

# What Separates Them Is Not the Field but the Narrowness of the Path

— For a molecule whose charge and size both scale with length, the free-solution mobility is  $1.061033 \times 10^{-8}$  for 100 and 5000 base pairs alike — adding a sieve makes the ratio **11.5883**, matching  $e^{a(n_2-n_1)}$  exactly — remove the sieve and the separation vanishes exactly — [Paper 473]

Yuuki YAMAGISHI (山岸 勇輝)  
Yamagishi Complexity Torus Lab, Japan  
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— *From thinking to syncing.* —

## Abstract

Electrophoresis is thought to separate molecules by an electric field. This paper shows that the field alone separates nothing—what separates is the mesh of the gel, and removing it makes the separation vanish exactly. No new theorem or law is claimed. First, the free-solution mobility is  $1.061033 \times 10^{-8}$  for 100 and for 5000 base pairs alike (Section 2). Second, the ratio is exactly **1.000000000000**: length does nothing (Section 2). Third, this is the core of the paper. Adding a sieve makes the ratio **11.5883** (Section 3). Fourth, that ratio matches the closed form  $e^{a(n_2-n_1)}$  exactly (Section 3). Fifth, setting the sieving coefficient to zero returns the ratio to exactly **1.000000000000** (Section 3). Sixth, the separator is whether the field separates or the medium does (Section 4).  
**Keywords:** electrophoresis, gel, electrophoretic mobility, DNA, sieving effect.

Scope of this paper (scope note): No new theorem or law is claimed—electrophoretic mobility, Stokes drag and gel sieving are all standard. No experiment is designed—buffer, gel concentration, voltage and staining are not the subject. The polymer shape is simplified—a rod-like approximation in which charge and drag both scale with length is used; real nucleic acids coil and reptate. Pulsed fields are excluded—pulsed-field methods for very long chains are not the subject. Isoelectric focusing is excluded—systems in which charge does not scale with length are not the subject. Relation to earlier papers: Paper 472 showed that keeping one body the same needs devices of opposite sign—there too, one name covered different things. Paper 300 showed that common root and distinct root can be decided —“driving by a field” and “separating by a medium” are distinct roots by that criterion. Paper 451 showed that what insulates is the air and not the snow—there too, the named thing and the working thing differed. What is added is giving the free-solution mobility at four lengths and showing them identical, giving the gel ratio as **11.5883**, matching it to the closed form exactly, showing that removing the sieve makes the separation vanish exactly, and placing the separator at field versus medium.

## 1. Notation and the Question

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Setting: A particle of charge  $q$  and radius  $r$  driven by a field through a liquid of viscosity  $\eta$  has electrophoretic mobility

$$\mu = \frac{q}{6\pi\eta r}$$

For a molecule whose charge and drag both scale with chain length  $n$  (rod-like),  $q \propto n$  and  $r \propto n$ . Express gel sieving by an exponential factor,

$$\mu_{\text{gel}}(n) = \mu e^{-an}$$

Below,  $\eta = 1.0 \times 10^{-3}$  Pa s and  $a = 5 \times 10^{-4}$ .

### Observation 1.1

Electrophoresis is thought to separate molecules by a field. The name says “electro”—apply a voltage and they part.

### Observation 1.2

But if charge and drag rise in the same proportion, the ratio does not change. The mobility is set by  $q/r$ —and the length cancels.

Question: Then what separates them.

## 2. In Free Solution Nothing Separates

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Computation 2.1: Take the free-solution mobility at four lengths.

| Length [bp] | Mobility                                    |
|-------------|---------------------------------------------|
| 100         | <b><math>1.061033 \times 10^{-8}</math></b> |
| 500         | $1.061033 \times 10^{-8}$                   |
| 1000        | $1.061033 \times 10^{-8}$                   |
| 5000        | <b><math>1.061033 \times 10^{-8}</math></b> |

### Observation 2.2

All four are the same. The ratio of 100 to 5000 is exactly **1.000000000000**—a fiftyfold difference in length doing nothing at all.

### Observation 2.3

The mobility is not zero.  $1.061033 \times 10^{-8}$ —the molecules move. They just all move at the same speed.

### Observation 2.4

Because the charge is  $n$  times and the drag is  $n$  times. Push and restraint rise together—the ratio holds, so the speed does not change.

### Observation 2.5

So a field alone cannot sort by length. Raise the voltage as far as you like—and everyone simply goes faster.

## 3. A Sieve Makes the Ratio 11.5883

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Computation 3.1: Take the mobility in the gel.

| Length [bp] | Mobility in gel            |
|-------------|----------------------------|
| 100         | $1.009286 \times 10^{-8}$  |
| 500         | $8.263333 \times 10^{-9}$  |
| 1000        | $6.435490 \times 10^{-9}$  |
| 5000        | $8.709489 \times 10^{-10}$ |

### Observation 3.2

The ratio of 100 to 5000 has become **11.5883**. From exactly 1.000000000000 in free solution—same field, same molecules, only the medium changed.

### Observation 3.3

The ratio matches the closed form  $e^{a(n_2-n_1)}$  exactly.  $e^{5 \times 10^{-4} \times 4900} = 11.588347$ —to within  $10^{-9}$  relative.

### Observation 3.4

Set the sieving coefficient  $a = 0$  and the ratio returns to exactly **1.000000000000**. The separation vanishes—all of it came from that term.

### Observation 3.5

This is a boundary confirmed. With  $a > 0$  they separate; with  $a = 0$  they do not—the phenomenon exists on one side only.

### Observation 3.6

So the word “electrophoresis” names only the driving. It does not name the separating—the field pushes everyone equally, and the mesh holds back only the long ones.

## 4. The Separator

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The separator: does the field separate, or the medium.

### Observation 4.1

If the field separates, changing the voltage changes the separation. Stronger means better resolved—that adjustment would work.

### Observation 4.2

If the medium separates, the voltage changes only the speed. Resolution is set by the fineness of the gel—a different thing to adjust.

### Observation 4.3

These are distinct roots by the criterion of Paper 300. Both are called “how well the electrophoresis performs”—one a quantity of driving, one of the medium.

### Observation 4.4

This stands where Paper 451 stands. There, what insulated was the air and not the snow—here what separates is the gel and not the field. In both, the named thing and the working thing differ.

### Observation 4.5

It overlaps Paper 472 as well. There, one term “osmoregulation” covered two things of opposite sign—here one term “electrophoresis” covers driving and separating, two different roles.

### Observation 4.6

And where charge does not scale with length, the story changes. In isoelectric focusing of proteins, charge itself becomes the separator—two mechanisms under one name.

#### Observation 4.7

To be honest—a rod-like approximation was used. Real nucleic acids coil and reptate through the mesh—11.5883 depends on that approximation; that separation vanishes in free solution follows only from charge and drag rising together.

## 5. Roll Call and Closing

1.  $1.061033 \times 10^{-8}$  in free solution (Computation 2.1): all four the same.
2. A ratio of exactly 1.000000000000 (Observation 2.2): fiftyfold does nothing.
3. The mobility is not zero (Observation 2.3): all at the same speed.
4. Charge and drag both  $n$  times (Observation 2.4): the ratio holds.
5. A gel ratio of 11.5883 (Observation 3.2): the core.
6. Exactly the closed form (Observation 3.3):  $e^{a(n_2-n_1)}$ .
7.  $a = 0$  returns 1.000000000000 (Observation 3.4): separation vanishes.
8. It exists on one side only (Observation 3.5): a boundary confirmed.
9. The separator is field or medium (Observation 4.3): distinct roots by Paper 300.
10. Isoelectric focusing differs (Observation 4.6): two mechanisms, one name.

Closing: Electrophoresis is thought to separate molecules by a field—the name says “electro”, and applying a voltage should part them. But if charge and drag rise in the same proportion the ratio does not change: the mobility is set by  $q/r$ , and the length cancels. In free solution nothing separates—100, 500, 1000 and 5000 base pairs all give  $1.061033 \times 10^{-8}$ , and the ratio of 100 to 5000 is exactly 1.000000000000: a fiftyfold difference in length doing nothing at all. The mobility is not zero—the molecules move, they just all move at the same speed. Because the charge is  $n$  times and the drag is  $n$  times: push and restraint rise together, so the ratio holds and the speed does not change. So a field alone cannot sort by length; raise the voltage and everyone simply goes faster. What separates is the mesh—in the gel, 100 gives  $1.009286 \times 10^{-8}$  and 5000 gives  $8.709489 \times 10^{-10}$ , a ratio of 11.5883, where free solution gave exactly 1: same field, same molecules, only the medium changed. The ratio matches  $e^{a(n_2-n_1)} = e^{5 \times 10^{-4} \times 4900} = 11.588347$  to within  $10^{-9}$  relative. Set the sieving coefficient to zero and the ratio returns to exactly 1.000000000000: the separation vanishes, because all of it came from that term. With  $a > 0$  they separate and with  $a = 0$  they do not—the phenomenon exists on one side only. So the word “electrophoresis” names only the driving, not the separating. The field pushes everyone equally, and the mesh holds back only the long ones. One thing separates them—does the field separate, or the medium. If the field, changing the voltage changes the separation and stronger means better resolved. If the medium, the voltage changes only the speed and resolution

is set by the fineness of the gel: a different thing to adjust. They are distinct roots by the criterion of Paper 300, one a quantity of driving and one of the medium. This stands where Paper 451 stands, where what insulated was the air and not the snow: in both, the named thing and the working thing differ. It overlaps Paper 472 too, where one term covered two things of opposite sign: here one term covers driving and separating. And where charge does not scale with length the story changes—in isoelectric focusing of proteins, charge itself becomes the separator, two mechanisms under one name. To be honest—a rod-like approximation was used, and real nucleic acids coil and reptate through the mesh. 11.5883 depends on that approximation; that separation vanishes in free solution follows only from charge and drag rising together.

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Yuuki YAMAGISHI (山岸 勇輝)

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