NATIONAL CENTER FOR CASE STUDY TEACHING IN SCIENCE

A Song from the Past: Long-Term Effects of Malnutrition During Development

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Part I – Types of Malnutrition

Despite one third of all food going to waste globally, malnutrition still affects over 230 million young children each year. The effects of malnutrition are particularly detrimental for children because they are still growing and their brains are rapidly developing. When we think of malnutrition, we usually think about a form of undernutrition in which a person is experiencing low calorie intake. However, malnutrition can also occur when a person does not eat enough of a particular nutrient like protein, a condition often referred to as protein energy malnutrition (PEM).

Effects of Undernutrition

Much of what we know about the long-term effects of undernutrition stem from studies of famines during which people experience a drop in the amount of food they have available. Some famines last only a few months while others can be persistent. Some commonalities of undernutrition in childhood are that as adults, these individuals are more likely to develop cardiovascular disease, type II diabetes, and impaired nervous system function (e.g., impaired motor skills, behavioral abnormalities, and learning disabilities).

Effects of Protein Energy Malnutrition (PEM)

Children experiencing PEM may be getting enough, or even too many calories, but they are not eating enough protein. Children who experience PEM are at higher risk for developing type II diabetes, cardiovascular diseases, stunted growth, and reduced IQ.

Questions

1. Explain the relationships between malnutrition, undernutrition, and protein energy malnutrition (PEM).

2. How is PEM distinct from undernutrition?

3. What is one thing that can happen if a person eats too few calories early in life?

4. What is one thing that can happen if a person does not consume enough protein early in life?

Part II – Malnutrition in Nature

Figure 1. Male zebra finch.

Humans aren't the only animals that experience the consequences of malnutrition. Animals in the wild routinely experience periods of food scarcity and food abundance. For example, in their natural range in Australia, zebra finches (*Taeniopygia guttata*) experience and breed under low- and high-food level conditions with the amount of protein available changing in addition to the overall quantity of food. Researchers have been working to understand how malnutrition affects the way zebra finch chicks develop and the lasting effects early nutrition might have into adulthood.

One trait that has received attention is the courtship song that males sing in order to attract a mate. Zebra finch song was a logical trait to look at because males learn their song when they are young and their song stays the same for their whole life. Song learning, like other forms of learning, can reflect cognitive function. Lastly, male song can affect whether or not a male finds a mate, which is important for them to be able to pass their genes on to the next generation. Females prefer males that sing songs that are more complex. Figure 2 below shows an example of what a zebra finch song looks like if you graph the pitch of the song over time. This is called a sonogram.

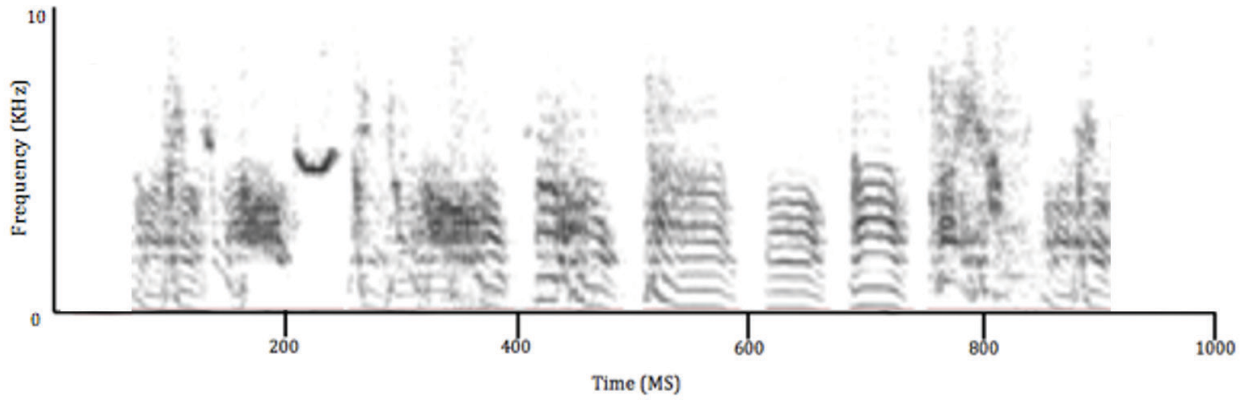


Figure 2. Sample sonogram of finch song.

Questions

5. Make a prediction about what might happen to a male bird's song complexity if the bird doesn't eat enough food (undernourished) early in life.

6. Make a prediction about what might happen to a male bird's song complexity if the bird doesn't eat enough protein (PEM) early in life.

Part III – Spencer et al. (2003)

Dr. Karen Spencer and her team explored whether male zebra finch song complexity was affected by the amount of food they received when they were young. Birds were raised under normal diet conditions or poor diet conditions. Under normal diet conditions, birds had normal access to food supplements and seed. Under poor diet conditions birds had access to half the normal amount of food supplements and empty seed shells were mixed in with their seed so that parents had to work harder for the same amount of food.

Question

7. What type of malnutrition is Dr. Spencer's study testing?

Dr. Spencer collected samples of courtship song from male birds once they reached adulthood and analyzed the songs for different metrics of complexity. Figure 3 below displays some of her results.

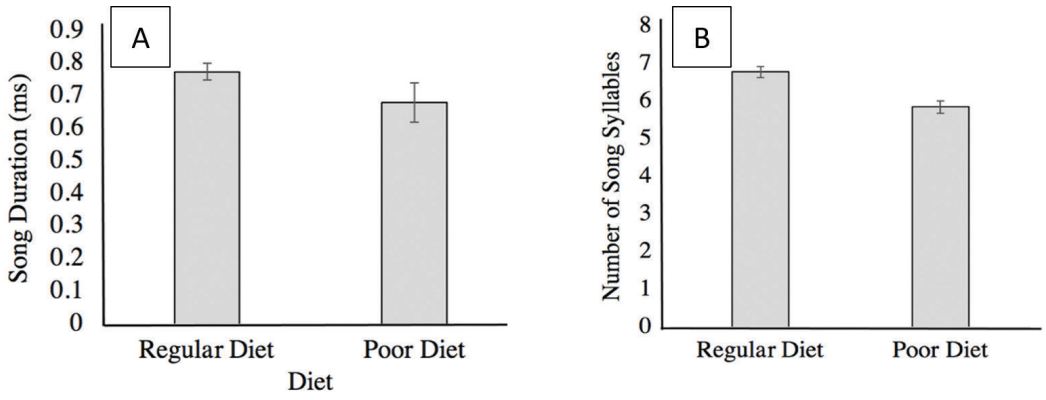


Figure 3. Selected results from Spencer et al. (2003). Panel A shows a two-sample t-test where $t = 71.02$ and $p < 0.0001$. Panel B shows a two-sample t-test where $t = 21.83$ and $p < 0.0001$.

Questions

8. Explain what the graph's statistical results (i.e., the p values) above tell us about the effect of this form of malnutrition on male bird song.

9. Do these results support your predictions? What do the results suggest about the effect of early life undernutrition on male brain development?

Part IV – Wilson et al. (2019)

Dr. Kerianne Wilson and her team explored whether male zebra finch song complexity was affected by the type of food they received when they were young. Birds were raised under favorable diet conditions or poor diet conditions. Under favorable diet conditions, birds had normal access to seed plus access to additional protein supplements. Under poor diet conditions birds had normal access to seed but no access to protein supplements.

Questions

10. What type of malnutrition is Dr. Wilson's study testing?

11. Make a prediction about how the amount of protein in the birds' diet will impact male song complexity.

12. Use the sonograms provided (pictures of zebra finch song on pp. 6–8 below) to collect data on song complexity. Work with your group to determine how complex each song is based on the number of syllables and song duration. Fill out the table below for each sonogram.

Sonogram ID	*Number of Syllables*	*Duration of song (milliseconds)*
Finch 1:		
Finch 2:		
Finch 3:		
Finch 4:		
Finch 5:		
Finch 6:		
Finch 7:		
Finch 8:		
Finch 9:		
Finch 10:		

13. Use the results from the table above to fill in the following information.

    A. Average number of syllables for high-protein birds: _____ low-protein birds: _____

    Standard deviation of syllable number for high-protein birds: _____ low-protein birds: _____

    B. Average song duration for high-protein birds: _____ low-protein birds: _____

    Standard deviation of song duration for high-protein birds: _____ low-protein birds: _____

    C. Run an independent *t* test to determine the *f* statistic and *p* value for the difference in number of syllables and song duration between the two diet groups.

    Number of syllables: f =_____ ; p = _____

    Song duration: f =_____ ; p = _____

14. Use the space below to make two graphs of your results.

15. Was there a statistical difference in the two measurements of song complexity between the high-protein and low-protein birds? Explain your response.

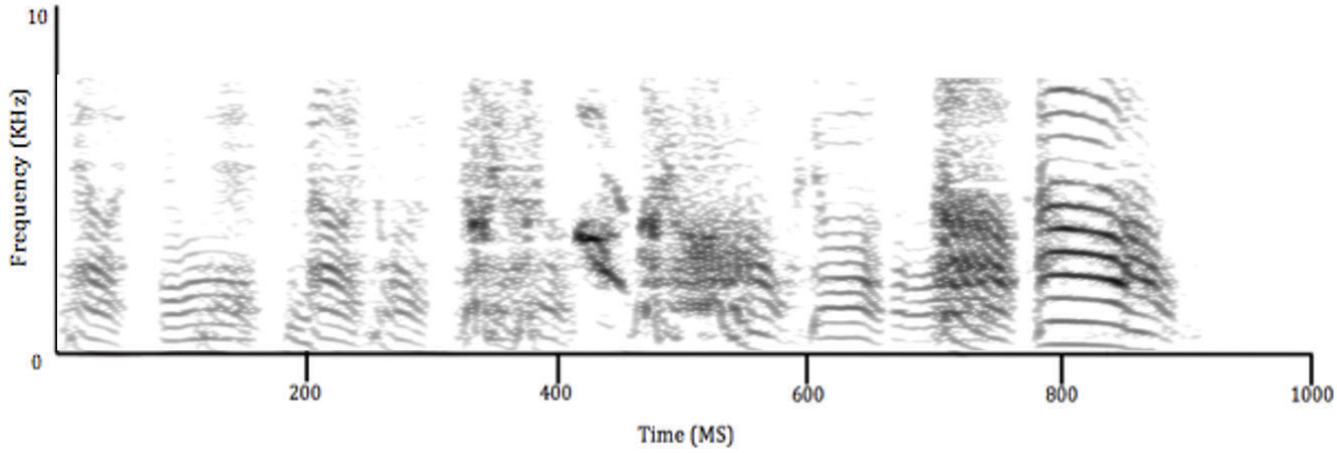
16. Explain what the graphs made in Question14 tell us about the effect of low-protein diets on male bird song.

17. What is the effect of high- versus low-protein diets on bird cognition?

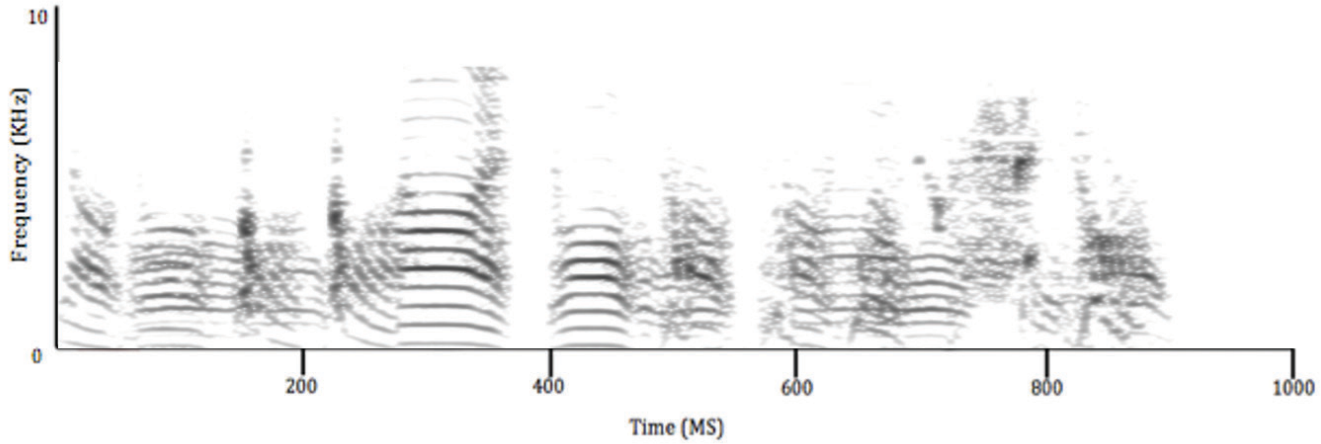
18. Which had greater impact on song complexity, undernutrition or PEM?

Sonograms from Wilson et al. (2019)

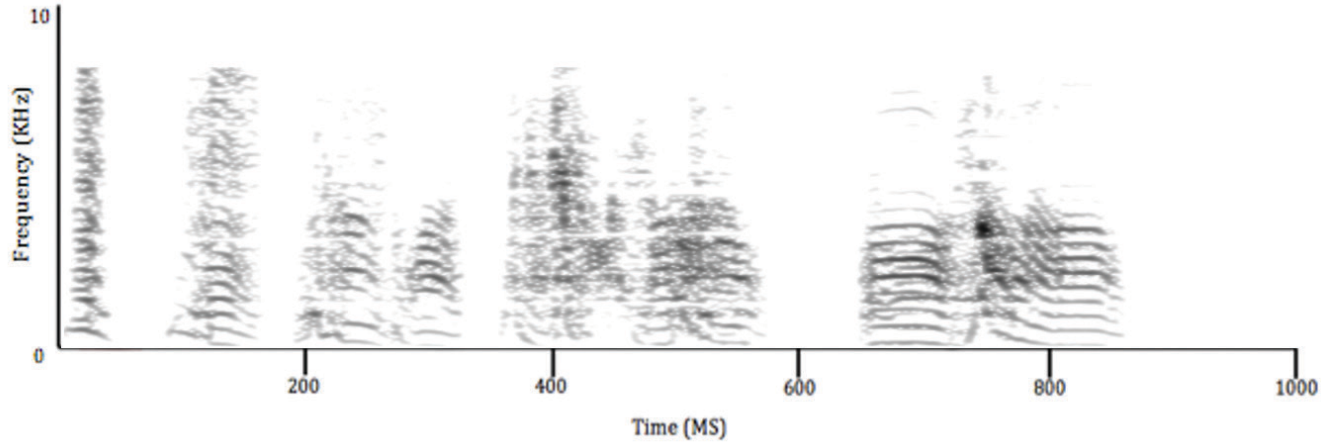
Male Zebra Finch 1.



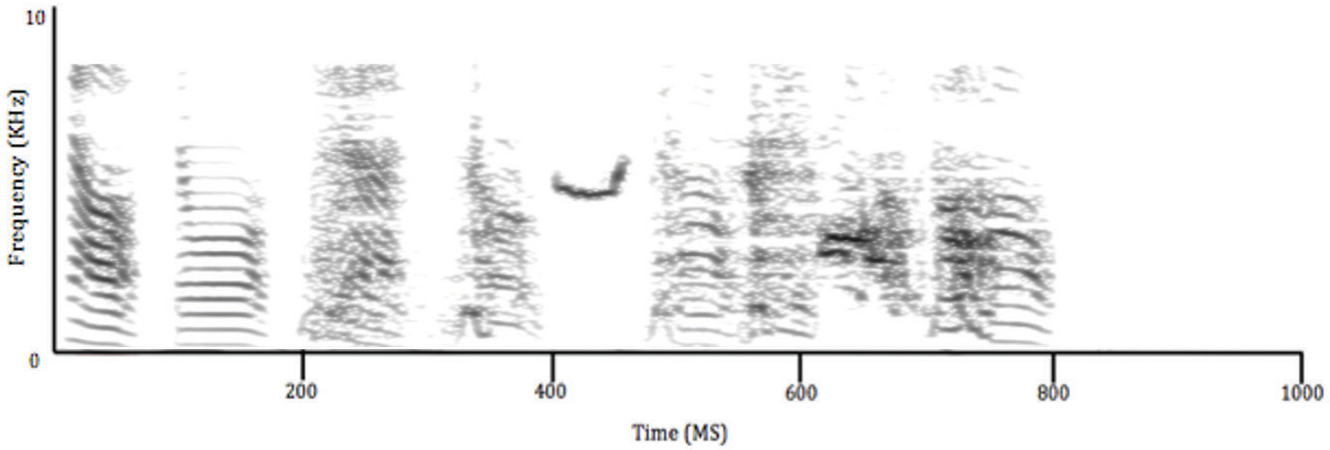
Male Zebra Finch 2.



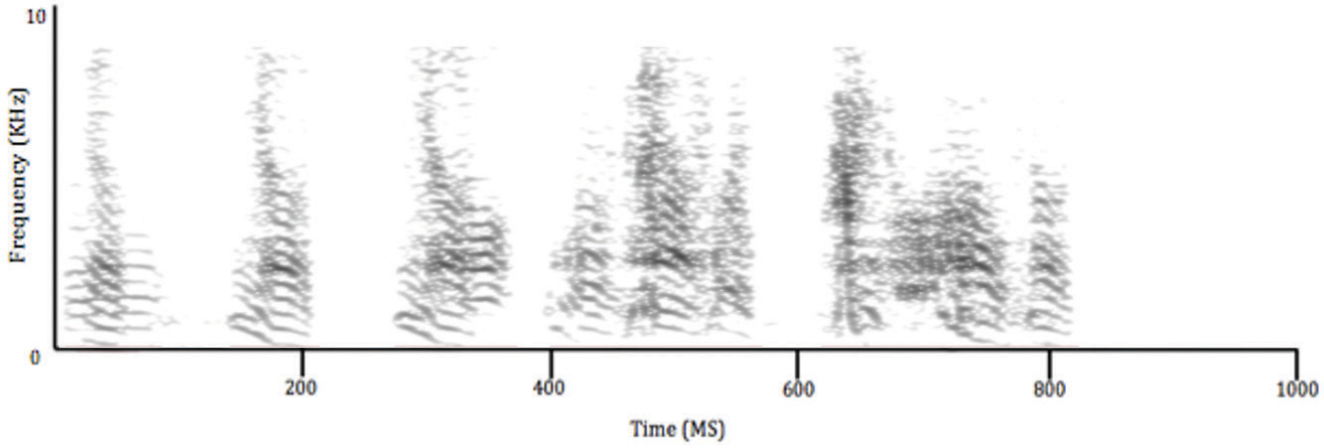
Male Zebra Finch 3.



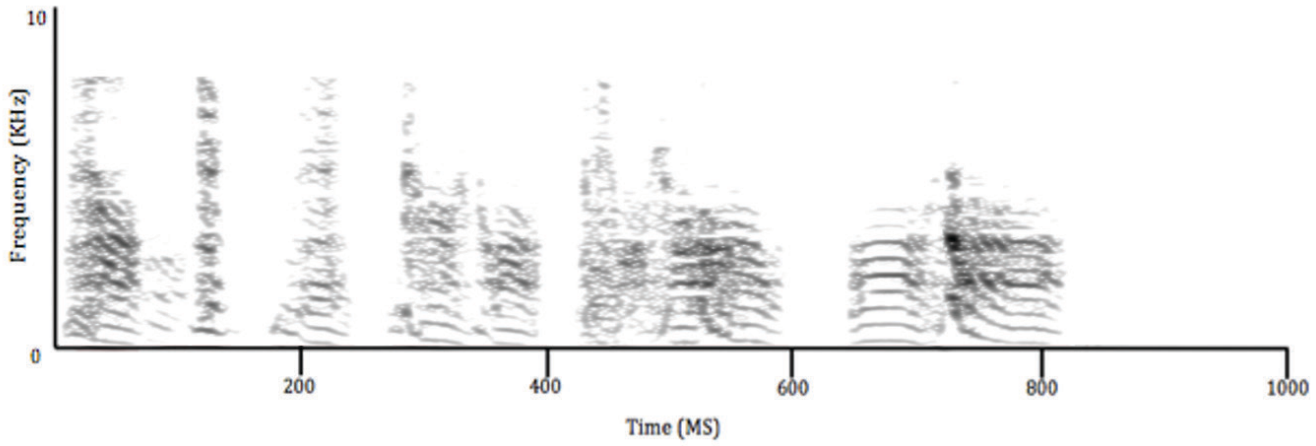
Male Zebra Finch 4.



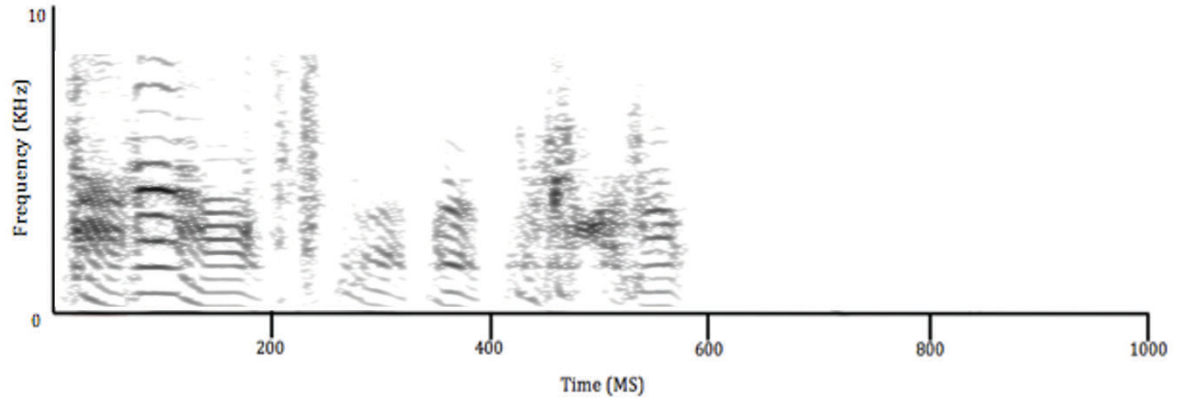
Male Zebra Finch 5.



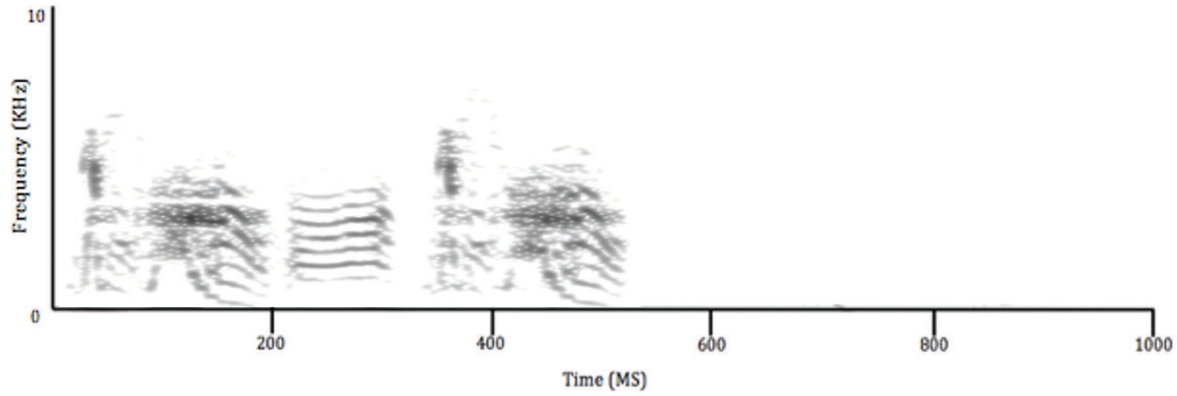
Male Zebra Finch 6.



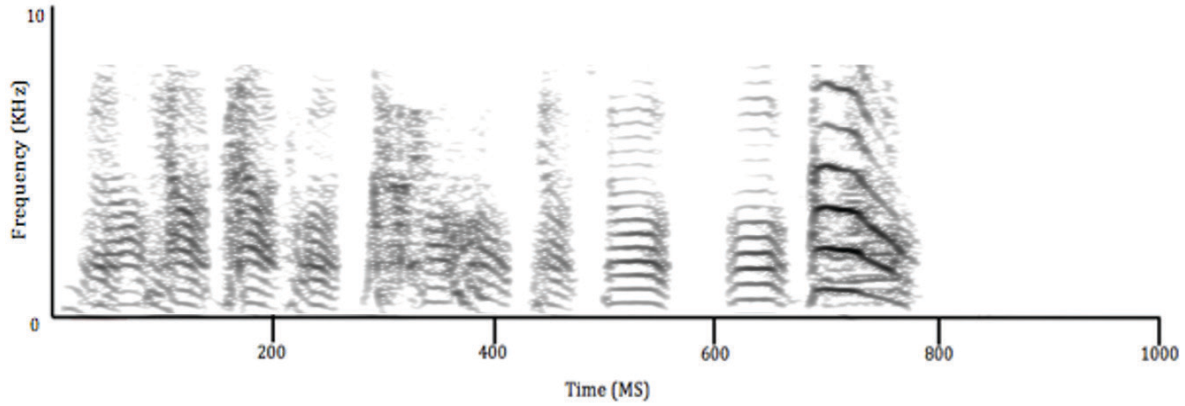
Male Zebra Finch 7.



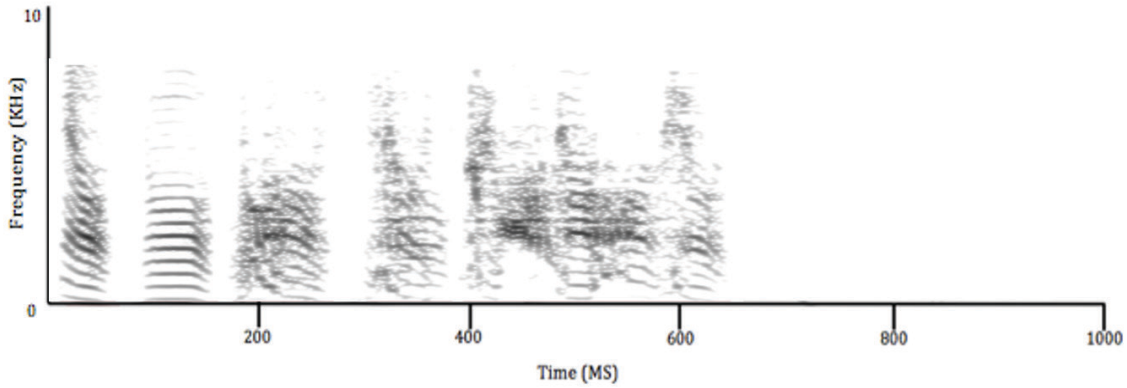
Male Zebra Finch 8.



Male Zebra Finch 9.



Male Zebra Finch 10.



Part V – Nutritional Imbalances in Humans

While the study in zebra finches focused on protein, nutritional imbalances in animals can also result from deficiencies in vitamins and minerals like iron, calcium, zinc, folic acid, and vitamins B12, C, D and E. For example, iron is found in foods like spinach, beans and certain meats, and is needed to transport oxygen in the blood. Low iron during early development can have lasting effects on the brain that results in reduced cognitive and motor function.

Questions

19. How do you benefit from getting balanced nutrition from your food?

20. What is something you could do to make sure you are not suffering from malnutrition?