propriate for this site without any further information acquired at or en route to the site.

Air was collected in two large (750-l) plastic containers at four sites located 11–15 km symmetrically around the loft. The air containers were transported back to the loft. Five pigeons were placed inside each, through a lockdoor, for a period of 2 h. The olfactory mucosae of all pigeons still inside the containers (see [3]) were then anesthetized with Gingicaine. The birds were then transported to one of the four sites where the air samples had been taken. The pigeons were released individually and their vanishing bearings recorded. Homing speeds were not recorded since differences between groups according to [3] were not expected. For the statistical treatment of data see [9, 10]. Pigeons with little experience, which had not visited the release sites in question, were used in all experiments. In all releases the sun was visible and light wind prevailed. Two series, each of 16 experiments, were carried out, involving a total number of 347 pigeons released.

The vanishing bearings of all experiments pooled (pseudopooled, see [10]) from the four sites with respect to home ($=0°$) were significantly oriented $\alpha = 325°$, $a = 0.158$, $n = 276$, V-test $p < 0.001$. Pooled with respect to the direction expected according to the air samples presented to the birds, the orientation is also significant ($\alpha = 343°$, $a = 0.117$, $n = 300$, V-test $p \sim 0.004$); in both cases the mean direction is not significantly different from the expected direction. A further analysis of the data, however, reveals that pigeons which had been exposed to air samples other than from the actual release site show a perfectly random distribution of vanishing bearings with respect to home, as well as with respect to the direction expected according to the air samples presented to them (Fig. 1a, b). Those pigeons, however, which had been exposed to the air of the actual release site were perfectly oriented in a homeward direction (Fig. 2a). The difference in dispersion between the two groups is highly significant ($p < 0.0001$). Both groups when pooled with respect to North, thus compensating for any home-specific or site-specific orientation, show a clear northeasterly orientation (Figs. 1b, 2c) also typical
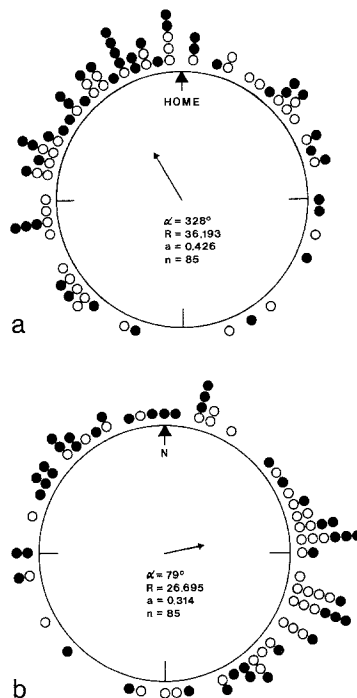

Fig. 2. Vanishing bearings of pigeons pooled from four sites and released at the site where the air sample was taken. a) With respect to home, b) with respect to North

for untreated pigeons from this particular loft [3]. A detailed evaluation of the data will be given in a forthcoming publication.

The results strongly suggest that site-specific airborne, possibly olfactory information alone is not sufficient to enable a pigeon to orient in an appropriate direction. Only airborne information together with some other matching route- or release-site-based information – possibly involving the earth's magnetic field – enables the pigeon to orient correctly. A navigation mechanism based on two matching sets of information naturally would be impervious to ambiguous information input – and it would also make many seemingly conflicting past results intelligible. How the two components are matched and what the basis of the components is remain unidentified.

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Magnetic Fields Modify the Surface Temperature of Pigeons

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Increasing scientific, medical, and industrial applications of steady magnetic-fields (H) around 1 Tesla and above – as in NMR tomography, plasma confinement and solid-state research – call for a reliable assessment of potential impacts of such fields on living organisms. Gremmel et al. [1] reported cool-

ing and warming effects of up to 5 °C occurring within several minutes in skin tissue of humans in $H \approx 1.5$ T at unmodified central temperature. Sperber et al. [2] noticed comparatively slow but overall changes up to 2.4 °C in body temperature of mice developing within several hours of exposure to about 2 T; the latter effect seems to depend on the field gradient rather than on intensity, and saturates above 2 T. We find homing pigeons particularly interesting for studying magnetic-field effects because of their ability to use the earth's magnetic-field in the process of orientation [3] – which can be influenced by strong magnetic-fields [4] – and for their easy handling and size suitable for fitting into a high-field solenoid.

We used five about 1-year-old male or female homing pigeons (*Columba livia*). Body and surface temperatures were measured every 10 s using 10 Fe-Constantan thermocouples, a computer-controlled scanner and digital voltmeter. The magnetic-field-dependent misreading of the probes is <0.1 °C in 12T as checked by temperature measurements on a cardboard dummy. One probe was introduced into the cloaca, others were attached to the skin: 0.05 cm-diameter thermocouples were pressed onto neck and left breast; 0.1 cm diameter thermocouples soldered on 0.5×0.5 cm² copper foils were attached to right breast, one or both legs, lower abdomen and, in some runs, under both wings near the shoulders. Pigeons were shackled and placed head up or head down in a conical cardboard holder. Probes were also located at the holder near right shoulder, ventral abdomen, and in the air space ca. 10 cm below the pigeon. The holder was placed in a cylindrical temperature-stabilized (±0.05 °C) copper housing of 12.7 cm inner bore and 110 cm in height. The housing was closed at the bottom and mounted into a vertical Bitter-type solenoid. Heart beat rate and breathing frequency were measured using a piezo-electric polymer foil (PVF_2) and on-line fast Fourier analysis, thus avoiding electrical pick-up problems encountered in standard ECG under magnetic-field due to mechanical motion of the electrodes. The breathing frequency was also measured using a thermocouple fixed close to the beak. The time a par-

ticular pigeon spent in the magnet, summed over all experiments, ranged from 5 to 15 h with a total exposure time (to various field intensities) between 2 and 6 h.

Once the pigeon was installed in the magnet, temperatures stabilized within 15 to 30 min. The magnetic-field was then switched on (usually) with a ramp speed of 0.4 T/s and held constant for ca 15 min. In the following, we describe findings from a total of 93 experiments. Figure 1 shows two 120-min records from the neck. A drop in temperature is already apparent some 10 s after switching on the field. The temperature approaches a field-dependent offset ΔT within several min, no substantial further changes occur (Fig. 2). ΔT does not depend on the field ramp speed (which was varied in one run between 0.03 and 0.65 T/s). We find similar magnitudes of ΔT in different pigeons at the same location. As also seen from Fig. 1 (and noticed in all experiments performed to check on this), ΔT has similar magnitude for head-up or head-down orientation of the pigeon.

Figure 3 shows the H dependence of ΔT typical for the upper body. ΔT seems to vary approximately linear with H, but considering the scattering

Fig. 2. Pigeon H313, a), b) raw data, c) data from b) corrected for the variations of the core temperature (a). Head up, central position, $T = 23.8$ °C
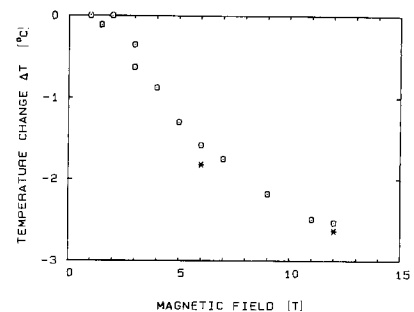
Fig. 3. Magnetic-field dependence of temperature change ΔT measured at the bend of the wing of pigeon AV74, head up, central position, $T_0 = 22.3$ °C, field polarity (o) north up and (*) north down. Data are corrected for fluctuations of the core temperature, as in Fig. 2c

of data a higher power increase at low H followed by some saturation is conceivable. In fact, inverting the field polarity does not change the sign of ΔT. At the lower abdomen a more complex field dependence is observed with ΔT having a maximum around 3 T and almost vanishing near 12 T. Magnitude and sign of ΔT strongly depend on the location of measurement: the cloacal temperature change is always <0.1 °C. At the skin both heating and cooling occur simultaneously at different locations (Fig. 2). Grouping data from 9 probes in 52 experiments on different pigeons (with head at center of the solenoid or below), we notice field-induced cooling of the neck-, breast-, and shoulder regions in 48 cases (vs. 4 unclear) and heating of the lower abdo-
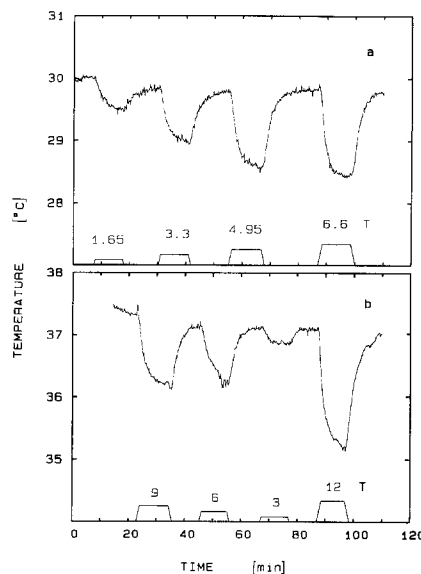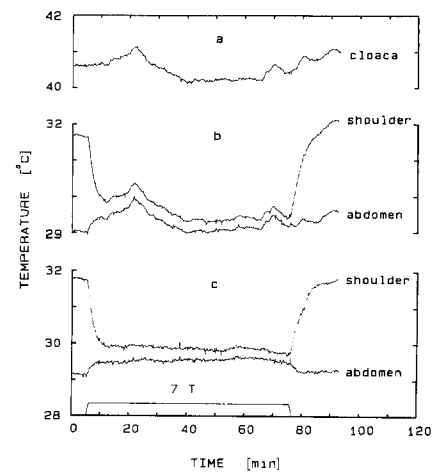

Fig. 1. Neck temperature of two pigeons in magnetic-fields of different intensities. *Numbers* are field values at the head. a) Pigeon H361, head 16 cm above center of solenoid, head down, $T_0 = 22.5$ °C. b) Pigeon H313, head in center, head up, $T_0 = 22.6$ °C. For the axial field variation of the solenoid see Fig. 4

men in 44 cases (vs. 8 unclear). The integral heating of the lower body surface was reliably detected also from the warming of air enclosed below the pigeon.

In order to examine an eventual relation between the inhomogeneous pattern of ΔT and the field gradient, we varied the pigeon's position along the axis of the solenoid (Fig. 4). To keep the environment constant, housing plus pigeon were displaced relative to the magnet. In upper and lower body, respectively, a different position dependence of ΔT is found: ΔT at outer shoulder and neck follows approximately the field *intensity* applied to the upper body (or head), whereas ΔT at the lower abdomen seems related to the field *gradient* at the head rather than at the probe site.

Much is known [5] about factors involved in thermoregulation such as vasoconstriction and -dilatation, heat production, piloerection, and panting, and about their changes with environmental temperature (T_0). We therefore studied ΔT at various T_0. We noticed [6] that ΔT is approximately proportional to the difference between T_0 and the core temperature T_c.

Our observations differ from the results on mice [2] and man [1] as far as response time, spatial distribution of ΔT and field dependence are concerned. A response time of several minutes allows significant temperature changes only within a thin surface layer of the animal, in agreement with our observation of field-independent T_c. The findings of no further field-dependent changes at the skin at longer exposure times, and of the coherence of fluctuations of all temperatures (Fig. 2) seem to indicate persistence of thermoregulation under magnetic-field; but regulation occurs around offset T-values. Neither heart nor breathing frequency are measurably modified under magnetic-field [6], suggesting that metabolic activity may not be substantially affected. Since, in addition, $\Delta T \sim T_c - T_0$, it seems tempting to speculate on magnetic-field effects on those mechanisms which involve heat transfer from body to skin; However, thermoregulation in pigeons is a complex process involving [5] a central control (hypothalamus), nervous conduction, internal and superficial thermosensors, and heat exchange with the environment mainly through blood flow controlled by vasomotoric action. The observed temperature reaction seems to depend on field intensity (and gradient) at the upper body (e.g., head) rather than at the actual probe site. This may perhaps argue against a direct influence of the magnetic-field on local thermosensors or immediate effects on the local blood flow.

Temperature measurements in locally applied fields, or using anesthetics, or direct observation of nervous activity and blood circulation in vivo and in vitro could help to understand the effect reported here, but also to clarify eventually related impacts of steady magnetic-fields.

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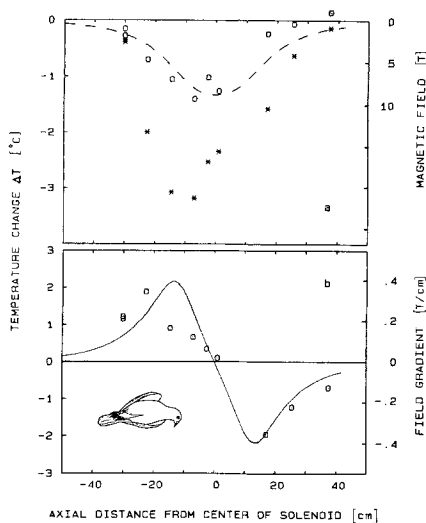

Fig. 4. ΔT values taken at neck (o), outer shoulder (*) and lower abdomen (b). Pigeon H363, head up, at different positions along the solenoid axis. Distances refer to the head. $T_0 = 22.5$ °C. Profile of field intensity (– – –) and of its spatial gradient (——)

Isolation and Functional Property of mRNA Coding for Hepatitis A, B, and Non A-Non B Viral Particles from Human Sera

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A population of hepatitis surface antigen (HBsAg)-like proteins and/or glycoproteins as defined by specific anti-HBsAg binding, were synthesized in vitro after incubation of poly(A)-mRNA from viral particles sedimented by gradient ultracentrifugation of sera from patients with hepatitis A, B and Non A-Non B in a cell-free protein synthesis system.

Although Non A-Non B hepatitis is the predominant form of post-transfusion hepatitis [1–5], and was recognized a decade ago, no specific test for the agent(s) has yet been identified and confirmed. In the absence of specific tests, level of a serum enzyme, alanine aminotransferase (ALT), a non-specific enzyme in blood donors has been sought. A possible correlation has been shown between donor ALT levels and the incidence of Non A-Non B hepatitis in transfusion recipients [2, 3, 6]. Seto et al. [7] reported particle-asso-