Chimpanzee Droppings Lead Scientists to Evolutionary Discovery

by

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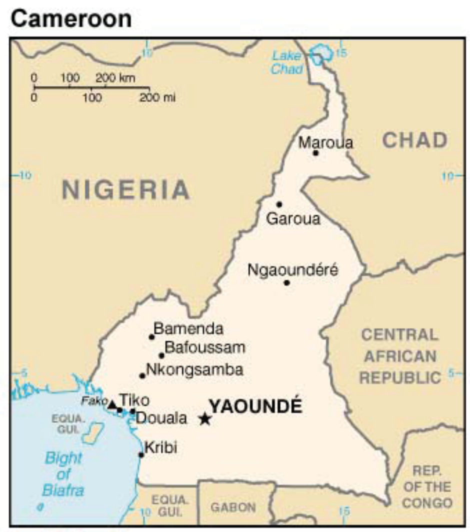
Part I—Chimpanzee Behavior



Far in the remote western African jungles of Cameroon, Dr. Beatrice Hahn and her team of scientists from the University of Alabama have been examining chimpanzee droppings. Members of the great ape family, chimpanzees typically travel in groups of 40 to 60 animals, forming smaller subgroups to forage during the day and then coming together again to sleep in trees at night. Communities lack a definite leader and are usually split into a number of subgroups, often when the animals go to forage. These subgroups (referred to as "fusion-fission groups") are temporary and change in composition within a matter of hours or days. Dr. Hahn and her associates are taking advantage of this social structure to collect droppings easily in the mornings at the sleep sites after the chimp troop moves on to continue foraging elsewhere in the forest.

Chimpanzees, like humans, are omnivores. The animals typically search for vegetation and berries to consume. At times, they hunt cooperatively with one another to attack and kill monkeys, such as the red colobus monkey. Moreover, chimpanzees have been known to engage in warfare if a neighboring troop enters their territory.

Each troop is very close, forming bonds that last a lifetime. Animals groom one another, share food at times, and engage in play. Many members are genetically related to one another. Males seldom or never leave the community into which they are born, and siblings and pairs of male friends often travel together. Females, however, may leave to join another group permanently when in estrus (the time when females are fertile), moving freely between communities because they have not yet given birth, or may return to their original group after becoming pregnant.

Membership in the community is typically composed of mothers, their offspring, and several adult males who are typically closely related to one another. There is a loose dominance hierarchy, with both males and females establishing high-ranking positions; however, all adult males rank over all females. Males within the group will sometimes try to take over the top position and, if successful, the defeated male will remain in the group. The dominant male who is in charge of the group overall typically has access to all females during estrus. In addition to grooming one another and sharing food, individuals within the community interact socially in order to win favors with one another. With such interactions come alliances. In some cases, males forming such political alliances with one another will band together in order to overthrow the dominant male and establish a new dominant male from the alliance.

Questions

1. The social structure and behavior of chimps in their communities or troops suggest many questions. What research questions might Dr. Hahn and her associates ask?
2. Choose one of the research questions from above and consider it in more detail. Based upon the question, what would be a reasonable hypothesis?
3. Based upon this hypothesis, what types of data might the scientists collect and for what reasons? How would these data allow Dr. Hahn to test the proposed hypothesis?
4. Dr. Hahn and her associates are specifically collecting fecal pellets. Why do you think Dr. Hahn is interested in the contents of fecal pellets? Generate a list of the possible "contents" of fecal matter.
5. How might the social structure of the chimpanzee community influence what is contained in the fecal matter? How might chimp social interactions influence what is contained in the fecal pellets or how they are distributed on the forest floor?

Part II—Viral Evolution

Over seven years, Dr. Hahn, who is a virologist at the University of Alabama in Birmingham, and an international team of European and Cameroonian scientists have tested hundreds of chimpanzee droppings. Using test tubes containing a preservative, the scientists collected 599 fecal samples from 10 forest sites and later analyzed them in Dr. Hahn's laboratory.

The team was interested in tracing the evolution of HIV (human immunodeficiency virus) to investigate the origins of HIV/AIDS. There is a simian virus known as SIV (simian immunodeficiency virus) that is closely related to HIV and has been found in 23 species of African primates, ranging from various species of monkey (e.g., Blue monkey, L'Hoest monkey) to mangabeys (e.g., red-capped mangabey), colobus, baboons, mandrills, and chimpanzees.

Both HIV and SIV are considered to be retroviruses, containing RNA instead of DNA as their genetic material. Because the virus must insert its genetic material into a host cell to take over that host cell, a retrovirus has to convert its RNA back into DNA form. Only after this "backstep" (hence the term "retro") occurs, can the virus successfully insert its genetic material (now in DNA form) into the host's DNA.

RNA is slightly different from DNA. RNA contains only one genetic strand, whereas DNA is a doubly-stranded molecule. In addition, the sugars of these molecules are slightly different. DNA contains the sugar deoxyribose while RNA contains the sugar ribose. In both cases, the sugars act as the backbone for the molecule and provide a place for the bases to attach. The bases determine the order of amino acids and thus proteins that are used to make more virus particles. RNA and DNA share three common bases with one another: cytosine (C), guanine (G), and adenine (A); however, RNA contains the base uracil (U), whereas DNA contains the base thymine (T).

The researchers are interested in finding out whether the SIV found in wild chimpanzees is the same virus as the SIV found in captive Western chimpanzees, *Pan troglodytes troglodytes*. This subspecies of chimpanzees lives in the wild in Cameroon, Gabon, and the Congo Republic. If this virus were to be found in wild chimpanzees in one of these three countries, the scientists could identify the location where HIV evolved, as the SIV is thought to have "jumped" from chimpanzees to humans (a process called zoonosis). This process was estimated to have occurred 50 to 75 years ago.

Questions

1. What is it about chimpanzee society that may have contributed to the spread of the SIV virus?
2. If the virus found in captive Western chimpanzees is the same virus found in wild Western chimpanzees, how would you be able to verify this? What types of techniques might be employed? What types of data would be desired?
3. What might scientists gain from knowing the location of the origin of HIV?
4. How might SIV have "jumped" from a chimpanzee to a human? Outline the series of events that would have led to the origin of HIV from an SIV ancestor.
5. What methodology might Dr. Hahn use to detect the SIV in the fecal droppings? (*Hint:* it is the same way that we test humans for the presence of HIV.)
6. The researchers are engaged in field, or basic, science. They are studying the virus and collecting data in order to more fully understand the virus: knowledge for the sake of understanding. What value do you place in this type of research? Explain your thoughts.

Part III—Methodology and Hypothesis

If the virus found in captive Western chimpanzees was the same as that found in wild Western chimpanzees, Dr. Hahn and her associates should be able to determine that by examining the molecular sequences for the viruses. For example, if part of the virus genome in the captive chimpanzees reads "AUUCGAGGUAAC," you would expect the wild virus' genome in this area to also read "AUUCGAGGUAAC" or something very similar. Likewise, if the same virus is present in the two wild chimpanzee populations, you would expect the base sequence to be very similar though not necessarily identical because changes/mutations happen often with retroviruses.

In order to successfully jump from chimpanzee to human, SIV must have evolved to be compatible with the human host (into what we now call HIV). In 2006, HIV affected 65 million people around the world, with the strain HIV-1 causing the vast majority of AIDS cases. In addition to the virus evolving to infect humans, a successful transfer from a primate to a human must have taken place as well. Possibly the virus might have transferred when a person was butchering a chimpanzee for food ("bushmeat"). This hypothesis, favored by Dr. Hahn's group, suggests that SIV was transmitted to humans as a result of cutaneous or mucous membrane exposure to infected animal blood. Humans could also have been infected with the virus if they consumed uncooked contaminated meat.

A competing hypothesis suggests that poliovirus vaccination trials carried out in the Belgian Congo in the late 1950s were responsible for the zoonosis of SIV from primates to humans. The primates who are prime candidates for zoonosis, the chimpanzee and the sooty mangabey, were not used in vaccine preparation—rather, the rhesus monkey was used. In addition, a group of HIV-1 virus, known as the M group, is estimated to have originated 10 to 50 years before the vaccine trials were conducted. For these reasons, the polio vaccine hypothesis is not accepted by most scientists today.

The evidence suggests that HIV evolved from SIV because the genetic sequences of these two viruses are similar. For example, the two viruses share 70% of the same code for the protein GAG. Regardless of whether we focus on HIV or SIV, there will be variants among the population because of the high mutation rates in these viruses. Some variants will do better than others in the face of a counterattack by the host's immunological system, and these will take over more host cells, leading to a vast production of many genetically "new" virus particles. Shifts in the proportion of different genetic variants within a population in response to *selective pressure* (in this case, the host's response to the virus) are referred to as *microevolution*.

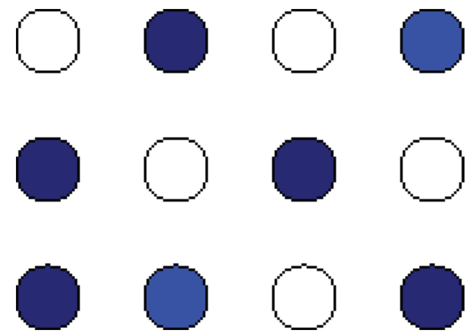
Such changes can be large (e.g., SIV → HIV) or small (e.g., variants within a population of HIV). When a population of HIV changes because of mutation and selection, leading to RNA sequences that are substantially different from the original population (but not so different that we say a new "species" has formed), we say a new strain has arisen. As a result, the human host cells do not recognize the new strain, and the human immune system does not attack the virus. This is part of the reason our bodies have a tough time resisting HIV infection.

If we were to examine the genetic sequences of several strains of HIV, we might see something similar to these samples:

- Sample 1: GACCTTACGGGATTCATA
- Sample 2: GACTTAACGGGGGTCATA
- Sample 3: GACCTTACGGGTTACATA
- Sample 4: AACTACGTCAAGCACAGG
- Sample 5: AACCTATCCCGATTCTAC

Which two strains of HIV are most closely related to one another? Which two are least closely related to one another?

Dr. Hahn and her associates were looking for similar types of patterns between SIV and HIV. The way in which Dr. Hahn and her associates test for the presence of SIV in the chimpanzee droppings is to test for antibodies—chimpanzee proteins that attach to the virus and help prevent them from causing further damage to cells. When we test for HIV in humans, we do the same thing. Using a test called ELISA (Enzyme Linked Immunosorbent Assay), a patient's blood serum or saliva is added to wells or depressions in a plastic plate that contains HIV antigen. If the serum contains anti-HIV antibodies, they will bind to the antigen in the well. In order to see if this has happened, a secondary antibody that recognizes the anti-HIV antibody is added. This secondary antibody has an attached enzyme on it. If HIV is present in the well, a noticeable change in color occurs in the well (see figure at right). We then say this person has tested positive for HIV, although further tests would be employed for verification.



Note: The above figure represents an ELISA plate with its results. Each circle or well contains a different sample that has been treated (e.g., each well contains a sample from a person—so in this case, 12 people are being tested). If the well changes color (e.g., blue), the person has tested positive for HIV. Some samples from individuals may respond more strongly to the antigens found in the wells (compared to other individual samples) and therefore may appear darker in color.

After testing for such antibodies, Dr. Hahn found evidence of chimpanzee infection with SIV in five of the 10 field sites. The team found that the prevalence of SIV infection was up to 35% in three chimpanzee communities or groups, 4–5% in two chimpanzee communities, and none in five chimpanzee communities. This basic research can now be used to help foster applied science or research.

Questions

1. Define evolution. There are many parameters and conditions that need to be in place in order for evolution to occur. One such parameter is that the population trait in question must be variable. i.e., there will be variations of a trait found in the population. What are some additional parameters and conditions necessary for evolution to take place?
2. Define microevolution. How does a selective agent lead to microevolution within a population?
3. Dr. Hahn and her colleague Dr. Gould believe that the fact that AIDS appeared as an epidemic in the 20th century and not before is due to a combination of factors such as more roads providing greater access to forested areas, urbanization, prostitution, social disruption, and other socio-behavioral changes. Why would these factors lead to an epidemic?
4. The team of researchers found different prevalence of SIV in the different chimpanzee communities. What is the significance of this finding?
5. Distinguish between applied science and basic science. Is one more important to society than the other or are they equally important? Explain your answer.

References

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