

§01 · MEASURE

EN · English

ALL THIS FOR A DROP OF BLOOD.

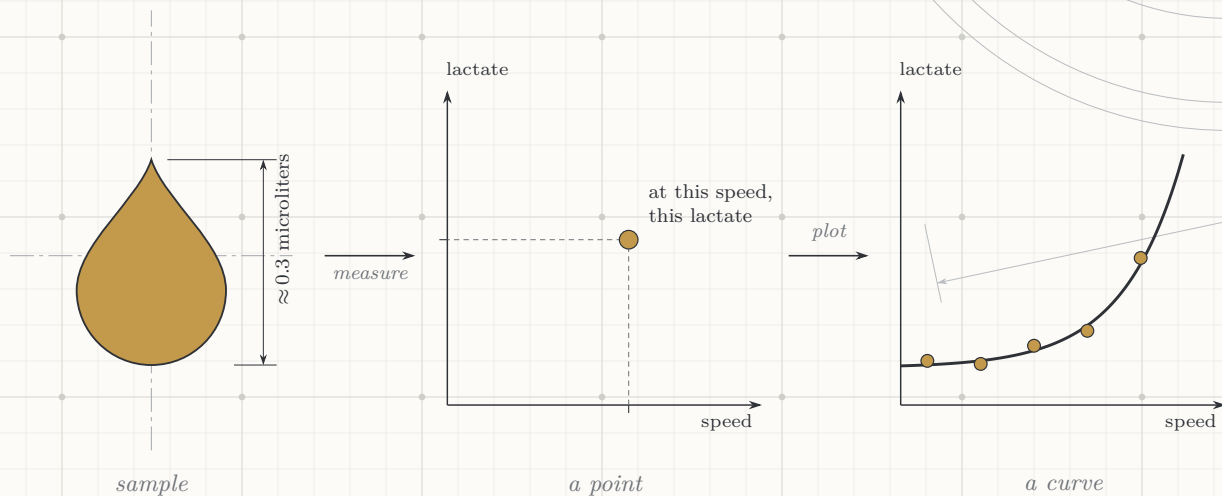
What can a drop of blood tell me about how I run?

WHAT IS LACTATE?

A molecule the body produces all the time when getting energy from glucose, and in larger amounts the harder the effort. It is not a waste product: muscles, heart and liver reuse it as fuel.

WHY DOES IT MATTER IN SPORT?

Its level in the blood reflects how demanding an effort is for the body. Measuring it helps find each athlete's thresholds and set training zones tailored to them.



drop $\rightarrow$ point $\rightarrow$ curve

135

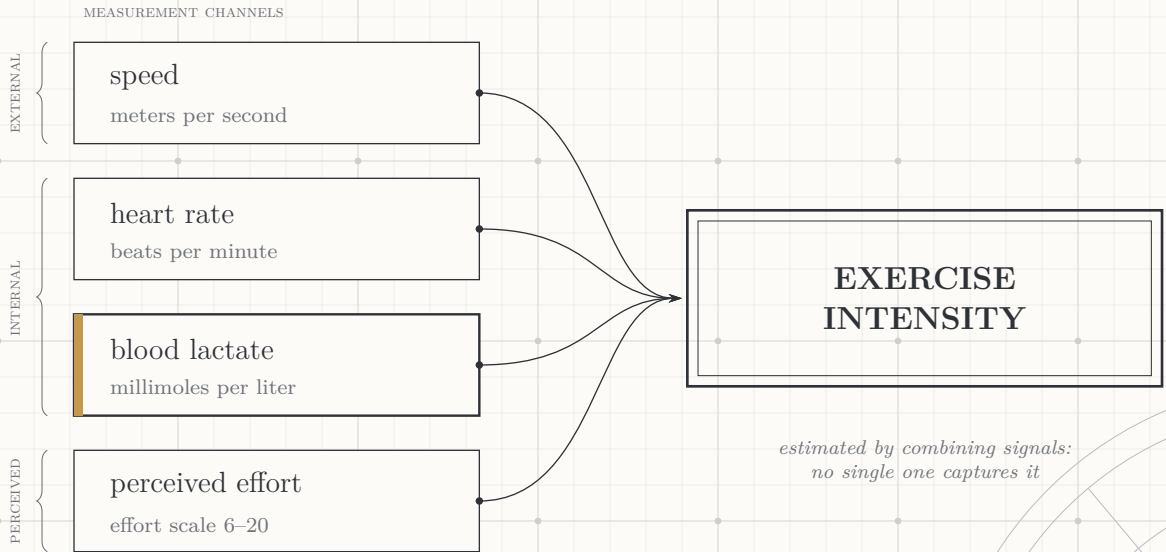
EXERCISE PHYSIOLOGY / DATA / MATHEMATICAL MODELING

$$\{(v_i, L_i)\}_{i=1}^n \mapsto \hat{f}$$

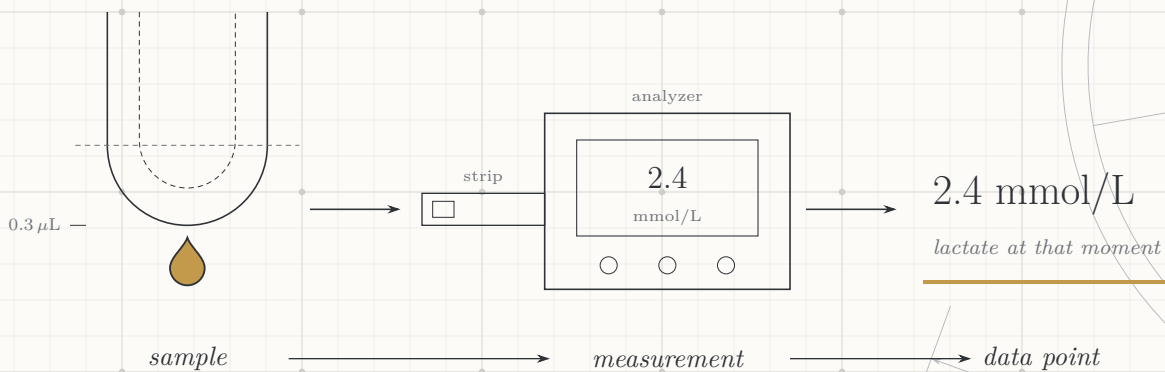
A simple biological measurement, turned into quantitative information.

§ 02 · MEASURE

AM I REALLY IN THE ZONE I THINK I AM?



SCHEMATIC OF A CAPILLARY LACTATE TEST



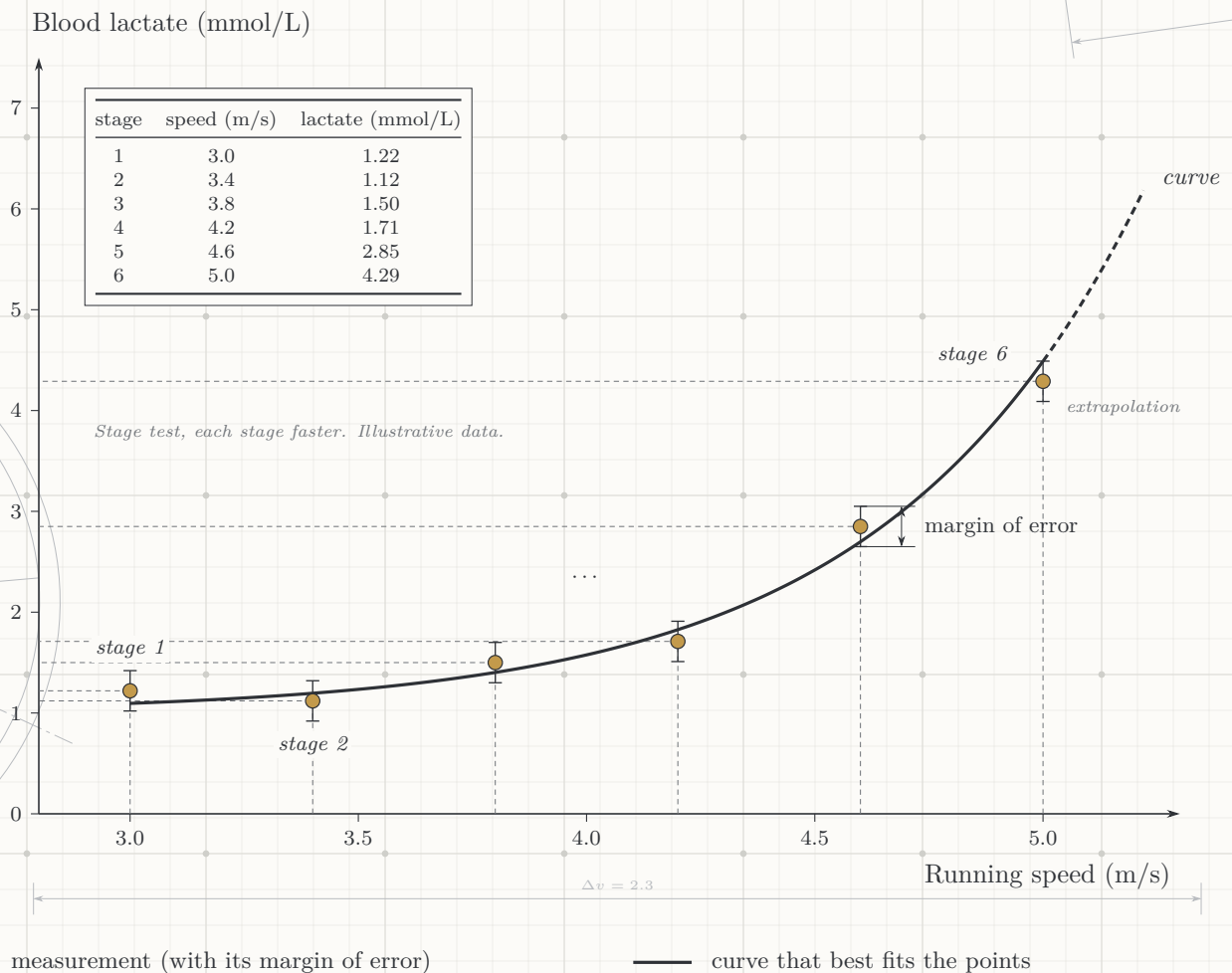
*Measuring does not replace feel.
It complements it.*

$$y = h(x) + \varepsilon$$

§03 · PLOT

ONE MEASUREMENT DOESN'T SAY MUCH.

Many measurements start to reveal a pattern.

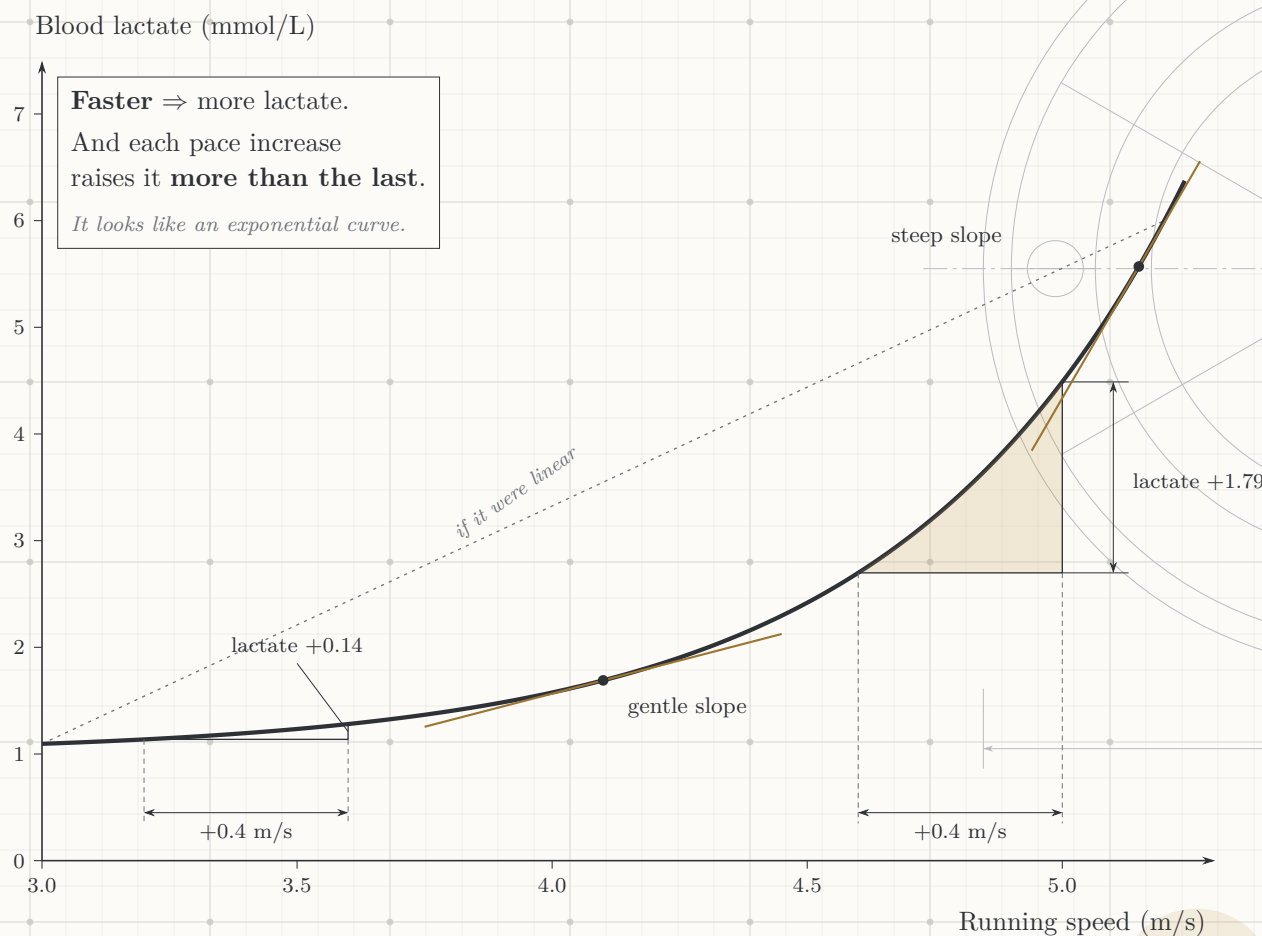


The points are what I measured; the curve is a model that connects them.

§04 · MODEL

IT'S NOT A
STRAIGHT LINE.

$$\frac{d^2 L}{dv^2} > 0 \Leftrightarrow \text{convexity}$$



The lactate response is usually curvilinear and can be modeled mathematically.

In this example, adding 0.4 m/s at a high pace raises lactate about twelve times more than at a low pace.

§ 05 · MODEL

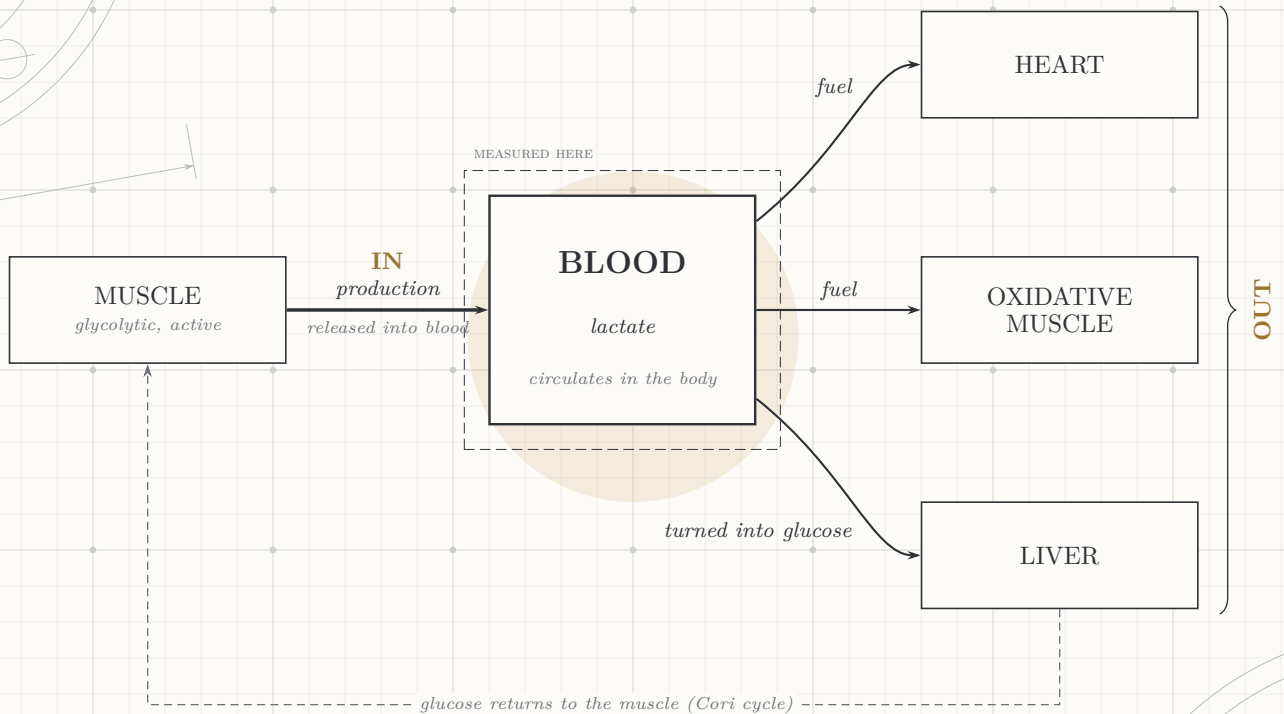
LACTATE IS NOT ONLY PRODUCED.

It is also transported, oxidized and reused.

$$V_d \Delta[\text{Lac}] = \int_0^T (R_a - R_d) dt$$

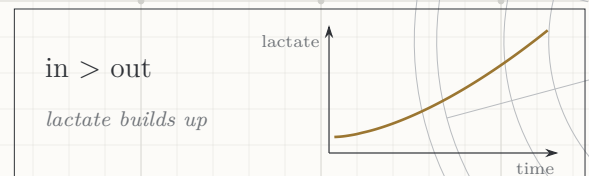
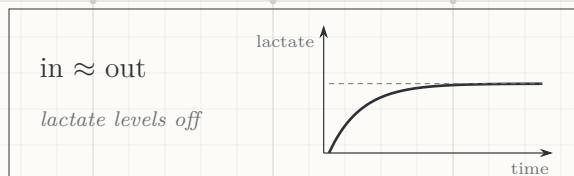
METABOLIC FLUX — lactate circulates: it is not simply a waste product

Simplified schematic: the same muscle can both produce and consume lactate; other tissues are also involved.



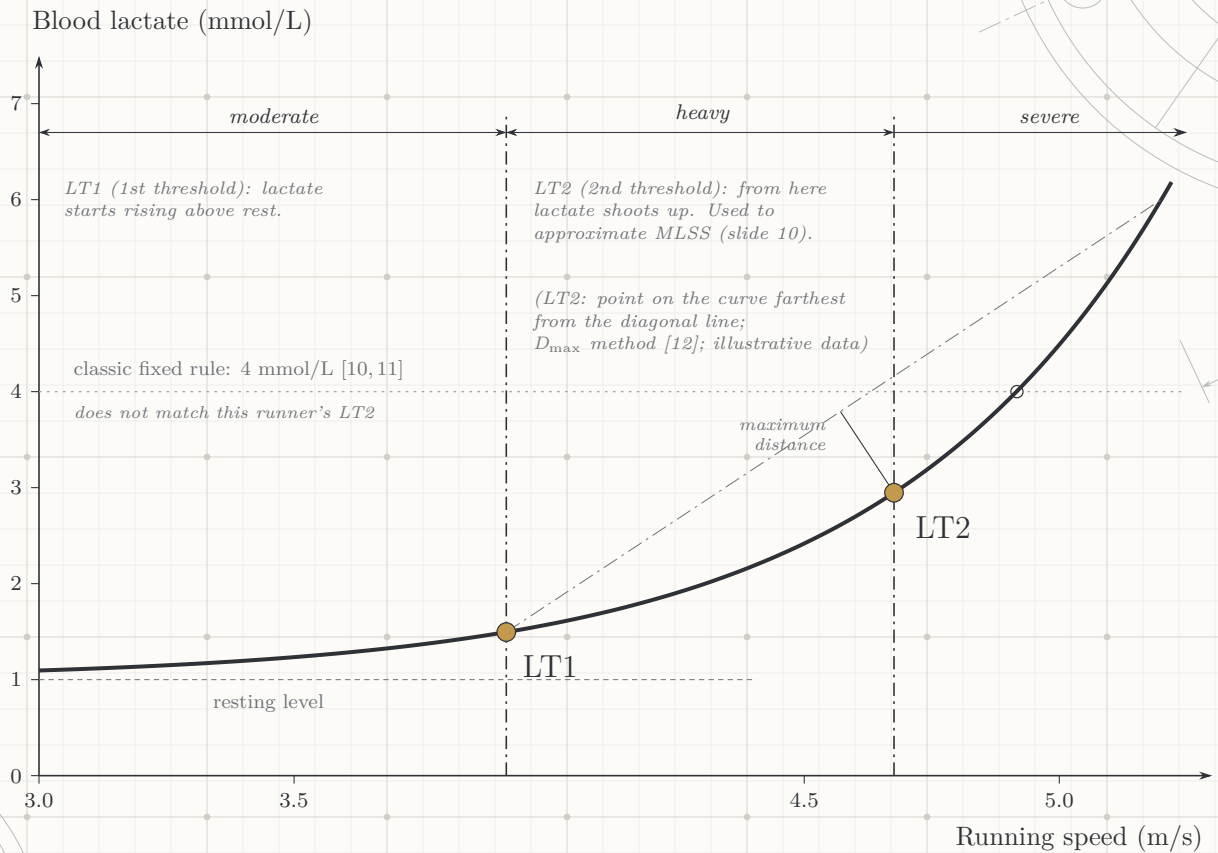
change in blood lactate = **what comes in** — **what goes out**

What the drop measures is the balance of both flows, not just production.



§ 06 · UNDERSTAND

AND THIS IS WHERE THRESHOLDS APPEAR.



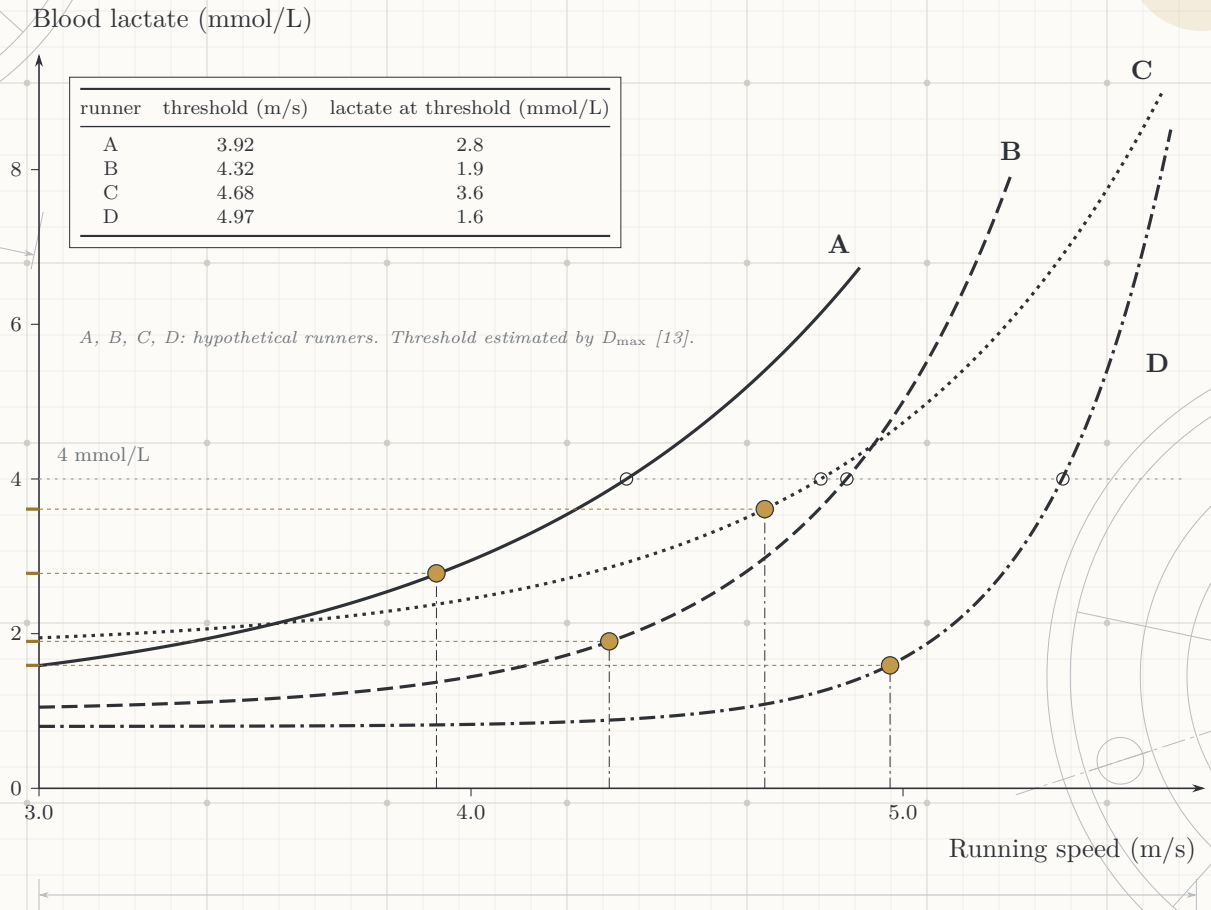
Your thresholds depend on your physiology, how the test is done and the method used to compute them.

They are not simply “4 mmol/L”.

Moderate, heavy and severe are the three intensity domains; here they are split roughly by LT1 and LT2. Strictly, the heavy-to-severe boundary is associated with critical speed (slide 9) [9].

§07 · UNDERSTAND

THE THRESHOLD IS INDIVIDUAL.

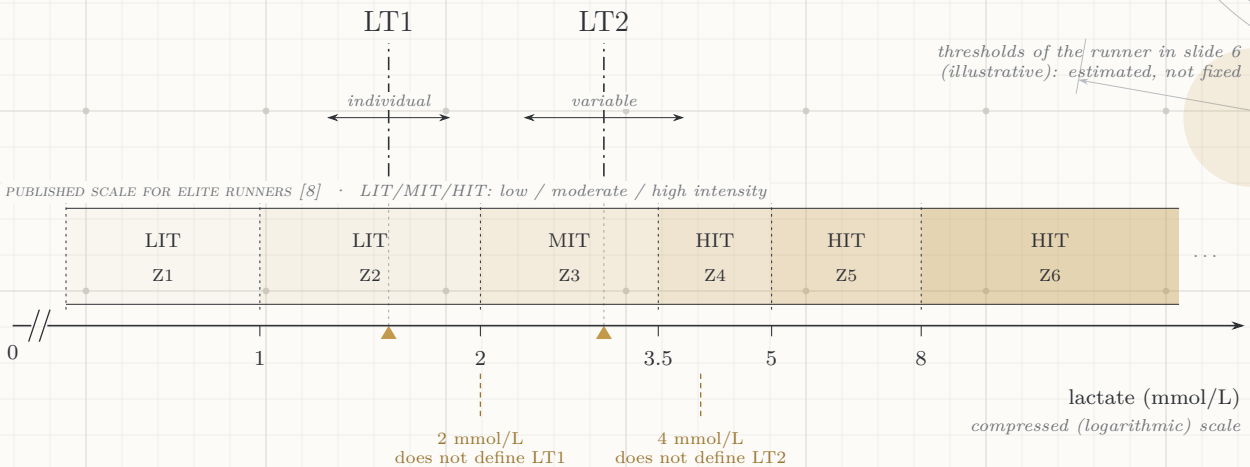


The threshold is **not** a fixed lactate value: each runner has their own.

Hollow circles mark where each runner reaches 4 mmol/L; filled ones, their actual threshold. They never coincide, and the gap between them varies a lot from runner to runner.

§ 08 · UNDERSTAND

HOW DOES LACTATE TRANSLATE INTO TRAINING?



Zone	Lactate (mmol/L)	Typical pace*	Typical methods
Z1 · LIT	< 1.0	—	warm-up and cool-down; easy long runs
Z2 · LIT	1.0–2.0	—	long runs, uphill runs, progressive runs
Z3 · MIT	2.0–3.5	(half) marathon	threshold runs and intervals, fartlek
Z4 · HIT	3.5–5.0	10,000 m	VO ₂ max [†] intervals, hill repetitions
Z5 · HIT	5.0–8.0	1500–5000 m	VO ₂ max [†] intervals, competitions
Z6 · HIT	> 8.0	800–1500 m	“lactate tolerance” (a training term), hill repetitions

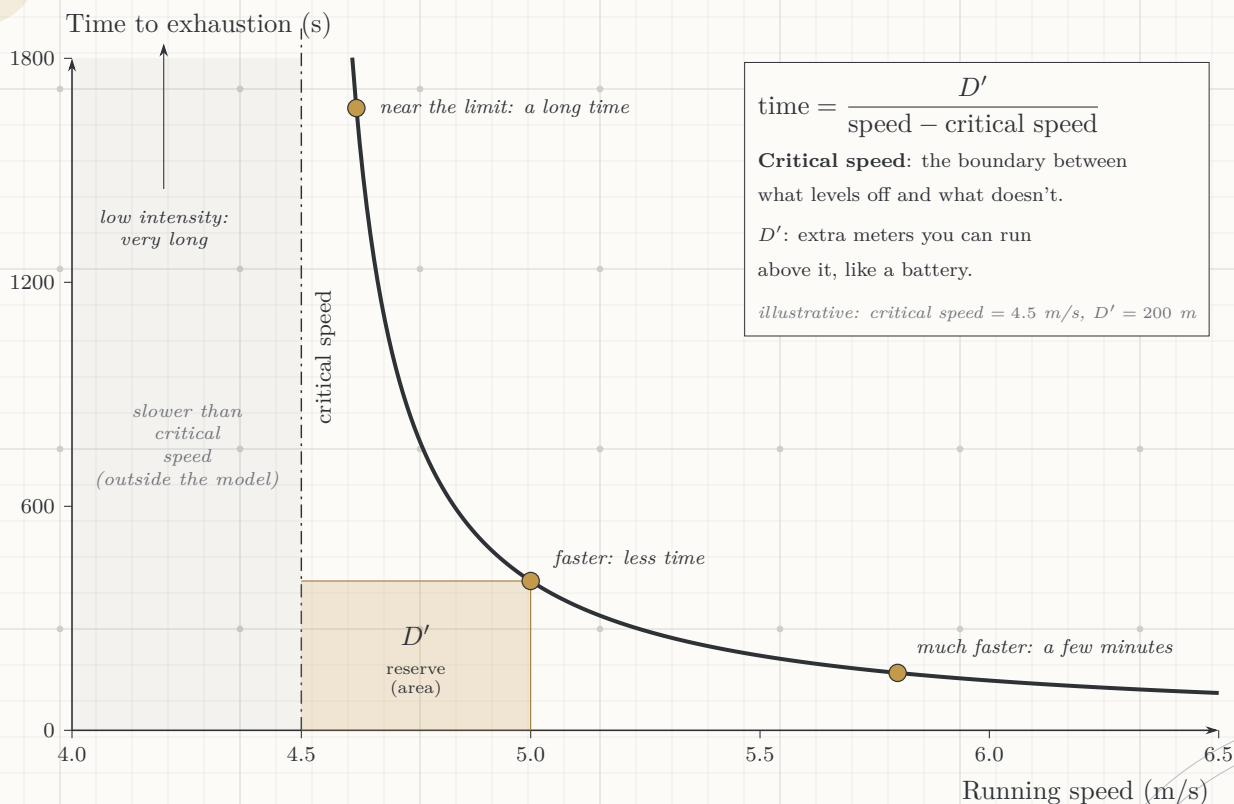
Adapted from table 3 of [8], described for world-class distance runners as a training guideline; lactate: typical normative values in red-cell-lysed blood (Z7: 60–400 m sprints, no lactate range). * Typical intensity associated in this classification; it does not imply that each distance is run at a single concentration: race lactate varies with the athlete, duration, pace, sampling time and protocol. † VO₂max: pace at which maximal oxygen uptake is reached.

The ranges are descriptive reference values. Individual zones should be determined from the athlete’s physiological response. E.g.: the runner in slide 6 has their LT2 at ≈2.9 mmol/L; for them, Z4 (3.5–5.0) would already be above their LT2.

§09 · UNDERSTAND

HOW LONG CAN YOU SUSTAIN AN INTENSITY?

$$D' = (v - CS) t_{\text{lim}}$$



As speed approaches the critical one, the model predicts infinite time.

a mathematical limit, not a physiological promise

In practice, nobody runs at that speed forever.

Note: this curve (a hyperbola) is the traditional speed–duration model [6, 9]. It is fitted with all-out efforts of ~2–15 min [7, 9]; outside that range it is extrapolation. Critical speed is proposed as the boundary between the heavy and severe domains [9]; even so, no pace can be held forever [9].

§ 10 · UNDERSTAND

MLSS: MAXIMAL LACTATE STEADY STATE.

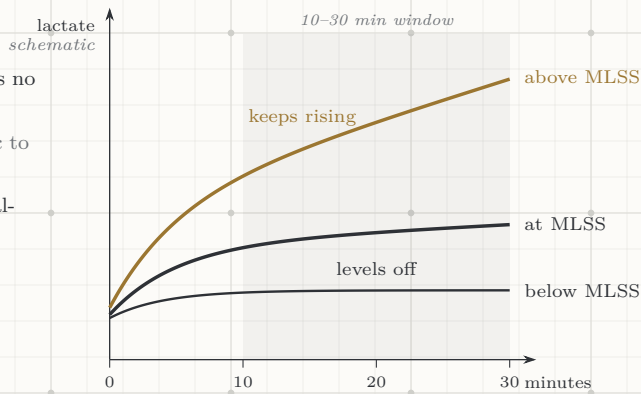
MLSS — DEFINITION

The **highest** intensity at which lactate still **stays stable** over time.

Usual criterion: running at a constant pace, lactate rises no more than 1 mmol/L between minutes 10 and 30 [5].

It is found with several constant-pace tests: it is specific to each person.

Lactate at MLSS varies a lot between people: it is not always 4 mmol/L.



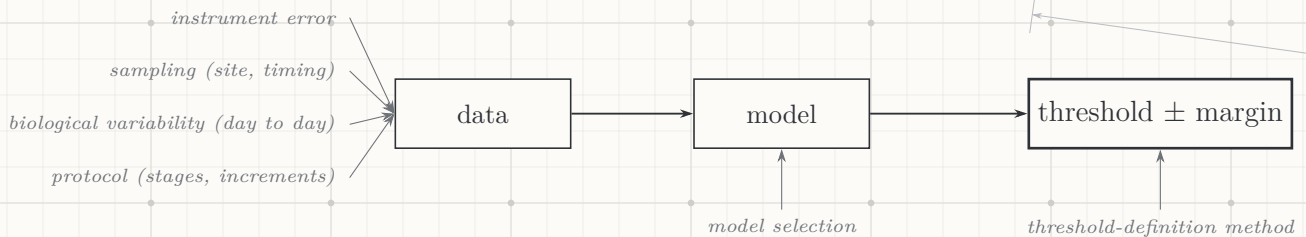
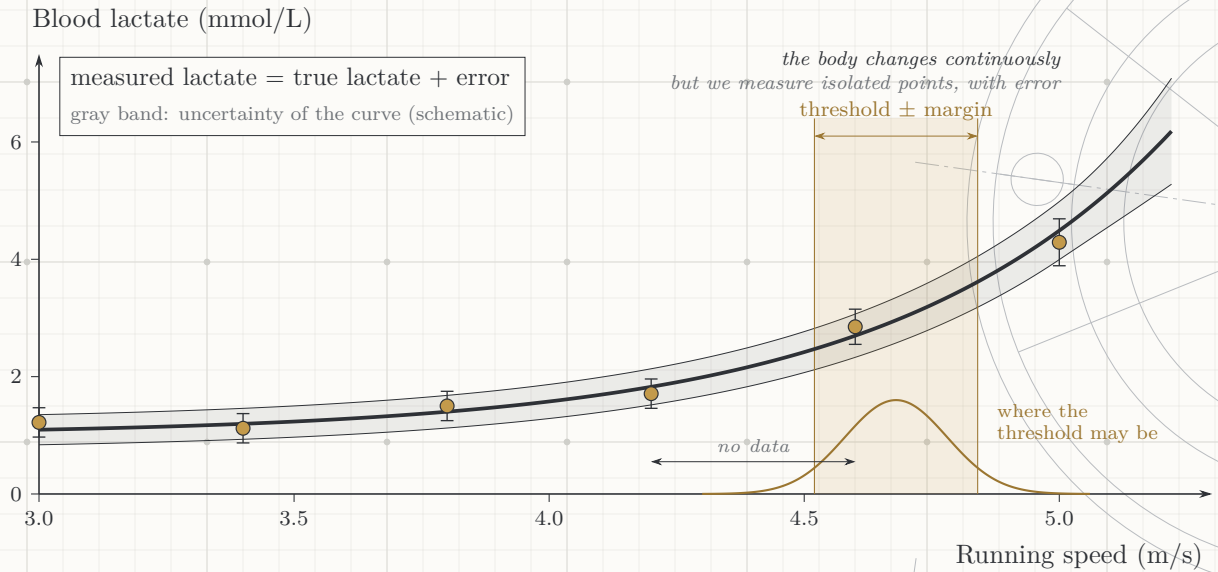
Intensity →	What lactate does →	Domain →	How long you last
below LT1	almost like at rest	moderate	a very long time
LT1–LT2	higher, but levels off	heavy	a long time
≈ MLSS	the highest possible stable level (per protocol)	limit of what is stable	quite long, but not forever
above critical speed	doesn't level off: keeps rising	severe	minutes (slide 9)

LT2, MLSS and critical speed are close but distinct ideas: they are measured with different tests and models. Critical speed usually lies close to MLSS, but they are not the same [9]; the exact relationship is still debated [4].

§ 11 · QUESTION

BUT THERE IS A PROBLEM.

$$\sigma_i^2 = \text{Var}(\varepsilon_i)$$



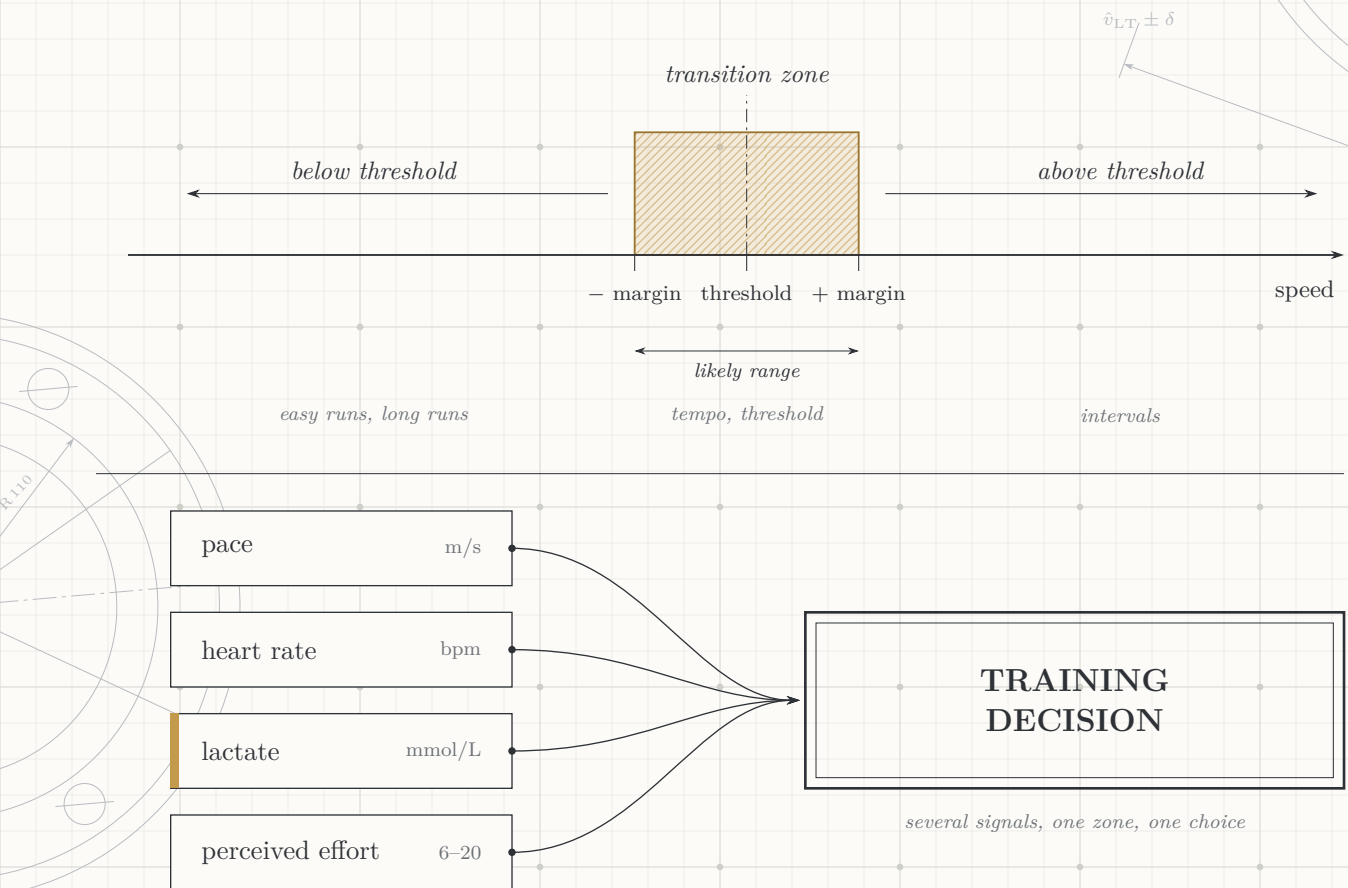
threshold = data + model + method

Physiology is continuous; the model introduces an estimate.

I AM NOT MEASURING “THE THRESHOLD”
I AM ESTIMATING IT.

§ 12 · APPLY

SO, WHY MEASURE?



*I don't chase an exact point.
I train within a zone.*

uncertainty does not mean useless data

Uncertainty does not invalidate measurement: it changes how it should be interpreted. Measuring is useful because it lets us build better models of a complex biological system, not because it yields perfect numbers.

project
 $n + 1$

§ 14 · BIBLIOGRAPHY

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Bracketed numbers at the foot of each slide refer to this list. Figure data are illustrative; lactate ranges are descriptive reference values, not universal biological constants.