprocal connections with the Septum.
- The Septum is believed to be involved in memory.
- We'd *expect* food-storing birds to have larger Septal volume than non-storing birds.

  - They do! (Shiflett et al., 2002)
- We'd *expect* food-storing birds to have a fall peak in Septal volume

  - They do! (Shiflett et al., 2002)

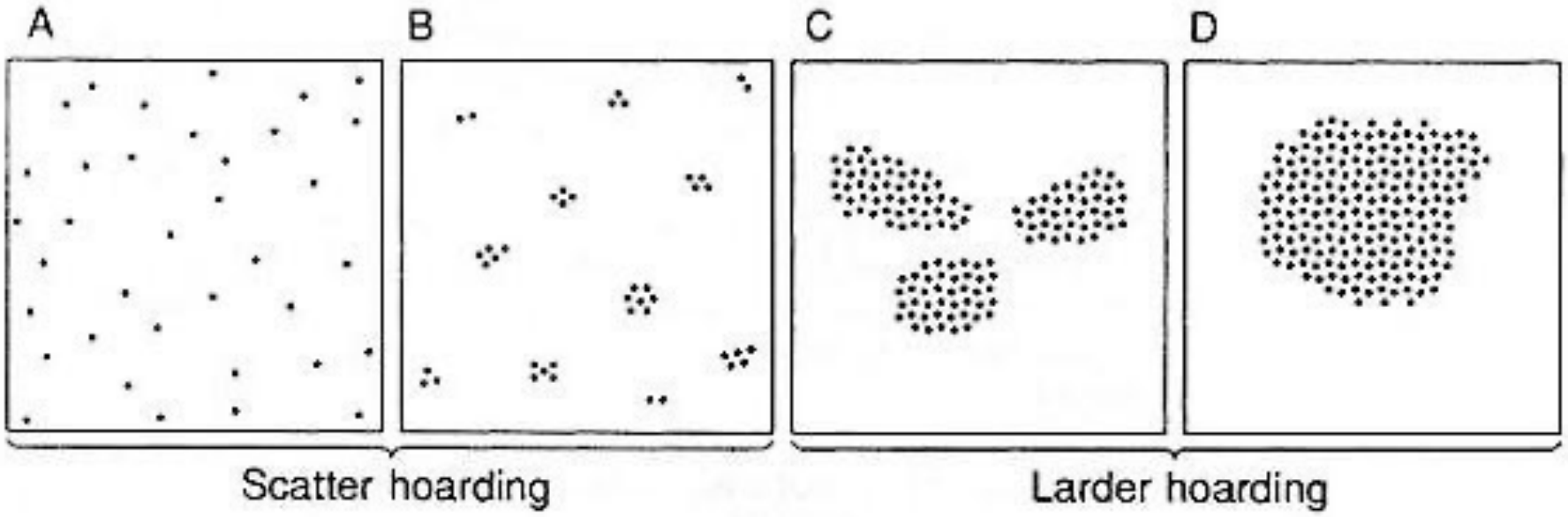


Cache Recovery

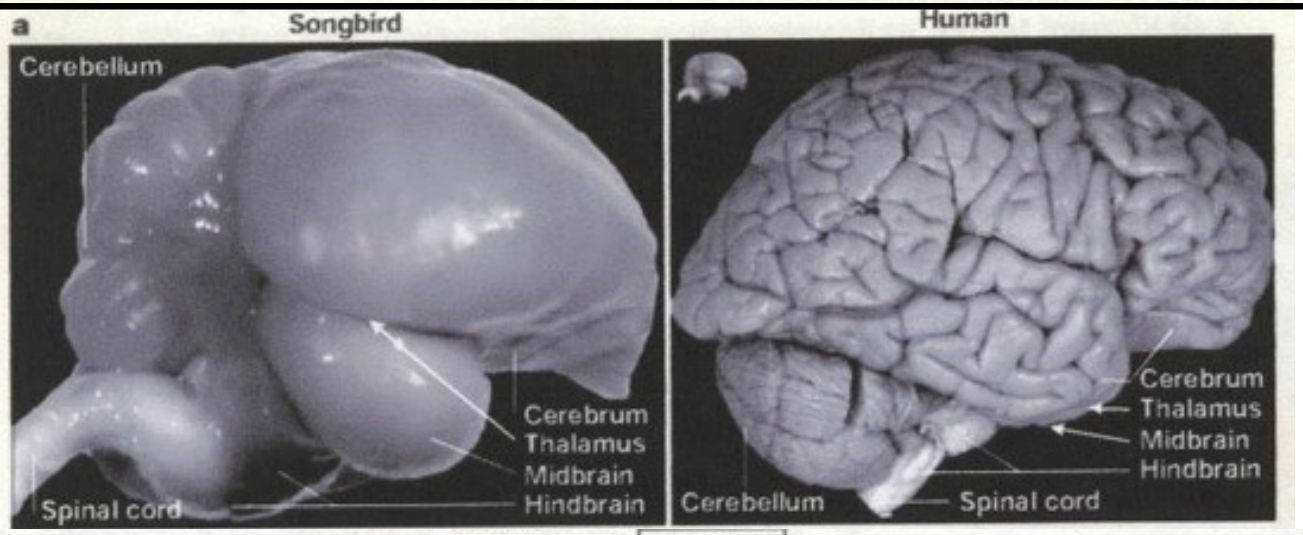
- Research has demonstrated that food-storing birds retrieve their caches by remembering where they placed them.
    - Recall by a number of variables:
        1. Time of storage
        2. Type of food stored
        3. Relationship of one cache to another
        4. Mapping territory by reference to landmarks
        5. Position of the sun

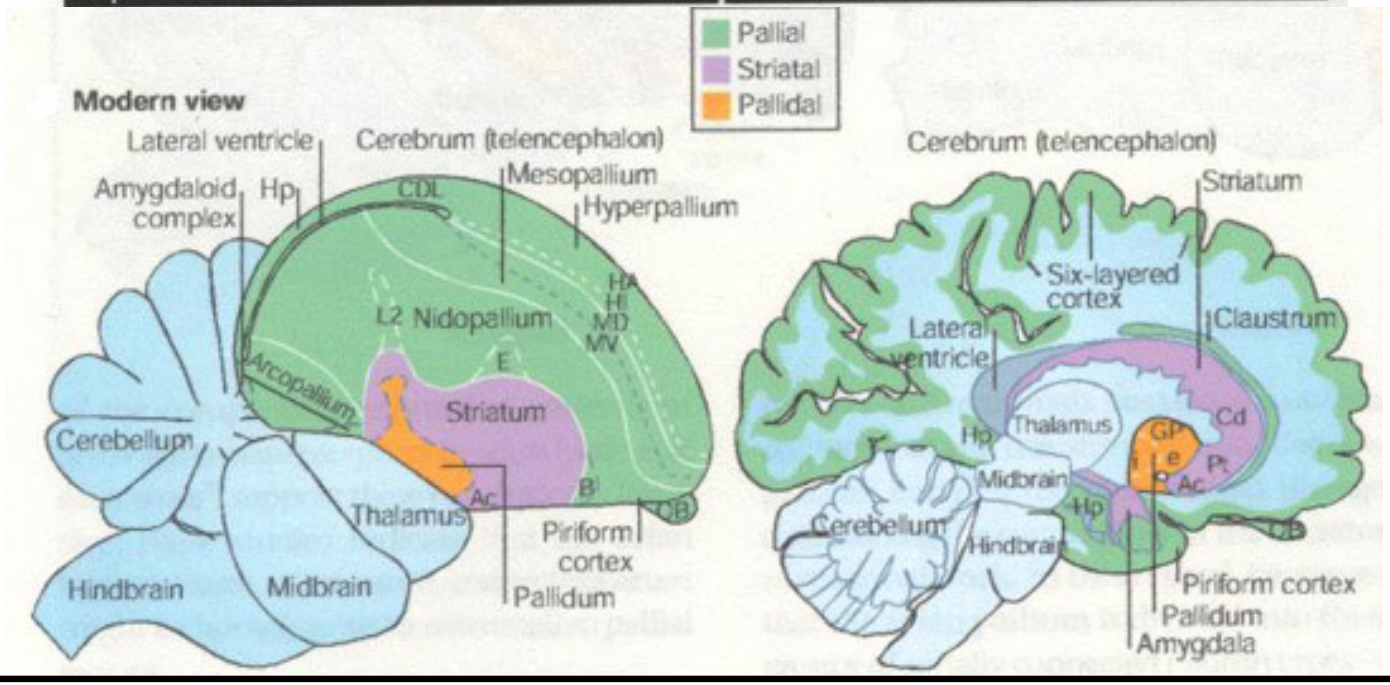
General Terms & Concepts

- Cache: Stored food.
  - Scatter Hoarding: Food is stored in a variety of locations (A & B)
    1. Win-Shift: An animal, having found food in one location, shifts its next visit to an alternative cache.
  - Larder Hoarding: Food is stored in one or only a few locations (C & D)
    2. Win-Stay: Making repeated visits to a cache



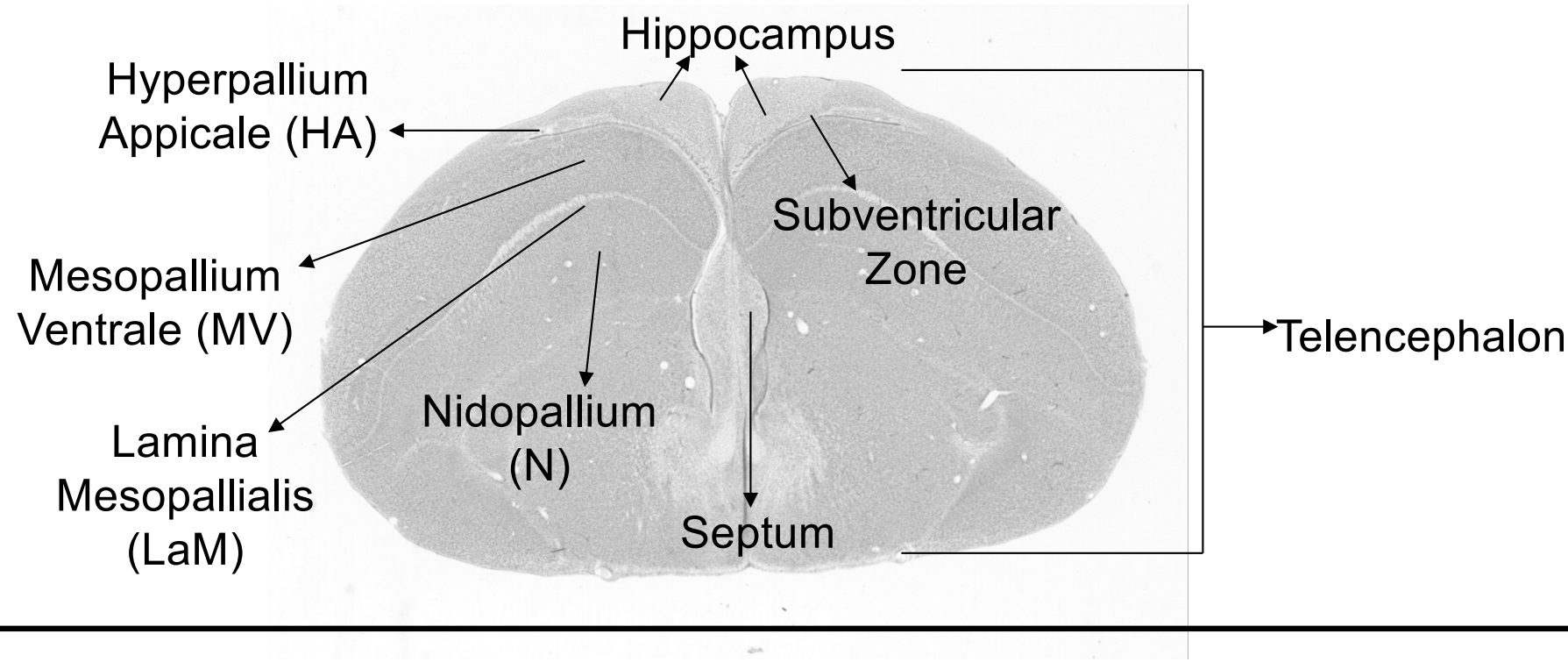
The Avian Brain





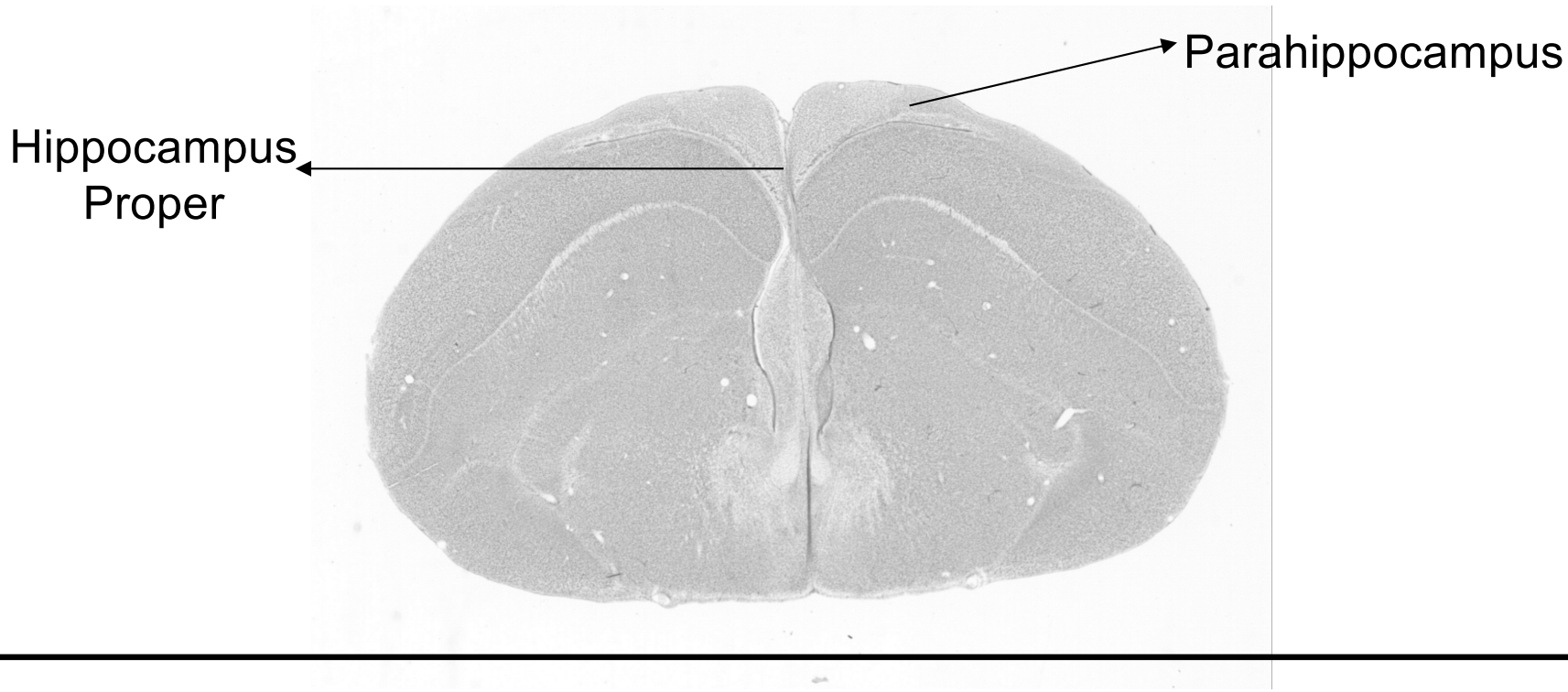
The Avian Hippocampus

- In birds, the hippocampus is part of the telencephalon and is located in the dorsomedial cortex.
- The hippocampus is closely located to the subventricular zone, a stem cell rich layer of the brain.



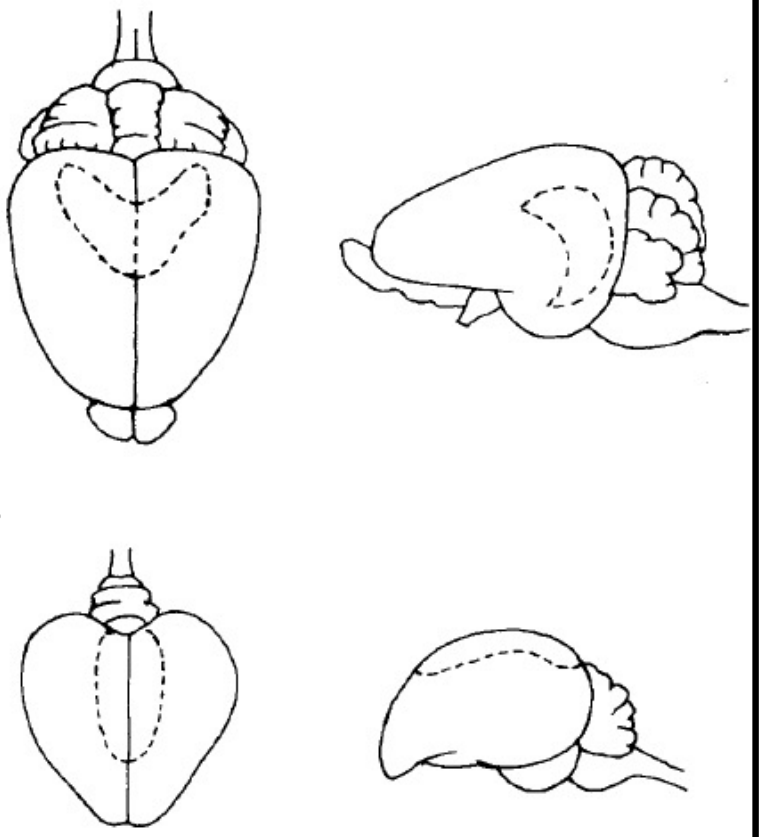
The Avian Hippocampus

- The most lateral boundaries of the hippocampus are called the parahippocampus.
- The “V” shaped ventral part is referred to as the hippocampus proper.



The Avian Hippocampus

- Embryological, anatomical, physiological, and neurochemical evidence suggest that the avian and mammalian hippocampi are homologous.
- Both the mammalian and avian hippocampi show topological similarities. However, throughout evolution the avian hippocampus remained in its original position, while the mammalian hippocampus changed locations.



The Avian Hippocampus