

## Magnetic Effects on the Bacterium *Escherichia coli*

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### Introduction

Davis and Rawls, (2,3), have claimed that there are distinct differences between the north and south magnetic fields with regard to their effects on living organisms. This claim is based on their theory that the nature of the magnetic field surrounding a magnet is essentially quite different in nature from the conventionally accepted view. It has been traditionally held that the path of travel of magnetic lines of force is a direct one from pole to pole. However, Davis and Rawls claim that the magnetic lines of force travel from the south pole into the center of the magnet and from the center they travel to the north magnetic pole. The south pole of the magnet is characterized by lines of magnetic force spinning to the right (clockwise or positive spin) and the lines of force of the north pole spin to the left (counterclockwise or negative spin). The center of the magnet therefore posses a region of zero magnetism. According to this theory, the lines of magnetic force show the same overall effect as that of conventional theory, namely, that of traversing from the south pole to the north pole of the magnet. The only difference is that the center of the magnet is a region of null field strength, since the magnitude and opposing directions of the north and south magnetic spins give a cancellation effect. This difference in spin effect is not a function of the shape of the magnet but bar magnets of definite dimensions and structural material were found to be most effective in investigating the effects of the different magnetic pole energies or field strengths on various living organisms.

Davis and Rawls (2,3) used a flat slate-like non-metallic magnet with an average field strength of 3000 gauss (N-1 type biomagnet), 6" long by 2" wide by 1/2" thick with a lifetime of from 3 to 5 years.

They found that the south pole of such a magnet when placed in close proximity to a living organism has a positive, enhancing effect, while the north pole has a negative, retarding effect. For example, in their study of the growth and development of chickens, the application of the N-1 biomagnet south pole for a definite time period caused these organisms to grow faster and stronger than north pole treated animals. The north pole treated animals turned out to be light eaters and developed slower than control animals. The north pole treated animals were also more sensitive to surrounding noises and weather conditions. This was in distinct contrast to the overly strong south pole treated animals. Similar results, on other living systems, showing the different positive and negative effects of the south and north magnetic pole energies were obtained by Davis and Rawls. Some of their other studies include the effects of north and south pole energies on seeds and other small animals such as snakes, birds, mice,

and rats. In all cases, the application of north and south magnetic pole energies were different from control studies and produced opposite effects. The sex life, aging, and the increase or reduction of the normal life span of animals was also the subject of their investigations. In all cases, with regard to organism growth, the south pole magnetic field has a positive, enhancing growth effect while the north pole magnetic field has a negative, retarding effect.

Other reports of magnetic effects on living systems have been published. Some of those that claimed an effect included Schaarschmidt et al (10), Persinger et al (9), Moskwa and Rostkowska (8), Grensler et al (5), and an early report by Kimball (7). However other workers including Jennison (6), Steen and Oftedal (11), and Dymshits et al (4) were unable to show effects of magnetic fields on biological systems.

If Davis and Rawls were correct about the differential effects of north and south magnetic fields on living systems this might explain the apparent discrepancies in the published data. We attempted to test this theory in our laboratory by studying the effect of north and south magnetic pole energies on *E. coli* using the N-1 type bar magnet obtained from the laboratory of Davis and Rawls. These investigations were performed under three different conditions, application of the south magnetic field, application of the north magnetic field, and no magnetic exposure, all at constant 37° temperature. Our studies included the effect on growth rate, mutagenesis, and viability of *E. coli* in non-growth conditions.

### Methods and Materials

*Strains and Growth Conditions:* *E. coli* WWU was a gift of R.C. Brockrath and C. N. Newman and was grown either in A-1 medium with appropriate supplements or nutrient broth plus glucose as described by Brockrath et al (1). The number of arginine revertants was determined on A-1 medium lacking arginine and viability was determined on Difco Nutrient Agar plus 1% glucose plates. Liquid cultures were grown in 13 x 100 mm culture tubes and bubbled with air through a manifold to insure equal oxygenation. The 37°C growth temperature was maintained by a hair dryer with a variable autotransformer wired in series with the heating element.

*Magnetic Exposure:* The culture tube with 5 ml of growth medium was clamped to the appropriate pole of the magnet or not exposed to a magnetic field (control) as was needed. The type N-1 (3000 gauss) magnet was purchased from Davis and Rawls.

### Results

The effect of magnetic fields on growth of *E. Coli* WWU was determined by diluting an over-night culture 1 to 10 on the morning of the experiment. When this diluted culture was in exponential growth it was further diluted to give at least five doublings before stationary phase was reached. The culture was then exposed to the magnet and at twenty minute intervals samples were taken and diluted and plated on nutrient agar to determine viable titer. Figure 1 shows the results of one such experiment. The correlation coefficients were: control = 0.98, north pole = 0.93, and south pole = 0.98. The slopes of all three lines were 0.03. It

appeared that the magnet produced no measureable effect on growth (five doublings) in nutrient broth plus glucose.

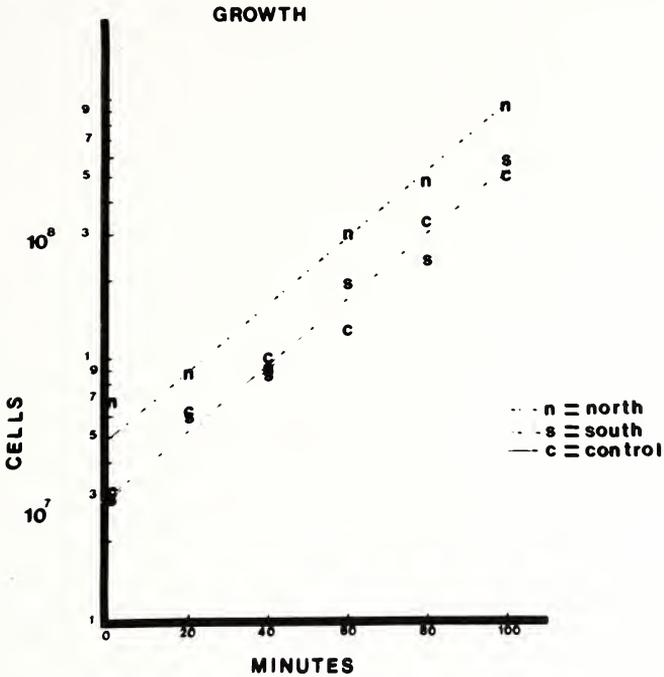


FIGURE 1. Effect of the magnetic exposure on the growth of *E. coli*. N = north magnetic pole exposure, S = south magnetic pole exposure, C = no magnetic exposure.

Next, the effect of the magnetic field on long term viability was determined. The bacterial cells were grown overnight and diluted as before except the exponential culture was washed and suspended in AO buffer (1). Five ml of this suspension were placed in a 25 cm<sup>2</sup> tissue culture flask and placed on the appropriate pole of the magnet or left unexposed (control). Viability was determined as before. Figure 2 shows the results of the south pole exposure as compared with the control exposure. The north pole experiment (not shown here) produced similar results. The correlation coefficients for both lines (south and control) were 0.85 and the slopes of both lines were -0.11. It appeared that the magnet produced no measurable effect on viability of this bacterium when held in AO buffer.

The final set of experiments was conducted to determine if the north or south magnetic field (3000 gauss) was mutagenic for *E. coli* WWU. Table 1 demonstrates that mutation can be quantified in this organism by determining the number of arginine revertants. The number of arginine revertants was determined per 0.2 ml while viability was expressed per 1.0 ml. As can be seen in the last row of the table, the number of revertants per 10<sup>8</sup> viable cells increased dramatically with only 30 seconds of ultraviolet light exposure. For tables 2 and

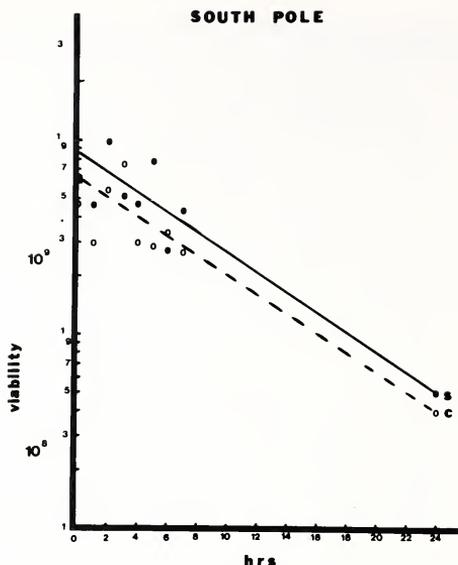


FIGURE 2. Effect of the magnetic exposure on the viability of *E. coli* in buffer (non-growth conditions).  
● = south magnetic exposure, ○ = no magnetic exposure.

3 the bacteria were treated as in the viability experiment and the cells were plated on agar medium lacking arginine. In both cases there was no significant difference between those cells exposed to the magnetic field and the unexposed controls.

TABLE 1. The Effect of Ultraviolet Light on *E. coli*.

Seconds of UV Exposure <sup>1</sup>	0	5	10	15	20	30
Viability	$3 \times 10^8$	$1.5 \times 10^8$	$1.3 \times 10^8$	$8.2 \times 10^7$	$9.8 \times 10^7$	$1 \times 10^7$
Arginine Revertants	10	173	530	518	512	281
Net Revertants	0	163	520	508	502	271
Net Revertants/ $10^8$ Viable Cells	0	543	2,080	3,200	2,600	13,600

<sup>1</sup>The cells were suspended in buffer and irradiated with UV light (8-10 ergs per mm<sup>2</sup> per second).

TABLE 2. The Effect of the North Magnetic Field on *E. coli*.

Hours of Exposure <sup>1</sup>	0	1	2	3	4	5
Viability (Not exposed)	$1.3 \times 10^8$	—	$1.2 \times 10^8$	—	—	$1.2 \times 10^8$
Arg. Revertants (Not exposed)	4	5	7	7	10	5
Viability (Exposed)	$1.3 \times 10^8$	—	—	—	$7 \times 10^7$	$1.2 \times 10^8$
Arg. Revertants (Exposed)	4	6	7	9	5	8
Net Revertants	0	1	0	2	-5	3

<sup>1</sup>Cells were suspended in buffer in a 25 cm<sup>2</sup> tissue culture flask and placed directly on the magnet.

TABLE 3. *The Effect of the South Magnetic Field on E. coli.*

Hours of Exposure <sup>1</sup>	0	1	2	3	4	5
Viability (Not exposed)	5 x 10 <sup>8</sup>	—	—	—	1 x 10 <sup>9</sup>	1 x 10 <sup>9</sup>
Arg. Revertants (Not exposed)	4	3	2	6	2	4
Viability (Exposed)	5 x 10 <sup>8</sup>	—	6 x 10 <sup>8</sup>	—	—	4 x 10 <sup>8</sup>
Arg. Revertants (Exposed)	2	3	4	5	4	5
Net Revertants	-2	0	2	-1	2	1

<sup>1</sup>Cells were suspended in buffer in a 25 cm<sup>2</sup> tissue flask and placed directly on the magnet.

### Discussion

We have attempted to determine if the type N-1 magnet (3000 gauss) of Davis and Rawls could produce measurable effects on *E. coli*. The data in figure 1 seem to indicate that there was no effect of either the north or south poles of the magnet on growth. The forty minute data from the north pole did seem to vary from the line of best fit, but this might be explained by experimental error since similar results were not seen in other experiments.

Since it is difficult to maintain exponential growth in closed systems for long periods of time, we felt that measuring viability of cells held in buffer might be a more sensitive method to measure magnetic effects. Figure 2 showed, that while there is some scatter to the data, there was no significant difference in the slope of the two lines over a 24 hour period.

Finally, if the magnetic field caused mutations, the effect would not be readily seen in the first two types of experiments. Therefore, we measured mutations directly using the arginine revertant system. Table 1 showed that a 30 second exposure to UV light produced 13,600 mutations per 10<sup>8</sup> cells while a 5 hour exposure with a magnet, using either the north or south pole, produced a number of mutants that was not significantly different from the unexposed controls. In conclusion, we could not detect any effect of the type N-1 magnet on *E. coli* WWU.

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