6×10^8 years, about 300 times longer than that for Earth. The longer lifetime for Venus reflects the higher abundance of ^{4}He (factor of 100) and the lower escape efficiency (factor of 3). Escape from Venus is limited by the relatively small quantities of gas which extend above the plasmapause.

Venus has lost a quantity of ^{4}He equivalent to 1.8×10^{22} cm^{-2} over the past 6×10^8 years. The present atmosphere is unlikely to retain appreciable quantities of its initial helium—escape would lead to a reduction of the primordial abundance by a factor of 5×10^{-4} (*17*). Contemporary escape should mirror the average quantity of ^{4}He released by the solid planet over the past 10^9 years. The necessary source would be supplied by decay of uranium and thorium if the abundance of these elements in Venus's lithosphere were similar to that for Earth (*18*).

Venus's atmosphere also includes measurable quantities of ^{40}Ar, formed by decay of ^{40}K. The relative abundances of ^{40}Ar in the terrestrial and Venus atmospheres suggest that the averaged source of ^{40}Ar at Venus's surface is less than that for Earth by about a factor of 4 (*19, 20*). The lower release rate could reflect either smaller abundances of ^{40}K or less efficient mechanisms for transfer of gas to the atmosphere. Measurements by Venera 13 and Venera 14 (*21*) suggest that potassium in Venus's surface material is similar to that for typical terrestrial basalts. In this case the lower abundance of ^{40}Ar on Venus could be due to less efficient degassing, perhaps reflecting a reduced role for tectonic activity in the presence of high surface temperatures (*22*). However, we might expect a differential effect for helium. Helium can escape by molecular diffusion from a depth of 1 km on Venus, aided by the high surface temperature, while the corresponding diffusion length for Earth is only 400 cm (*23*).

In summary, Venus's atmosphere contains 160 times more ^{4}He than the atmosphere of Earth. The source of ^{4}He is similar in magnitude for both planets, suggesting comparable abundances of uranium and thorium. Independent arguments suggest that the two planets have similar abundances of potassium, and it follows that the magnitude of the planetary heat flux should be similar for both bodies. From these results, together with information for nitrogen (*24*), carbon, water (*25*), and noble gases (*19*), we conclude that Venus and Earth had similar origins. The high concentration of primordial noble gases on Venus is attributed to capture of solar wind materials prior to planetary formation (*19, 26*); the low abundance of H_2O is due to escape of H and O (*12, 25, 27*) evidenced by enrichment of contemporary deuterium (*28*).

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Desickling of Sickled Erythrocytes by Pulsed Radio-Frequency Field

Abstract. *Electric fields were found to deform sickled erythrocytes. When the intensity of applied fields exceeded a threshold value, sickled erythrocytes transformed into a spherical shape. Prolonged application of the field usually caused hemolysis of erythrocytes. Deformation of red blood cells could be partly reversed if the field was turned off at an early stage. The cause of desickling may be the interaction of the field with the erythrocyte membrane and also with gelled intracellular hemoglobin S molecules.*

In patients with sickle cell anemia, red cell sickling is caused by the intracellular polymerization of deoxy-hemoglobin-S molecules. This polymerization can be inhibited by chemicals that interact with the hemoglobin molecule (*1, 2*) or with the erythrocyte membrane (*3, 4*). Chemicals such as cetiedil interact with the red cell membrane to increase water intake and inhibit red cell sickling at a concentration of 1 to 3 percent of intracellular hemoglobin (*3–5*).

We report a method for reversing red cell sickling without using chemicals. We found that sickled cells were converted within several minutes to a spherical shape by the application of pulsed radio-frequency (RF) fields. Experiments were carried out by placing a suspension of sickled red blood cells in an isotonic saline solution between two parallel Pt-Ir wires (see legends to Figs. 1 and 2 for details). We chose a short pulse width of 5 msec with an interval of 1 second to facilitate heat dissipation. The RF fields were applied to the sample with an attenuator so that the input voltage could be adjusted in small steps. The scheme of the general setup is shown in Fig. 2 (inset).

Blood samples were obtained from persons with sickle cell anemia. Erythrocyte suspensions in a small vial were deoxygenated by flushing nitrogen gas at 37°C for at least 30 minutes. A trace of sodium hydrosulfite was then added to the suspension to prevent reoxygenation. Figure 1a shows sickled red blood cells prepared by this method. The field strength was increased stepwise with a waiting period of 10 to 15 minutes at each step. Once the threshold was reached, the shape change of erythrocytes took place within a few minutes. The time course of the change was followed by light microscopy and recorded by a series of photographs. Figure 1b shows that the change to a spherical shape occurred in the presence of RF fields. If we continued to apply an RF field for 15 to 20 minutes, red cells began to hemolyze.

The desickling of red blood cells occurs at a well-defined threshold, which is determined by the frequency of the applied field, the duration and interval of pulses, and the length of the waiting period. The shape change can be only partly reversed if the field is turned off at an early stage. Thresholds at different frequencies (between 10 kHz and 1 MHz) were determined; the results are shown in Fig. 2. Although threshold values increase with the frequency of the applied field, the rise is much less than expected.

Previous studies showed that pulsed electric fields produce effects on normal red cells including changes in orientation, alignment, and shape (*6–10*). Kinosita and Tsong (*11–14*) found that square pulses at levels of a few kilovolts per centimeter for a duration of 20 to 30 μsec caused pore formation in the red cell membrane, increasing the flux of Na^+, K^+, and oxygen. They stated that the pores induced by pulsation were large enough to permit the influx of water. This observation suggests that dilution of hemoglobin S by water influx is a mechanism for desickling by RF fields. However, dielectric measurements by Delalic (*15*) indicated that an a-c field of 10 V/cm is sufficient to at least partly reverse extracellular gelation of hemoglobin S if the concentration and temperature are near the critical region. This observation indicates that RF fields can interact directly with gelled hemoglobin S molecules and deform or disintegrate liquid crystalline tactoids. Recently, Tanaka *et al.* (*16*) reported that a potential of a few volts can cause reversible volume changes of polyelectrolyte (acrylamide) gels. This suggests field-induced structural changes of polyelectrolyte systems.

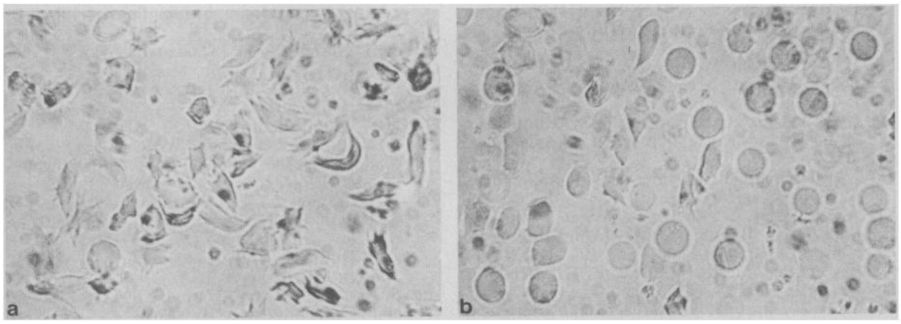

Fig. 1. (a) Sickled red blood cells before exposure to pulsed fields (×800). (b) Shape change in the presence of the field at 100 kHz. The field strength was about 3.5 kV/cm with a pulse duration of 5 msec and an interval of 1 second. The intervals between these photographs are about 2 minutes; they were taken while the field was on. Because of the short pulse width and long interpulse interval, no temperature rise was noted during the exposure of samples to RF fields.

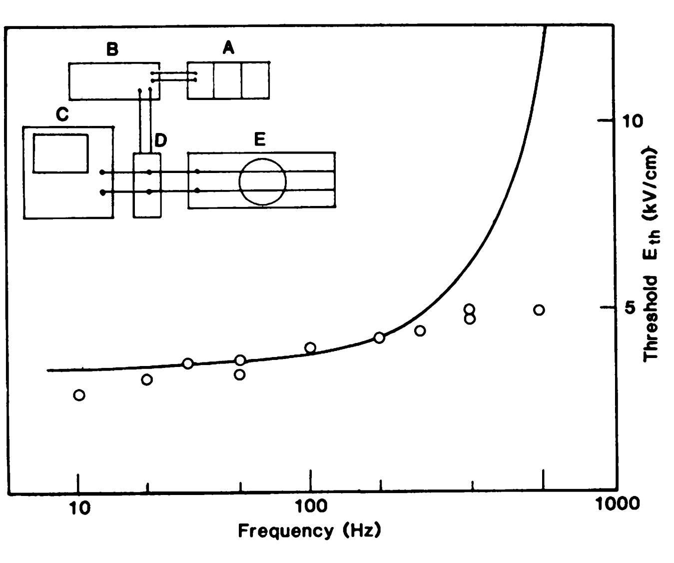

Fig. 2. Frequency dependence of threshold E_{th} for the field-induced shape change. The experimental conditions are as described in the legend of Fig. 1. (Solid line) Theoretical values calculated from Eq. 1 (time constant T assumed to be 5.3×10^{-7} second). (Inset) Experimental setup; A, Tektronix TM500 oscillator and plug-ins for pulsation; B, ENI 240L power amplifier; C, Tektronix 5403 oscilloscope; D, General Radio attenuator; E, sample holder, which consists of two Pt-Ir wires (50 μm with a spacing of 0.5 mm).

However, at low frequencies, the electrical field inside the cell would be smaller than that of the applied field because of the high electrical resistance of the erythrocyte membrane. Therefore, the membrane effect seems to play a dominant role at low frequencies. The potential produced by an external field, E_0, across the membrane of spherical cells can be calculated from (*17*)

$$\Delta V = \frac{1.5RE_0}{\sqrt{1 + (\omega T)^2}} \qquad (1)$$

where R is the radius of the cell, ω is the angular frequency ($2\pi f$), and T is the time constant. At sufficiently low frequencies, the potential difference across the membrane becomes $\Delta V = 1.5RE_0$. Assuming the average radius of erythrocytes to be about 4×10^{-4} cm, the potential ΔV is about 1.8 V. This value is somewhat larger than the critical field of pore formation—1.0 V—found by Kinosita and Tsong with normal red cells. Because the conformation of sickled erythrocytes differs considerably from the spherical shape, these calculations may not apply directly to sickled cells. In fact, we observed that severely sickled cells are hard to deform and require higher field strengths than slightly sickled cells. In addition, the membrane of sickled erythrocytes may be more rigid than that of normal red cells. Considering these factors, our value and that observed by Kinosita and Tsong are sufficiently close. The large potential induced across the membrane is the cause of pore formation, which entails the influx of water in red cells.

At high frequencies, the induced potential across the membrane decreases as indicated by Eq. 1. Therefore, a larger field must be applied to the cell suspension to induce a significant potential across the membrane. The threshold E_{th} is calculated theoretically from Eq. 1 and is shown in Fig. 2 along with measured points. The rate of increase in E_{th} is slow below 100 kHz and the agreement between the theoretical and experimental results is satisfactory. However, above 200 kHz the theoretical curve begins to rise sharply and the disagreement between the theoretical and experimental results becomes apparent. Since the erythrocyte membrane is electrically shunted at these frequencies, the field intensity in the cell would be much higher than at low frequencies. Therefore, the internal field would become sufficient to perturb the structure of gelled hemoglobin S. This may be why the observed frequency dependence of E_{th} deviates from the curve predicted by Eq. 1.

From these results and theoretical considerations, we assume that the application of RF fields causes changes in the red cell membrane that may induce water uptake into the cells. In addition, RF fields seem to perturb the structure of intracellular hemoglobin S gels.

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Female Moorhens Compete for Small Fat Males

Abstract. *Female moorhens in flocks competed with each other to obtain mates. The heaviest females won most of the agonistic encounters, and these females paired with males that had large fat reserves. Fat males tended to be small, possibly because of energetic constraints on birds of large body size. Females paired with fat males initiated more nesting attempts in a season.*

Any attribute that improves the chance of mating success should, theoretically, be subject to strong positive selection, a process that Darwin (*1*) called sexual selection. Although many field studies have led to the identification of characteristics that are likely to be responsible for success in competition for mates (intrasexual selection) (*2*), few studies have resulted in the identification of characteristics in one sex that are preferred by members of the opposite sex (intersexual selection) (*3*). A field study of the moorhen *Gallinula chloropus* has revealed a characteristic in males that is subject to intersexual selection in a situation in which females compete for access to their preferred mates.

A female's choice of mate may be a critical determinant of reproductive success in situations in which males contribute to parental care or defend critical resources (*4, 5*). Females may benefit by competing for mates when the males they acquire represent, or otherwise provide, an important scarce resource (*6*). Male American jacanas (*Jacana spinosa*) perform all of the postlaying parental care, and females that are successful in competition gain exclusive access to more than one male. They thus create a scarcity of males so that unsuccessful females sometimes fail to gain any male partners (*7*). In species in which there is no shortage of available mating partners, female competition could theoretically occur if variance in male quality resulted in a scarcity of "high quality" males (*6*). Moorhens are a species in which the male performs most of the incubation (*8*). This report provides evidence that female moorhens compete for high quality males (those with large fat reserves) and that females paired to fat males start more clutches in a season since the fat males can incubate for longer than thinner males.

The moorhens in the study area (*9*) formed small flocks (5 to 40 birds) between October and March (*10*). Pair formation occurred in these flocks before the birds left to establish territories (*11*). Females (*12*) initiated courtship (*13*) more frequently than males ($N_1 = 87$, $N_2 = 12$; binomial test, $P \sim 1.0 \times 10^{-15}$; combined observations from the winters of 1978–79 and 1979–80) (*14*). Agonistic encounters (*15*) were common and typically occurred when a female approached a courting pair (*10*). These encounters sometimes led to fighting, with the antagonists jumping into the air and striking at each other with their sharply clawed feet. Marked females in competition for males participated in more fights than marked males ($N_1 = 26$, $N_2 = 12$; binomial test, $P = .033$; combined observations from the 1978–79 and 1979–80 winters). During the 1978–79 and 1979–80 winters, the numbers of agonistic encounters observed (including fights) were 85 and 152, respectively, in encounters in which both members of a dyad were marked, and 171 and 73, respectively, in encounters in which only one bird was marked. These data were used to express each female's success in terms of the percentage of agonistic encounters won (*16*). The best predictor of the outcome of aggressive encounters in flocks was body weight (*17*). However, weights can be compared only if the birds are weighed at the same time of year since there is considerable seasonal variation in body weight (*10*). In January 1979 and February 1980, 62 and 52 percent, respectively, of the females in the study population were weighed. The weights of females that were not caught at these times were adjusted with correction factors based on mean differences in weight from month to month (differences were at most 19 g) (*10*). In both years, a higher proportion of agonistic encounters was won by heavier females than by lighter females (1979: $r_s = .63$, $P < .01$, $N = 16$; 1980: $r_s = .56$, $P < .01$, $N = 21$) (*18*).

Since females court and compete for males in flocks in which there is no shortage of available males (*19*), it seems likely that the females compete for access to high quality partners. Moreover, since heavy females win contests the heaviest females should be paired to the highest quality males. Males perform 72 percent of the incubation (*8*) so that one hypothesis is that high quality males are those that can incubate for long periods. Since incubation in the moorhen is energetically expensive (*8*) and males lose weight during the breeding season (mean January weight, 386 g; mean June weight, 357 g; $t = 2.28$; $P < .05$), energy or nutrient reserves might be an important component of male quality.