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GLYPHS, AND WHAT THEY SIGNAL

# The Alphabet

Greek, blackboard bold, and the decorations. Once you can name a symbol you can stop being frightened of it.

A NOTATION COURSE FOR PEOPLE WHO ALREADY THINK IN CODE

INSIDE

1. the Greek set
2. blackboard bold
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SAY PARSE SCOPE PRODUCE

THE LETTERS YOU WILL ACTUALLY MEET

# The alphabet

Greek letters are not decoration. In practice they are used for the things that do not have a natural Latin name: a rate, a difference, a parameter, a small quantity, a boundary. Learn fourteen of them and you have covered almost everything.

| LETTER | NAME | USUALLY |
|---|---|---|
| $\alpha$ | alpha | an angle, a rate, a first parameter |
| $\beta$ | beta | a second parameter, a coefficient |
| $\gamma$ | gamma | a third, or a ratio |
| $\delta$ | delta | a **small** change, or a boundary |
| $\Delta$ | Delta (capital) | a **large** change, or a difference operator |
| $\varepsilon$ | epsilon | an arbitrarily small quantity |
| $\theta$ | theta | an angle, or an unknown parameter |
| $\lambda$ | lambda | a rate, an eigenvalue |
| $\mu$ | mu | a mean |
| $\pi$ | pi | 3.14159..., or a projection |
| $\rho$ | rho | a density, a correlation |
| $\sigma$ | sigma | a standard deviation |
| $\Sigma$ | Sigma (capital) | **sum** — a completely different thing |
| $\phi$ | phi | 1.618..., or a phase, or a map |
| $\omega$ | omega | an angular frequency |

KEY

**The one that catches everybody.** $\sigma$ and $\Sigma$ are the same letter. Lower case is a *quantity*; upper case is an *operator*. One is a number, the other is a loop.

THE TWO ALPHABETS YOU CANNOT AVOID

# Blackboard bold, and what it is telling you

Five letters, drawn double-struck, name the number systems. They are a *type*: they tell you what kind of thing a symbol is allowed to be.

$$\mathbb{N} \subset \mathbb{Z} \subset \mathbb{Q} \subset \mathbb{R} \subset \mathbb{C}$$

| SYMBOL | NAME | WHAT IT CONTAINS |
|---|---|---|
| $\mathbb{N}$ | the naturals | $0, 1, 2, 3, \ldots$ |
| $\mathbb{Z}$ | the integers | $\ldots, -2, -1, 0, 1, 2, \ldots$ |
| $\mathbb{Q}$ | the rationals | every fraction of two integers |
| $\mathbb{R}$ | the reals | every point on the line |
| $\mathbb{C}$ | the complex | the reals, plus $i = \sqrt{-1}$ |

Read the chain aloud: *the naturals are a subset of the integers, which are a subset of the rationals…* — and every $\subset$ is a claim that everything on the left is also on the right.

THE RULE OF THUMB

**If it is a name, it stands up. If it is a thing, it leans.** Functions with names are set upright; variables are italic. That is why $\sin x$ looks different from $sin$.

## Case and slope

A letter's **case** is a type annotation. Almost everywhere, in the same order:

- lower case italic — a scalar, or a single element: $x$, $n$, $\theta$
- upper case — a set, a matrix, or a random variable: $X$, $A$, $\Omega$
- **upright** — a *name*, not a thing: sin, log, max, exp, d$x$

## The four that are not Greek or Latin

- $\ell$ — "ell": a length, or a line.
- $\aleph_0$ — "aleph nought": the size of the naturals — an infinity.
- $\hbar$ — "h bar": the reduced Planck constant.
- $\varnothing$ — "the empty set": a set with nothing in it.

EVERY MARK ON A LETTER MEANS SOMETHING

# Hats, bars, tildes and stars

A symbol is rarely bare. The marks above and beside a letter are a small vocabulary of their own, and they are *conventional* rather than fixed — so check the paper's own key. But these are the defaults.

| MARK | READS AS | USUALLY MEANS |
|---|---|---|
| $\hat{x}$ | "x hat" | an estimate, or a unit vector |
| $\bar{x}$ | "x bar" | a mean (an average) |
| $\tilde{x}$ | "x tilde" | a transformed or approximate version |
| $\dot{x}$ | "x dot" | a derivative with respect to time |
| $x'$ | "x prime" | a derivative, or the next value |
| $x^*$ | "x star" | an optimal value, or a conjugate |
| $\vec{v}$ | "v vector" | a vector |
| $\|x\|$ | "norm of x" | a length |
| $\langle x, y \rangle$ | "inner product" | a projection, a similarity |

KEY

**The trap.** $\bar{x}$ and $\hat{x}$ are not the same mark and not the same idea: the bar is an average of what you *measured*, the hat is a guess at what you *did not*. In statistics the difference is the whole subject.

## Brackets mean things

| BRACKETS | READS AS | WHAT IT IS |
|---|---|---|
| $(a, b)$ | "the pair a, b" — or "the open interval" | a pair, or everything strictly between |
| $[a, b]$ | "the closed interval" | everything between, ends included |
| $\{a, b\}$ | "the set of a and b" | a collection |
| $\langle u, v \rangle$ | "the inner product of u and v" | a projection, a similarity |

DRILL A · NAME EVERY SYMBOL

# Build the symbol table

Copy each symbol into the table, then write its name and what it is. Guessing is fine; a guessed entry that is wrong is worth more than a blank one.

| SYMBOL | NAME | WHAT IT IS |
|---|---|---|
| $\Sigma$ | | |
| $\sigma$ | | |
| $\Delta$ | | |
| $\delta$ | | |
| $\mathbb{R}$ | | |
| $\bar{x}$ | | |
| $\hat{\theta}$ | | |
| $\|\|v\|\|$ | | |
| $\lambda$ | | |
| $\mu$ | | |
| $\nabla$ | | |
| $\partial$ | | |

**The test.** Cover the right-hand column and name each symbol aloud. If you can name it, you can read it. If you cannot, nothing else on the page will work.

## And your own

Three symbols from your own reading that you could not name. Write them here, and carry them until you can.

| SYMBOL | NAME | WHAT IT IS |
|---|---|---|
| | | |
| | | |

DRILL B · SAY THE WHOLE THING

# Marks, then letters

Read each aloud, in words, naming every mark. Write the spoken form first; the speaking is the proof.

$$\hat{\theta} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

$$\|x - \bar{x}\|^2$$

$$f : \mathbb{R}^n \to \mathbb{R}$$

$$p(x \mid \mu, \sigma) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right)$$

IF IT HELPS

Start with the outermost thing — a fraction, a square, an arrow — and name it before you name anything inside it.

ANSWERS · FOLD UNDER BEFORE YOU LOOK

# What the drill was testing

## Drill A

- $\Sigma$ — "Sigma", capital: the sum operator.
- $\sigma$ — "sigma", lower case: a standard deviation. Same letter, different job.
- $\Delta$ — "Delta", capital: a large change, or a difference operator.
- $\delta$ — "delta", lower case: a small change, or a boundary.
- $\mathbb{R}$ — "the reals": every point on the number line.
- $\bar{x}$ — "x bar": the mean of the $x$ values.
- $\hat{\theta}$ — "theta hat": an estimate of the parameter $\theta$.
- $\|v\|$ — "the norm of v": the length of the vector $v$.

## Drill B

- $\hat{\theta} = \frac{1}{n}\sum_{i=1}^{n} x_i$ — "theta hat equals one over n, times the sum from i equals one to n, of x-sub-i." That is: an *estimate* is the *average* of the observations.
- $\|x - \bar{x}\|^2$ — "the norm of x minus x bar, squared."
- $f : \mathbb{R}^n \to \mathbb{R}$ — "f, from R-n to R": a function taking a list of $n$ numbers and returning one number.

> KEY
>
> **The habit.** Every symbol you could not name in this issue goes on a card. Those cards are your alphabet, and there are fewer of them than you fear.

CARRY THESE

# Six cards, and the next rung

$\sigma$ vs $\Sigma$

Lower case is a quantity; upper case is an operator. One is a number; the other is a loop.

$\delta$ vs $\Delta$

Small change vs large change. Same letter, different scale.

$\mathbb{R}$

The reals — a *type*. It tells you what a symbol is allowed to be.

$\bar{x}$ vs $\hat{x}$

The bar is an average of what you measured; the hat is a guess at what you did not.

Upright vs italic

A name stands up (sin, log); a thing leans ($x$, $\theta$).

$\|$

x\|$ | The norm: a length. Not an absolute value, though it behaves like one.

## Where this sits

0 name it · 1 say it · 2 parse it · 3 write it · 4 code it · 5 read unaided

You can name the parts. Next: the grammar — what binds tighter, and how to draw the tree.

KEY

**Before Issue 2.** Open any paper. Copy one line of symbols onto a card. Name each. Keep the ones you could not, and throw the rest away.

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