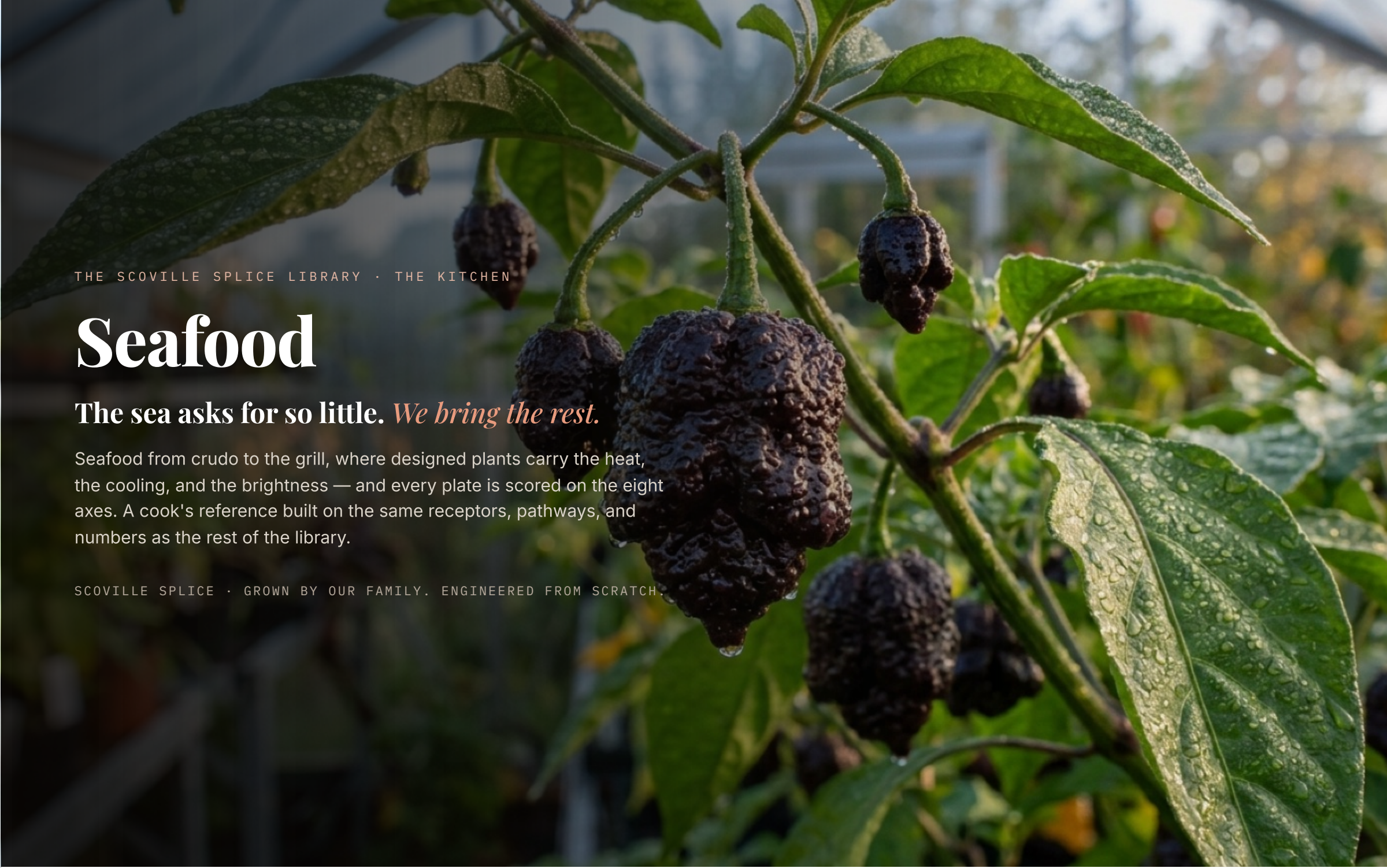

THE SCOVILLE SPLICE LIBRARY · THE KITCHEN

# Seafood

## The sea asks for so little. *We bring the rest.*

Seafood from crudo to the grill, where designed plants carry the heat, the cooling, and the brightness — and every plate is scored on the eight axes. A cook's reference built on the same receptors, pathways, and numbers as the rest of the library.

SCOVILLE SPLICE · GROWN BY OUR FAMILY. ENGINEERED FROM SCRATCH.

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# Opening essay · The sea asks for so little

We did not grow up cooking the sea. Ours was a garden table — vegetarian for as long as any of us can remember — and for most of our lives the fish was something other people cooked, beautifully, somewhere else. When we finally came to it, we came the only way we know how to come to any living thing we intend to put on a plate: with reverence first, and then the quiet question that governs this whole library. *How little can we do, and still be true to the thing?*

The sea rewards that question better than almost anything we have ever cooked. A line-caught fish an hour out of the water already carries the one taste our entire platform was built to restore — umami, the savory round that tells the body *here is nourishment.* It arrives as free glutamate settling onto mGluR1 and the TAS1R1·TAS1R3 heterodimer; and alongside it, locked in the muscle of the fish itself, inosinate — the 5′-ribonucleotide that does not merely add to glutamate but multiplies it. Two savory signals meeting at one receptor, and the response the brain hears is not their sum but their product. The ocean had worked out umami synergy a few hundred million years before anyone thought to give it a number.



The founders in the research greenhouse at dawn — where the question that governs this library was first asked, and where we learned that the lightest hand is usually the most skilled one.

So this is a book written with the lightest hand we own. The fish we leave very nearly alone — a cold knife, a little salt, a minute over fire. The design work lives in everything *around* it: in the sharp green pungency of a mustard built to stand in for wasabi, bright and then mercifully gone; in the cooling rush of an engineered mint that never touches the temperature of the plate; in a heat read from the very bottom of a ladder that climbs all the way to nearly three million Scoville; and in the brightness that does, at a crudo, the work a flame would do anywhere else.

Everything we design is scored on the same eight axes, and so is every plate in this book. The Iyengar Flavor Index gives each sensation a single number anchored to the half-maximal activation

of a receptor — not how much of a compound a food holds, but how *loudly* that compound speaks:

```
IFI(candidate) = 1,000 × EC₅₀(reference) ÷ EC₅₀(candidate)
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$EC_{50}$ is the concentration at which a stimulus drives its receptor to half of full response. Invert it against a fixed reference, scale by a thousand, and loudness becomes a score a scallop, a chili oil, and a cup of clear broth can be read against on one page. We did not build the Index to replace the pleasure of eating. We built it because you cannot design — or cook with intention — what you cannot measure. Across the library the same rule holds: **42** host organisms, **8** sensory axes, roughly **19,000** engineered constructs, a batch-to-batch consistency we hold at **≤7%**. In this book those numbers come to the table as plants, and the plants come to the table around a fish.

This book is built in six parts, and the order is an argument. We begin not with a recipe but with the sea's own chemistry — the savory synergy and the quiet sweetness a good fish already carries — because every design choice that follows is made *in relation to* what the flesh brings unaided (Part I). Then we move through the cold end of cooking, where our work is loudest precisely because the fish is barest: the cooling that is not cold, the pungency that flashes and clears (Part II); the slow transformations of salt and acid that cook without any fire at all (Part III); the deep savory center where plant and sea complete one another on a single receptor (Part IV); and only then to fire, laddered gently up from the very bottom rung of a heat scale that climbs to nearly three million Scoville (Part V). We close on the pantry itself, every plant scored, so the book ends as a reference you can cook straight from (Part VI).

A word on why we score at the table at all, since a scored recipe is a strange object. We are not asking you to taste with a calculator. The number is there for the reason a composer writes a dynamic marking over a phrase: so the intention survives the journey from the one who made it to the one who performs it. *Pianissimo* is not a feeling you must manufacture out of nothing; it is an instruction you can follow, and then feel. IFI-C 700 beside a scallop is the same — a cool set exactly where we meant it, as repeatable in your kitchen as in ours, because it is anchored to a receptor and not to a mood.

We are vegetarian-first by nature, and we do not apologize for the sea here, nor explain it away. We honor it the way we honor a pepper: by designing the plants around it so precisely that the fish can simply be itself. Every plate is scored, so you can taste the intention and read it at the same time. The sea asks for so little. This is a book about bringing exactly — and only — the rest.



PART I OF VI

# How the Sea Already Tastes

umami synergy · the sweetness of flesh · reading a plate on eight axes

# Chapter 1 · The Savory Ocean — *the synergy at the center*

Before we add a single engineered leaf, the sea has already done the hardest thing in savory cooking, and done it without us. To cook seafood well is first to understand what the fish brings on its own, because almost everything this book designs is placed *in relation to* that gift. The gift is umami, and umami is not one note. It is a synergy — two molecules, two binding events, one receptor, and a response far larger than arithmetic would predict.

Umami registers on two receptor systems that our library treats as a single axis, IFI-U. The first is the metabotropic glutamate receptor mGluR1, a taste-adapted splice variant of the same receptor family the brain uses for glutamate signalling. The second, and the one that matters most here, is the TAS1R1·TAS1R3 heterodimer — two class-C G-protein-coupled receptors clasped together, each carrying a large extracellular "Venus flytrap" domain that closes around its ligand like a hinge. L-glutamate binds in the cleft of the TAS1R1 flytrap and nudges it toward its closed, active conformation. On its own, that produces the clean savory signal of a ripe tomato or a sheet of kombu.



Shiitake — one of our umami hosts, carried on the same mGluR1 / TAS1R1·TAS1R3 axis as the glutamate in a fish's own flesh.

The multiplication happens when a second molecule arrives: a 5′-ribonucleotide. Inosine-5′-monophosphate (IMP, inosinate), guanosine-5′-monophosphate (GMP, guanylate), and to a lesser degree adenosine-5′-monophosphate (AMP, adenylate) bind not in the flytrap's cleft but at a separate allosteric site near its hinge, on the outer rim. There they act like a doorstop: they stabilise the closed, glutamate-bound conformation so it cannot spring open. The practical consequence is that glutamate's effective affinity for the receptor rises severalfold the instant a ribonucleotide is present. Measured as a dose-response, the $EC_{50}$ for glutamate drops — the

same savory intensity now reached at a fraction of the glutamate concentration — and because IFI is the inverse of $EC_{50}$, the axis score climbs. The receptor is not hearing *glutamate plus inosinate.* It is hearing *glutamate, amplified.*

Food scientists wrote this down before they knew the receptor. The classical form, from Yamaguchi's sensory work on the glutamate–inosinate system, approximates perceived umami intensity as

```
y ≈ u + k · u · v
```

where *u* is the glutamate concentration, *v* is the ribonucleotide concentration, and *k* is a large synergy constant. The telling term is the product *u·v*: when both are present even in small amounts, it dominates, and intensity rises far above either alone. In the receptor picture, *k* is the measure of how firmly the ribonucleotide holds the flytrap shut.

This is the oldest trick in savory cooking, arrived at independently by every culture with a coastline. Kombu (glutamate) with katsuobushi (inosinate) becomes dashi. Tomato (glutamate) with anchovy (inosinate) becomes the base of half the Mediterranean. Parmesan with mushroom; soy with dried fish; the long-simmered stock with the browned bone. None of these cooks had a receptor model. All of them had tongues, and the tongue is an exquisite assay for a product term.

Now the sea's particular generosity. In living fish muscle, energy is stored and spent as adenosine triphosphate. The moment the fish dies, that ATP begins a well-mapped decay: ATP → ADP → AMP → **IMP** → inosine → hypoxanthine. For the first day or two post-mortem, IMP — pure inosinate, the amplifier — accumulates in the flesh. This is the chemical meaning of "fresh": not merely unspoiled, but *loaded*, at the peak of its ribonucleotide charge, before the enzymes carry IMP onward to the flat, faintly bitter hypoxanthine of age. A fish one day out of the water is a delivery system for the exact molecule that makes glutamate roar.

Shellfish bring something extra again. Scallops, clams, mussels, oysters, and crustaceans carry free glutamate and AMP, and — uniquely — a seam of **succinic acid**, the four-carbon diacid that gives clams and cockles their particular deep, slightly mineral savor. Succinate is the "shellfish note" proper; it is why a clear clam broth tastes of more than salt and sweetness. Taken together, the bivalve brings glutamate, ribonucleotide, and succinate in one body — a near-complete umami chord before the pot is even lit.

| SOURCE | PRINCIPAL UMAMI MOLECULE | ROLE IN THE SYNERGY |
|---|---|---|
| White fish, tuna, mackerel | inosinate (IMP) | the amplifier, peaking 1–2 days post-catch |
| Scallop, shrimp, crab | glutamate + AMP + glycine | savory base with a sweet edge |
| Clam, cockle, mussel | glutamate + succinate | the deep mineral "shellfish" note |
| Kombu / kelp | glutamate | the classic savory base |
| Our restored tomato | glutamate (grown back in) | the plant half of the chord we supply |
| Koji, shiitake, engineered yeast | glutamate (+ GMP in dried shiitake) | depth we build at the source |

How large is the multiplication, in numbers a cook can hold? In the classical sensory work, glutamate and inosinate in a one-to-one mixture can taste roughly seven to eight times as intense as the same total mass of glutamate alone; glutamate with guanylate, from dried shiitake, stronger again. In receptor terms the ribonucleotide drops glutamate's $EC_{50}$ severalfold, which on the Index means a few hundred points of IFI-U become well over a thousand the instant both are present. This is why a small inosinate-rich addition "wakes up" a glutamate-rich dish out of all proportion to its quantity — and why the sea, arriving pre-loaded with inosinate, needs so little glutamate from us to taste profound.

Here is where the library enters, and it enters gently. Most of the sea's umami is already *present*; our job across this book is usually not to add savor but to *complete the chord* — to supply the half the fish does not carry, in a plant grown to carry it cleanly. A mussel brings inosinate and succinate; we bring glutamate, grown back into a tomato that decades of shipping-first breeding had quietly emptied. Put the two in one pot and the broth tastes deeper than the sum of what went in, because the receptor is doing multiplication, not addition. That single dish — mussels in a tomato-and-garlic broth, Chapter 9 — is the book's thesis made edible: two sources of one axis, meeting on one receptor, each incomplete without the other.

It is worth saying plainly what this means for how hard you should cook. If the sea already supplies the amplifier and much of the base, then reductions, long stocks, and heavy seasoning are not building umami so much as *burying* it — and burying, often, the inosinate that spoils fastest under heat and time. The reverent move and the rigorous move are the same move: buy the fish fresher, cook it less, and let the plant you add supply only the note the sea left out. The sea asks for so little because it has already done the multiplying.

# Chapter 2 · The Quiet Sweetness of Flesh — *the axis you taste before you name it*

Taste a raw scallop at the edge of cold and, a beat after the salt, something sweet arrives — faint, clean, with no sugar anywhere near it. That sweetness is real chemistry, and understanding it changes how you season the sea, because the most common mistake with delicate seafood is to reach for an acid or a salt that flattens a sweetness the flesh was giving you for free.

Sweetness is IFI-S, carried on the TAS1R2·TAS1R3 heterodimer — the sibling of the umami receptor, built from the same class-C architecture, the same two Venus-flytrap domains hinged together, but tuned to a different set of ligands. Sugars bind it; so do the intensely sweet plant proteins and glycosides our sweetness program works with. And so, more weakly but unmistakably, do several free amino acids. **Glycine** is the quiet star: the simplest amino acid, frankly sweet on the tongue, and abundant in the free-amino-acid pool of shrimp, crab, scallop, and sweet white fish. Alanine, serine, and proline add to it; a little free arginine rounds it. These are not trace curiosities — in sweet shrimp (amaebi) and raw scallop, free glycine runs high enough to be a primary flavor, not a footnote.



Monk fruit — one of our sweetness hosts. Its mogrosides read loud on TAS1R2·TAS1R3, which is exactly why we almost never need them near a scallop.

So the flesh brings its own IFI-S, usually in the 300–500 band on a good raw scallop or sweet prawn — low on the axis, but present, and placed where the palate notices it precisely because nothing else is loud. The design lesson is one of restraint: on the cold plate, we add *no* sweetness at all. We set a contrast beside the flesh — a cool note, an acid, a sharp green — and let the fish's own glycine read brighter by comparison. A squeeze of lime does not sweeten a scallop; it makes the scallop's existing sweetness legible by giving it an edge to stand against.

This is also why our sweetness library mostly stays in the cupboard during a seafood meal, and it is worth knowing what is in that cupboard even when you do not open it. The platform's sugar-free sweetness work lives in a handful of hosts, each loud on TAS1R2·TAS1R3 by a different molecule:

| HOST | SWEET MOLECULE | CONSTRUCTS | NOTE |
|---|---|---|---|
| Monk fruit | mogroside V | 80 | clean, fast onset, no linger |
| Stevia | rebaudioside A / steviol glycosides | 910 | intense; a faint bitter tail we breed down |
| Sugarcane | sucrose (yield/profile work) | 200 | the reference sugar, optimised |
| Tomato (composite) | restored sugars + glutamate | 2,040 | sweetness and umami together |

A note on why these molecules, so wildly different in size, all read as *sweet.* The TAS1R2·TAS1R3 receptor is promiscuous by design: between its two Venus-flytrap domains, the cysteine-rich linker, and the transmembrane bundle, it offers several distinct docking sites, so sugars settle into the flytrap cleft, the small sweet amino acids wedge nearby, and the intensely sweet plant *proteins* — brazzein, monellin, thaumatin — bind a larger surface again, propping the flytrap shut the way a ribonucleotide props the umami receptor shut (Chapter 1). The platform works all three registers: glycoside sweeteners (monk fruit, stevia), optimised sugar (sugarcane), and the sweet proteins where a protein's clean, slow-building sweetness suits the task. For a fish, though, the sweetness that matters is the humblest of the set — the free amino acids the flesh makes on its own — and the design lesson only sharpens: we almost never add to it.

Mogroside V, the principal sweet glycoside of monk fruit, is on the order of a couple of hundred times as sweet as sucrose by mass — which, in IFI terms, means it half-activates TAS1R2·TAS1R3 at a correspondingly tiny concentration, and so scores very high on IFI-S. That loudness is a gift in a dessert and a hazard near a scallop; a milligram in the wrong place would erase the flesh's own quiet 400. When sweetness does belong in this book, it belongs in a cure (Chapter 7), where sugar is a tool for drawing water and seasoning the salt, not a flavor meant to be tasted — and there we reach for monk fruit precisely because it reads clean and brief, seasoning the cure without leaving a sweet tail on the finished fish.

One more mechanism earns a place here, because it is why "sweet" and "fresh" so often arrive together in shellfish. Free amino acids are liberated by the same post-mortem enzymatic activity that governs the ribonucleotides — autolysis slowly breaks muscle protein into free amino acids, which is why a scallop can taste *sweeter* a few hours out of the shell than at the instant of shucking, then fades as spoilage organisms take over. There is a narrow, glittering window where glycine is high, IMP is high, and decay has not yet begun. Great raw-seafood cooking is, in large part, the discipline of eating inside that window. The axis you taste before you can name it is a clock as much as a flavor; the design around it exists to frame it, never to replace it.

**The mechanism, exactly.** Free glycine is a weak agonist on a molar basis — its $EC_{50}$ on TAS1R2·TAS1R3 sits far above a sugar's, so it would take a great deal to register. In sweet shrimp it registers anyway, because the flesh accumulates glycine to grams per kilogram in the free pool, enough to clear threshold and read frankly sweet. Beside it sits free AMP, doing double duty: a faint sweetness of its own, and a quiet suppression of bitterness and certain fishy off-notes, so the sweet edge reads *cleaner* than its concentration alone would predict. This is why a raw sweet prawn tastes sweet and clean at once — two molecules, the effect of two receptors' worth of signalling, and not a grain of sugar between them.

# Chapter 3 · Reading a Plate — *eight axes, one number each*

Every recipe in this book ends with a scorecard, and before we cook a single thing it is worth learning to read one, because the scorecard is not decoration. It is the same instrument we use to design a cultivar, pointed at a finished dish. Learn to read it and you can taste a plate and predict its profile; design a plate and read it back to check that the thing you built is the thing you meant.

The instrument has eight axes. Each is a receptor, a mechanism, and a single number.

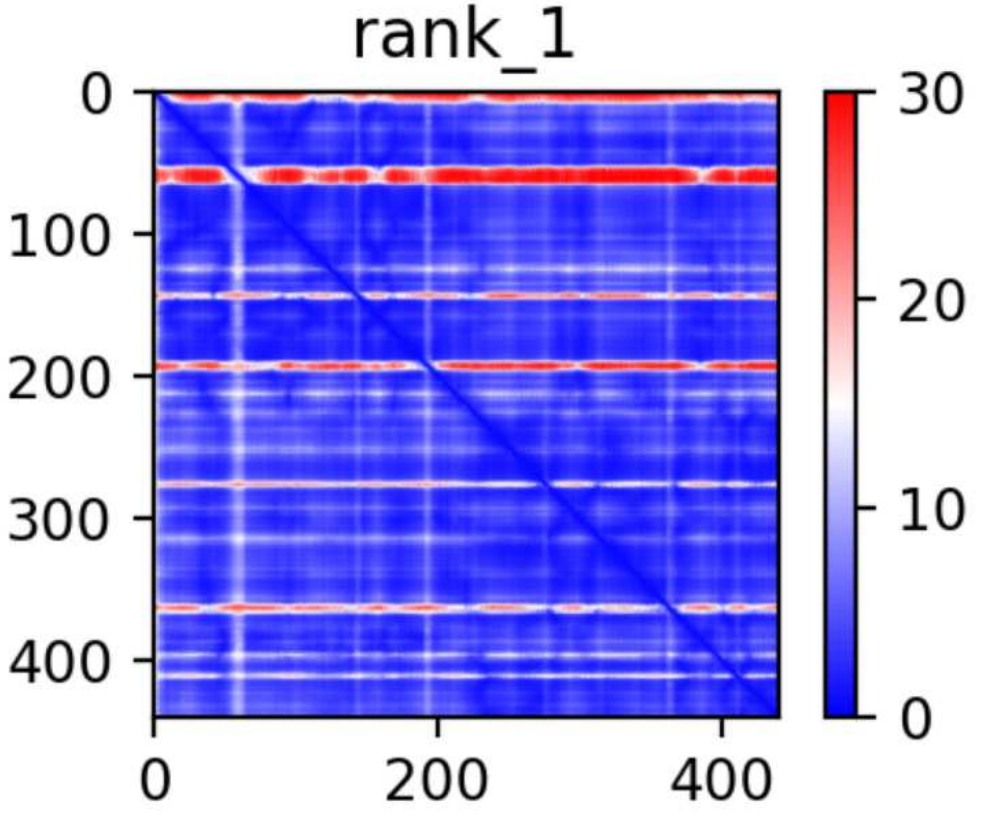
| CODE | AXIS | RECEPTOR | WHAT IT MEASURES |
|---|---|---|---|
| IFI-H | Heat | TRPV1 | capsaicin-type warmth and burn |
| IFI-S | Sweetness | TAS1R2·TAS1R3 | sugar-free sweetness |
| IFI-U | Umami | mGluR1 / TAS1R1·TAS1R3 | savory depth, brothiness |
| IFI-B | Zero-Bitter | TAS2R38 | bitterness *attenuation* (20–65%) |
| IFI-K | Kokumi | CaSR | richness, continuity, mouthfeel |
| IFI-C | Cool-Burn | TRPM8 / TRPV1 | cooling and warming thermomodulation |
| IFI-P | Pungency | TRPA1 | mustard, wasabi, ginger, allium sharpness |
| IFI-A | Astringency | salivary PRPs | tannin and acid grip |

The number on each axis is the IFI, and the IFI is a ratio of loudness:

> $\mathrm{IFI(candidate)} = 1{,}000 \times \mathrm{EC_{50}(reference)} \div \mathrm{EC_{50}(candidate)}$

Read it slowly, because the inversion is the whole idea. $EC_{50}$ is the concentration of a stimulus that drives its receptor to half of maximal response — a measure of *how little it takes.* A loud stimulus has a small $EC_{50}$: a tiny amount already half-opens the channel. A quiet one

has a large $EC_{50}$. Because the candidate's $EC_{50}$ sits in the denominator, loudness and score move together. Double the loudness — half the $EC_{50}$ — and the IFI doubles. The reference is a fixed anchor, chosen per axis by convention — like how the Scoville scale is defined by dilution-to-threshold — scaled so that a score of 1,000 corresponds to the reference's own half-activation. Each axis is normalised to a working ceiling of **5,000**, keeping every scorecard on a consistent visual frame; each axis sits against its own defined reference convention, so a score of a given number on one axis marks where you stand *on that axis* rather than offering a direct cross-axis comparison.




A predicted-aligned-error heatmap from one of our structure models — the kind of data behind the numbers. A scorecard is the eating end of this discipline.

Work an example, because the arithmetic is the argument. In Chapter 12 we cook a tuna tartare over a chili oil scored at IFI-H 160. What does 160 mean? Rearrange the formula: an IFI of 160 implies $EC_{50}$(candidate) = 1,000 ÷ 160 × $EC_{50}$(reference) = 6.25 × $EC_{50}$(reference). It takes 6.25 times more of this chili's capsaicin to half-activate TRPV1 than it takes of the reference — so on the

tongue it is roughly a sixth as loud as the anchor, a glow and not a strike. Now take the loudest thing we have ever built, **Phoenix**, at IFI-H 4,200: its $EC_{50}$ is 1,000 ÷ 4,200 = 0.238 × the reference, i.e. about 4.2 times *louder.* The ratio between the tartare's heat and Phoenix's is 4,200 ÷ 160 = 26.25. The glow on that raw tuna is one twenty-sixth of the fire at the summit of our ladder — and that ratio is not a feeling we are asserting, it is a number we can stand behind in July and in January, because it is anchored to a receptor and not to a memory of how hot last time felt.

That anchoring is the quiet revolution the Index performs for a cook. "A pinch of chili" is a hope. IFI-H 160 is a specification: the same warmth every time, independent of the cook's tolerance, the day's mood, or the batch of pepper. Our whole manufacturing discipline exists to honour it — we hold batch-to-batch variation at a coefficient of variation of **≤7%**, against the 40%-plus swing of conventionally grown chili — so that when a recipe says 160, the plate delivers 160.

Three more things to know before the scorecards start arriving.

First, **composites.** A dish, like a cultivar, is rarely one axis. When we want to speak of the whole eight at once we write IFI-F, full-spectrum — the territory of Phoenix, the only cultivar ever built to register on all eight axes simultaneously. Most plates here are the opposite of full-spectrum: two or three axes lit, the rest dark, on purpose. A crudo that reads cool-700, sweet-400, and nothing else is not an incomplete scorecard. It is a complete *idea* — restraint, rendered as a number.

The 5,000 ceiling on each axis is a deliberate choice with a consequence you can see. It means every scorecard in the library — a superhot at IFI-H 4,200, a crudo at IFI-C 700 — is drawn on the same frame, so the *shape* of a plate's radar is immediately legible. A long spike on one axis is a dish with a point of view; a small, even polygon is a composed, quiet plate; a wide full polygon is the rare full-spectrum design, the territory of Phoenix and almost nothing else. You will learn, a few chapters in, to read these shapes the way a musician reads a chord voicing at a glance: a tall narrow radar is a solo, a broad even one is an ensemble — and most of this book, true to the sea, is written for small ensembles playing softly.

Second, **the axes interact, and the scorecard does not always show it.** Umami and kokumi reinforce; a cooling note can make a heat read lower than it measures; astringency can sharpen the perception of everything around it. We score the stimulus each axis actually delivers, and we tell you in the prose where one axis is bending another. The reading on the page and the reading on your tongue are two instruments pointed at the same plate; where they differ, the difference is usually the story.

Third, **a number is a form of respect, not a replacement for pleasure.** We do not score a plate to turn a feeling into a spreadsheet. We score it because we grew the plants to a specification and we owe you the same precision at the table that we held in the greenhouse — and because a cook who can read the Index can *design*, can look at a plate that is almost right and know which single axis to move. That is the entire promise of this book:

the sea, left nearly alone, and around it a handful of plants placed by the numbers so exactly that the whole thing tastes like it simply grew that way.



PART II OF VI

# Cool Without Cold

TRPM8 · the menthol pathway · the cold plate · the sharp green flash

# Chapter 4 · The Menthol Pathway — *cool as a message, not a temperature*

This is the axis the whole book takes its color from, so we build it from the ground up. Cooling, properly understood, is one of the strangest and most useful facts in flavor: it is not a temperature at all. It is a message the tongue can be made to hear while the plate sits at room warmth — and a plant can be engineered to send it on demand.

The receptor is TRPM8, a non-selective cation channel on the sensory nerve endings of the mouth and skin. Its native job is cold detection: as tissue temperature falls, TRPM8 opens, calcium and sodium flow in, and the nerve fires the signal the brain reads as *cool.* The pivotal discovery — the one our Cool-Burn program is built on — is that TRPM8 also opens in response to certain chemicals, chief among them **menthol**, the cyclic alcohol of the mint oils. Menthol does not lower the temperature of anything. It binds TRPM8 and shifts the channel's voltage- and temperature-dependence so that the channel opens at a *warmer* threshold than it otherwise would. The mouth, at 36 °C, now receives the firing pattern it would normally get only in the cold. You feel a chill that the thermometer flatly denies.

The gating deserves one more sentence of precision, because it explains why a cook can feel menthol's cool arrive at a *threshold* and then level off at a *ceiling.* TRPM8 is a tetramer — four subunits around a central pore — and menthol binds a pocket in the voltage-sensor-like domain of each. Its action is to shift the channel's activation curve: the voltage, and the temperature, at which the channel is half-open both move, so that at mouth temperature a channel that should be shut is now partway open. More menthol shifts the curve further, up to a point — which is exactly why IFI-C climbs with dose and then saturates, every channel that *can* be recruited already open. Icilin, a synthetic super-agonist, shoves the same curve harder still; the medicinal cooling agents of chewing gum (WS-3, WS-23) are menthol-shaped molecules built to strike the same pocket without mint's flavor. We take the opposite road: keep the flavor of real mint, and engineer the plant to make the *right* cooling molecule, cleanly, at a dose we can set.



Engineered peppermint — our principal Cool-Burn host, built to carry the menthol route at full strength. IFI-C up to 2,100: the clean rush at the top of the axis.

On the Index this is IFI-C, anchored on TRPM8, and the beauty of it for seafood is total. A cold plate can only go so cold before the fish suffers; ice dulls aroma and stiffens texture. But a *cooling signal* has no such limit and no such cost. We can set a sea-breeze chill beside a raw oyster, under a cured fillet, or against a whisper of heat, and the plate stays at the temperature the fish wants while the tongue is told *cool.* Our engineered peppermint reaches IFI-C 2,100 — meaning it half-activates TRPM8 at roughly 1 ÷ 2.1 the reference concentration, better than twice as loud as the anchor — while carrying almost none of the bitterness that dogs natural mint oil at strength. Spearmint, built softer, sits lower on the axis (around IFI-C 700) with a rounder, grassier cool we reach for when peppermint would shout.

Where does the menthol come from? This is the engineering, and it is genuinely hard — peppermint is one of our *Hard*-difficulty hosts, carrying **2,360** constructs to hold the route stable and loud. Menthol is the end of a long terpenoid pathway that begins, as all monoterpenes do, with the universal five-carbon building blocks and runs through a series of stereospecific steps, each catalysed by its own enzyme, each setting a ring, a hydroxyl, or a reduction that the next step depends on:

| STEP | ENZYME | TRANSFORMATION |
|---|---|---|
| 1 | geranyl diphosphate synthase (GPPS) | DMAPP + IPP → geranyl diphosphate (GPP) |
| 2 | (−)-limonene synthase (LS) | GPP → (−)-(4S)-limonene |
| 3 | (−)-limonene-3-hydroxylase (CYP71D, a P450) | limonene → (−)-trans-isopiperitenol |
| 4 | isopiperitenol dehydrogenase (IPD) | isopiperitenol → (−)-isopiperitenone |
| 5 | isopiperitenone reductase (IPR) | isopiperitenone → (+)-cis-isopulegone |
| 6 | isopulegone isomerase (IPI) | isopulegone → (+)-pulegone |
| 7 | pulegone reductase (PR) | pulegone → (−)-menthone |
| 8 | menthone reductase (MMR) | menthone → (−)-menthol |

Two features of this route drive the whole engineering problem, and they are worth a cook's attention because they explain why cheap mint flavor so often tastes wrong. First, **stereochemistry is everything.** The pathway produces a specific enantiomer at nearly every step; (−)-menthol is the cooling one, and its mirror images and

ring-isomers (neomenthol, isomenthol) are weaker or off-note. A route that loses control of stereochemistry makes a muddle that reads "minty" but not *cold.* Second, the branch point at **pulegone** is a quality fork. Pulegone itself is harsh and, at high levels, undesirable; a well-run pathway pulls pulegone forward to menthone and menthol quickly, leaving little behind. Our redesign weights the terminal reductases (steps 7 and 8) so the flux lands on (–)-menthol with a clean tail — the molecular reason our peppermint reads as *pure cool* rather than medicinal.

> **Why "hard."** Peppermint is one of our *Hard* hosts for a reason the table above only hints at: eight stereospecific steps make a long pipe, and flux through a long pipe is set by its tightest segment. A genome-scale flux-balance model of the mint pointed to the terminal reductases and the P450 hydroxylase as the controlling constrictions, and to the glandular trichomes — the plant's surface oil glands — as the only compartment where the whole route can run without poisoning the rest of the cell. Most of our 2,360 constructs are in service of two unglamorous goals: keeping flux high through those constrictions, and keeping the pathway penned inside the trichome. Loudness on IFI-C is, in the end, a plumbing achievement.

There is a second lever we exploit in this book, and it belongs to the same axis. IFI-C is called **Cool-Burn** because TRPM8 does not work alone; cooling is perceived against the backdrop of TRPV1, the heat channel, and the mouth reads the *contrast* between them as much as either signal alone. This is why a trace of warmth under a cooling note makes the cool feel brighter, and why our favorite trick on this axis is a plant built to send both messages at once. More on that contradiction in the next chapter, where we finally start to cook. For now, hold the central fact: cool is not cold. It is a channel, it is a number, and it is a plant — grown so that a slice of fish can taste of a sea breeze that was never actually chilly.

# Chapter 5 · The Cold Plate — *the lightest hand of all*

Begin where the design is almost invisible. A crudo is a fish, a cold plate, and three or four decisions, and it is the truest test of everything this book believes: that when the raw material is right, the cook's job is restraint, and the engineered flavor should arrive as an accent you feel before you can name. Nothing on a cold plate hides. There is no browning to build on, no reduction to lean on, no fat to carry a flaw past the palate. The flesh is naked, and so is every choice you make around it.

The physics of the cold plate is simple and worth respecting, because it protects both the texture and the chemistry. Chill the plate, keep the fish cold, slice at the last moment, and you hold the flesh firm, keep the fats from going slack and oily on the tongue, and — importantly — slow the enzymes that are carrying the inosinate and free glycine through their narrow window of perfection (Chapters 1 and 2). A warm crudo is not merely less pleasant; it is a crudo past its chemical peak. Cold is a preservative for the sea's own gifts.

The knife matters as much as the cold, and for a reason rooted in the fish's own anatomy. Fish muscle is built in short blocks — myomeres — separated by thin sheets of connective tissue, the myocommata, which is why cooked fish flakes and why raw fish must be cut *across* those blocks, against the grain, so each slice holds together and the bite yields cleanly. A dull or sawing blade crushes the cells at the cut face, spilling their enzymes and their liquid, dulling both the texture and the glittering inosinate-and-glycine window of the first two chapters; one clean pull of a very sharp knife leaves the cells intact and the face mirror-smooth. On a cold plate, where nothing is hidden, the quality of the cut *is* the quality of the dish.



Engineered spearmint — softer on the axis than peppermint, grassy and round. On a cold plate it reads as a breeze, not a blast.

Our contribution to the cold plate is almost always a single cool note set *beside* the flesh, never on it — so the contrast between the fish's own quiet sweetness and the engineered chill does the talking. The spearmint here reads IFI-C 700: a clean cooling signal lifting off TRPM8 with no drop in temperature and no menthol bite. Against the

fish's glycine (IFI-S ~400, Chapter 2), it makes the whole plate taste colder and brighter than its thermometer. This is the Cool-Burn axis used at a whisper — the opposite end of the same channel that, dialled to 2,100, can dominate a dessert.

## Hamachi Crudo, Spearmint, Cold Lime

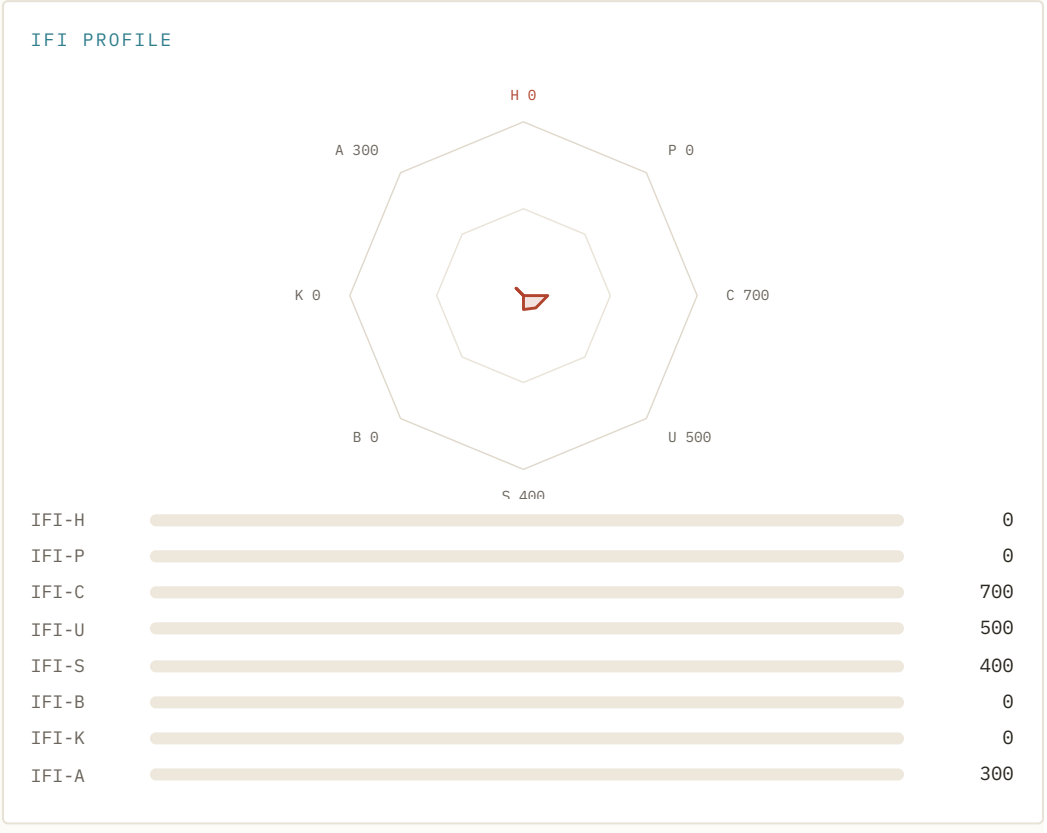
*Serves 2 · 15 minutes · the dish we make first for anyone who doubts us*

| | | |
|---|---|---|
| 200 | g | sashimi-grade hamachi (yellowtail), very cold |
| 1 | | lime |
| 2 | tbsp | cold-pressed olive oil |
| 6 | | leaves engineered spearmint, torn |
| | | flaky salt |

### Make it

1. Chill a wide plate in the freezer for ten minutes. A cold plate keeps the fish firm and the oil loose.
2. With your sharpest knife, slice the hamachi against the grain into pieces no thicker than a coin. Lay them flat, not overlapping, so each one stays cold.
3. Squeeze the lime, then whisk it with the oil and a pinch of salt. Spoon it over only at the last moment.
4. Scatter the torn spearmint and a last few flakes of salt. Eat at once, while the plate is still cold enough to hold a chill.

**Why it works** — The spearmint's IFI-C 700 lifts cleanly off TRPM8 with no cold and no bitterness, and against the fish's own quiet glycine the plate tastes colder and brighter than its temperature. The lime is not there to sweeten or to "cook" — it is astringent grip (IFI-A), an edge the glycine can lean against so the flesh reads sweeter by contrast. Nothing here is loud. Everything here is placed.




The second cold plate turns the cool note up a little and adds the book's signature contradiction — a cool that carries a buried spark of warmth, so a single plate sends the tongue both messages at

once. The cucumber that does this is a frontier plant, from the Cross-Family tier of our roadmap — *Contradiction*, built to read cool and faintly warm at the same instant. We are candid that it is a plant we are still building toward rather than one you will find on a shelf today; here it stands for an idea the finished book will let you taste, and a good market cucumber with a micro-pinch of mild chili approximates it on a weeknight.

## Oysters, Contradiction-Cucumber Mignonette

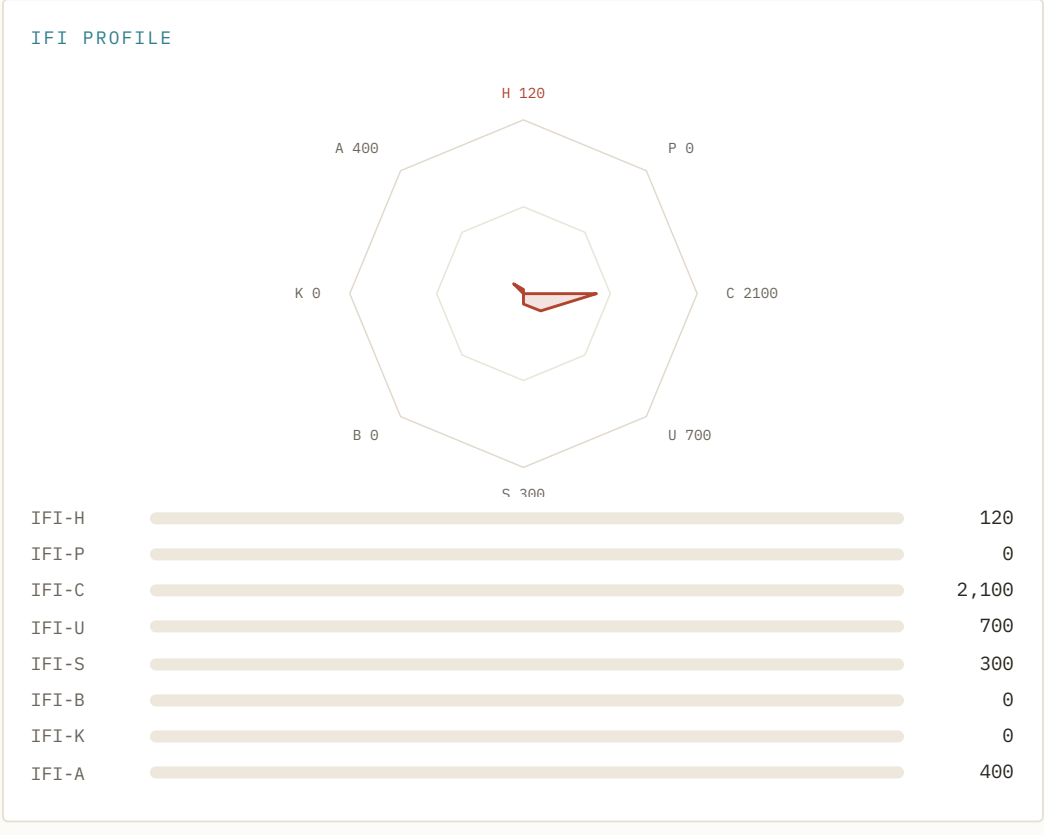
*Serves 2 · 15 minutes · the cooling axis, out loud*

| | |
|---|---|
| 12 | oysters, very cold, freshly shucked |
| 1/2 | Contradiction cucumber, in fine dice |
| 2 tbsp | rice vinegar |
| 1 | small shallot, minced |
| 6 | leaves engineered peppermint, minced |
| | cracked white pepper |

### Make it

1. Stir the vinegar, shallot, cucumber, and peppermint together and let them sit ten minutes so the cool note infuses the vinegar.
2. Keep the oysters on ice until the last moment; set them on a bed of it so they never warm.
3. Spoon a little mignonette onto each oyster. A single crack of white pepper across the dozen.
4. Eat in one, cold and bright, the mignonette leading and the brine answering.

**Why it works** — The engineered peppermint reads IFI-C 2,100, the clean rush at the top of this axis — nearly all cool, almost no bitterness — while the Contradiction cucumber slips a faint IFI-H 120 underneath, a warmth so low it registers only as *more alive.* The oyster stays exactly itself: cold, saline, sweet at the edge, carrying its own glutamate-and-succinate umami. The design is entirely in the breeze around it, and the buried heat is there only to make the cool feel colder, exactly as the Cool-Burn contrast predicts.



Two plates, one lesson. On the cold plate you are not cooking the fish — you are framing it, and the frame is a single engineered axis held at exactly the volume the flesh can carry. Turn spearmint's 700 against a scallop and it is a sigh; turn peppermint's 2,100 against an oyster and it is a wave. Same channel, same plant family, two numbers, two entirely different plates — and the fish, in both, left completely alone.

# Chapter 6 · The Sharp Green — *pungency, built to flash and clear*

Raw fish wants a sharp green heat, and for a thousand years the answer was wasabi — a flash of fire at the top of the nose that blooms, peaks, and then, mercifully, is gone. That particular shape of sensation, so different from chili's slow build and long burn, is not an accident. It is a different receptor, a different molecule, and a different set of kinetics, and once you understand all three you can build the wasabi flash into plants that grow readily, set its intensity by the number, and time its bloom to the table.

The receptor is **TRPA1**, the pungency channel, and it answers to a chemistry entirely unlike capsaicin's. Where capsaicin binds TRPV1 in a tidy lock-and-key, TRPA1 is an *electrophile sensor:* it carries reactive cysteine residues on its inner face (in human TRPA1, principally Cys621, Cys641, and Cys665), and it opens when an electrophilic molecule forms a covalent bond with those cysteines — a Michael addition or a thiol-isothiocyanate reaction that chemically modifies the channel and springs it open. This covalent mechanism is why TRPA1 pungency *blooms and fades:* the agonist reacts, the channel fires hard, and then the signal clears as the chemistry completes and the volatile molecule escapes — unlike the long non-covalent occupancy of capsaicin on TRPV1.



Engineered black mustard — our allyl-isothiocyanate host, the wasabi flash built to order through the sinigrin–myrosinase route.

The molecule that makes wasabi, mustard, and horseradish sting is **allyl isothiocyanate** (AITC), one of a family of isothiocyanates (the reactive –N=C=S group is the business end). And here is the detail that governs the cooking: AITC does not exist, ready-made, in the intact plant. It is manufactured on injury, in seconds, by an elegant two-component system the plant keeps deliberately separated until something bites it. In the cells sits a stable, odorless glucosinolate — in black mustard and in true wasabi, **sinigrin.** In a different compartment sits the enzyme **myrosinase**, a β-thioglucosidase. Rupture the cell — by grating, crushing, chewing — and enzyme

meets substrate: myrosinase hydrolyses sinigrin, cleaving off glucose, and the unstable aglycone rearranges (a Lossen-type rearrangement) into pungent, volatile allyl isothiocyanate plus a sulfate. The sting is a wound response, assembled at the moment of damage.

This is why real wasabi must be grated fresh and used within minutes, and why pre-made wasabi paste is a disappointment: the AITC blooms as the enzyme works, peaks within a couple of minutes, and then — being volatile and reactive — escapes and degrades, flattening within the hour. Our engineered black mustard (a *Hard* host, **2,790** constructs, primary axis P) is built to run this route cleanly and on demand: grate it, give it two minutes for myrosinase to do its work and the AITC to bloom, and serve it at the peak. We can set its loudness by the number — the paste here reads IFI-P 315, a bright green flash — and because the pungency clears, it wakes a slice of fish up and then leaves the palate ready for the next cold piece, exactly the rhythm raw-fish eating wants.

A note on the mustard family, because it explains why we chose black mustard and not white. White mustard (*Sinapis alba*) carries a different glucosinolate, **sinalbin**, which yields *p*-hydroxybenzyl isothiocyanate — far less volatile, so it bites the tongue rather than flashing up the nose, and it reads duller and more lingering. Black mustard's sinigrin → AITC is the volatile, nose-filling, fast-clearing sting that stands in for wasabi. Watercress (also a TRPA1 host in our library) carries yet another, gnarlier isothiocyanate (gluconasturtiin → phenethyl ITC) for a peppery, rooty lift. Same channel, three molecules, three shapes of sharpness — and the Index lets us place each one by number.

## Snapper Sashimi, Fresh Green Heat

*Serves 2 · 10 minutes · grate it to order or not at all*

```
200 g     sashimi-grade snapper or sea bream
1  tbsp   engineered black-mustard paste, grated to order
1  tsp    engineered ginger, grated
1  tbsp   light soy or tamari
1  tsp    engineered spearmint, very finely sliced
          a little cold water
```

**Make it**

1. Grate the black-mustard root into a fine paste, cover it, and let it bloom for two minutes — the pungency builds as myrosinase meets the air, then begins to fade, so time it to the table.
2. Slice the snapper thin on the bias. Fan it on a cold plate.
3. Loosen the soy with a few drops of cold water and the grated ginger. Pour a thread of it around, not over, the fish.
4. Set a small mound of the mustard paste to the side and a whisper of spearmint across the top. Each bite is yours to build.

**Why it works** — The mustard's IFI-P 315 is the fresh green flash off TRPA1, built to bloom and clear; the soy and the fish's own inosinate carry a steady IFI-U 1,100 underneath; the spearmint holds a cool

floor at the back of the bite. Three axes, three different timescales — pungency that spikes and clears, umami that stays, cool that lingers — layered so no two peak at once.

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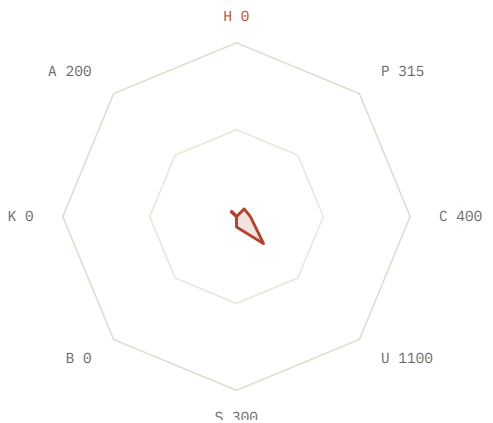



| | |
|---|---|
| IFI-H | 0 |
| IFI-P | 315 |
| IFI-C | 400 |
| IFI-U | 1,100 |
| IFI-S | 300 |
| IFI-B | 0 |
| IFI-K | 0 |
| IFI-A | 200 |

The second plate takes the flash to its coldest, most elemental use: a raw oyster with nothing but the sting and the brine. Here the mustard is not a condiment to the side but the single engineered gesture on the plate, and the timing matters more than ever — grate, bloom, spoon, eat.

## Oysters, Cold Green Flash

*Serves 2 · 10 minutes · bloom it, spoon it, eat it*

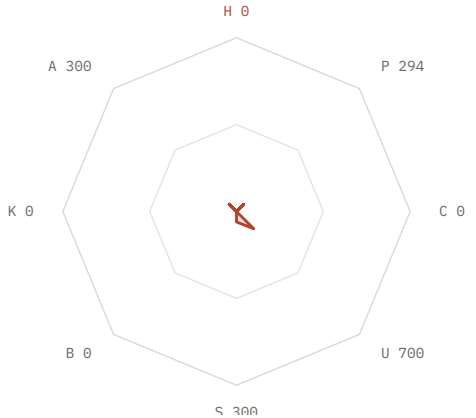
| | |
|---|---|
| 12 | oysters, very cold, freshly shucked |
| 2 tsp | engineered black-mustard paste, grated to order |
| 1 tsp | rice vinegar |
| 1/2 tsp | engineered ginger, grated |
| | a few micro-leaves watercress |

### Make it

1. Grate the mustard and let it bloom two minutes. Stir in the vinegar and ginger to make a loose, bright dressing.
2. Keep the oysters hard-cold on ice. Spoon the barest half-teaspoon of dressing onto each.
3. Top each with a single watercress leaf. Eat in one — the flash rises up the nose, the brine answers, and by the next oyster the palate is clear again.

**Why it works** — This is pungency almost alone: IFI-P 294 of AITC flashing off TRPA1, cleared before the next bite, with the oyster's native umami and sweetness (IFI-U 700, IFI-S 300) left entirely untouched beneath it. The watercress adds a second, rootier isothiocyanate — a hair of extra sharpness on the same channel. No heat. No cooling. Just the green fire that raw shellfish has wanted for a thousand years, now grown to order and placed by the number.

## IFI PROFILE




| | | |
|---|---|---|
| IFI-H | | 0 |
| IFI-P | | 294 |
| IFI-C | | 0 |
| IFI-U | | 700 |
| IFI-S | | 300 |
| IFI-B | | 0 |
| IFI-K | | 0 |
| IFI-A | | 300 |




PART III OF VI

# Cooking Without Fire

the cure · osmosis and water activity · the acid cook · astringency as structure

# Chapter 7 · The Cure — *salt, time, and the sweetness that seasons the salt*

A cure is the slowest cooking there is — no heat at all, only salt and sugar drawing water out of the flesh over hours until it turns dense, silky, and translucent, its flavors concentrated, its texture transformed. To cure is to cook with osmosis instead of fire, and because it is slow and gentle, it is one of the most forgiving and rewarding things you can do to a fish. It is also where our sweetness work earns its keep most quietly, because a cure is almost the only place in this book where sugar belongs — and it belongs not as a flavor but as a tool.

The mechanism is osmosis and **water activity.** Pack a fillet in salt and sugar and you create, at the surface of the flesh, a zone of very high solute concentration. Water moves across the cell membranes from the dilute inside to the concentrated outside, following the gradient; the flesh gives up moisture, its proteins draw closer together and partially denature, and the texture turns from soft to firm and silken. Salt (sodium chloride) does most of the osmotic pulling and most of the preserving — it lowers the water activity enough that spoilage organisms struggle. Sugar does three subtler things: it adds to the osmotic draw, it buffers the salt so the cure tastes balanced rather than aggressively saline, and it holds a little moisture back so the fish stays supple rather than going to jerky. A cure with no sugar reads harsh; the sugar is there to season the salt.



Engineered low-bitter orange — zest without the sulk. IFI-B worked in at the source, so the oil perfumes a cure instead of souring it.

Because the sugar is a tool and not a taste, this is the ideal place to use the cleanest, briefest sweetness we grow. We reach for engineered monk fruit: its mogroside V reads loud on TAS1R2·TAS1R3 but with fast onset and no lingering tail (Chapter 2), so it seasons the cure and draws its water without leaving a sweet ghost on the finished fish. A cure built this way carries far less fermentable sugar than the old salt-and-white-sugar brick and still

holds its balance perfectly — and while that is first a technique for flavor, we see no reason the gentler path and the better plate should be two different plates.

The aromatics in a cure go in cold and stay subtle, and the most useful of them in our pantry is a citrus engineered on a different axis entirely: **IFI-B, Zero-Bitter.** Citrus zest is a gift and a trap — the oil in the flavedo carries the bright perfume you want, but the pith and the oil also carry bitter limonoids (limonin) and flavanone glycosides (naringin) that read sour-bitter and sulky, especially as they sit. Bitterness is the TAS2R38 axis, the receptor family that reads thiourea and a wide sweep of plant defensive compounds, and our Zero-Bitter program attenuates it by 20–65% — here, by breeding the bitter limonoids and glycosides down at the source, so the engineered orange gives the full perfume of zest with the bitterness subtracted. A conventional orange zested into a cure can turn the whole thing resinous; ours reads bright for the full twenty-four hours. On the scorecard a high IFI-B is not "bitterness" but *bitterness removed* — the axis measures the attenuation, the quietness we built in.

## Citrus-Cured Salmon

*Serves 6 · 20 minutes hands-on · 24 hours in the cold*

```
600 g      salmon fillet, skin on, pin-boned
3  tbsp    flaky salt
2  tbsp    engineered monk-fruit sweetener (or fine sugar)
1          engineered low-bitter orange, zested
8          leaves engineered spearmint
           cracked black pepper
```

**Make it**

1. Stir the salt, sweetener, and orange zest together. Scatter a third of it on a tray.
2. Lay the salmon skin-down on the cure, blanket the flesh with the rest, and press the spearmint and pepper over the top.
3. Wrap tightly, weight with a plate and a tin, and refrigerate 24 hours, draining the liquid once at the halfway mark — the weight speeds the osmosis and keeps the texture even.
4. Rinse, pat very dry, and slice thin on the bias, leaving the skin behind.

**Why it works** — The cure concentrates the salmon's own umami as it draws water, lifting the flesh to IFI-U 900; the engineered orange reads IFI-B 2,200 (bitterness subtracted, perfume kept); the monk-fruit seasons the salt without leaving a sweet tail (IFI-S 500); the spearmint carries a cold thread (IFI-C 400) you taste through the chill. Four axes, none of them loud, all of them placed — a fish transformed by time and salt, framed by plants that correct exactly what a cure tends to get wrong.

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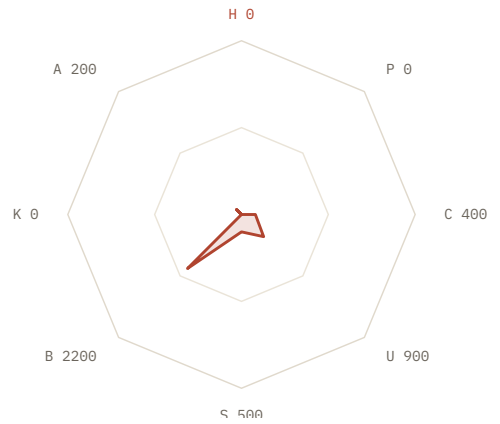


| | |
|---|---|
| IFI-H | 0 |
| IFI-P | 0 |
| IFI-C | 400 |
| IFI-U | 900 |
| IFI-S | 500 |
| IFI-B | 2,200 |
| IFI-K | 0 |
| IFI-A | 200 |

The second cure trades the citrus brightness for earth and color — a beet-cured ocean trout, where the beet stains the flesh a deep rose at the edge and lends an earthy-sweet note, and a little juniper and the same clean sweetener keep it from turning one-dimensional.

## Beet-Cured Ocean Trout

*Serves 6 · 20 minutes hands-on · 36 hours in the cold*

| | | |
|---|---|---|
| 600 | g | ocean trout or sea trout fillet, skin on, pin-boned |
| 3 | tbsp | flaky salt |
| 2 | tbsp | engineered monk-fruit sweetener |
| 1 | | medium raw beet, finely grated |
| 6 | | juniper berries, crushed |
| 1 | | engineered low-bitter orange, zested |
| | | cracked black pepper |

### Make it

1. Mix salt, sweetener, grated beet, juniper, orange zest, and pepper into a wet, vivid paste.
2. Lay the trout skin-down on a third of it, pack the rest over the flesh, wrap tightly, and weight.
3. Cure 36 hours in the cold, draining and re-pressing at the halfway point. The longer cure suits the leaner flesh and deepens the color.
4. Scrape off the cure, rinse briefly, pat very dry, and slice thin on the bias.

**Why it works** — The beet brings an earthy IFI-S 600 and its color; the orange's IFI-B 2,000 keeps the whole thing bright against the earthiness; the cure concentrates the trout to IFI-U 900. A hair more astringency than the salmon (the beet and juniper), which gives the slices a clean, grounding finish. Still no heat, still no fire — only salt, time, and two plants placed to keep an earthy cure from going dull.

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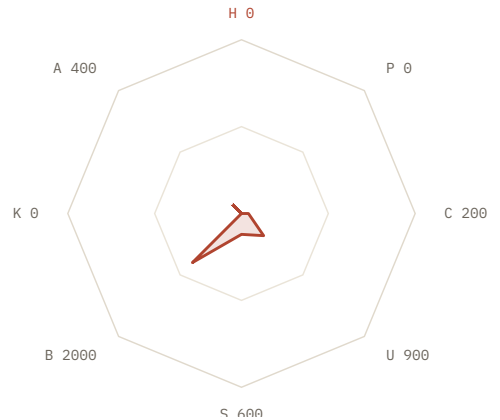



| | |
|---|---|
| IFI-H | 0 |
| IFI-P | 0 |
| IFI-C | 200 |
| IFI-U | 900 |
| IFI-S | 600 |
| IFI-B | 2,000 |
| IFI-K | 0 |
| IFI-A | 400 |

*Nourishment note, quiet: a cure that leans on engineered sweetness instead of a brick of sugar is still, first, a technique for flavor — but it is a kinder one, and we see no reason the gentler path and the better plate should be two different plates.*

# Chapter 8 · The Acid Cook — *denaturing without heat, and the backbone of brightness*

Ceviche is cooking without fire, and understanding it precisely frees you to control it instead of fearing it. Acid does to the fish's proteins something closely related to what heat does: it denatures them. Lower the pH around a protein and you disrupt the weak forces — hydrogen bonds, ionic interactions — that hold its folded shape; the protein unfolds and then re-associates into a firmer, whiter, opaque network. The flesh turns from translucent to opaque from the outside in, firming and whitening, exactly as a gently poached fish would, but at room temperature and below.

How fast this happens is a matter of pH and surface area, and a cook can reason about it directly. Citrus juice sits around pH 2 to 2.5; at that acidity the fish's muscle proteins — principally myosin — are driven well below their isoelectric point, their charge balance upset, so they unfold and re-aggregate into the opaque white network you can watch climb inward from the cut face. Smaller dice firm faster, because acid, like heat, works from the outside in: a one-centimetre cube sets at the edge in minutes while its core stays translucent, which is exactly the texture a good ceviche wants. Push it too long and the whole cube goes chalky and dense, the proteins over-aggregated precisely as an overcooked fish's are. The art is to stop the acid — by lifting the fish from most of its liquor — while the center is still barely raw. The tools are time and acid strength, and nothing else — which means the brightness you choose is not a garnish but the cooking medium itself.

That brightness is an axis in its own right: **IFI-A, astringency**, carried not on a taste receptor but on the salivary proteins. Astringency is the clean, drying grip you feel from strong tea, young red wine, or a squeeze of lime — and its mechanism is mechanical as much as chemical. Tannins and polyphenols, and to a related degree the hydrogen ions of a strong acid, bind and cross-link the **proline-rich proteins (PRPs)** and statherin that lubricate saliva. When those proteins are precipitated or stiffened, the mouth loses its slick film, and the brain reads the loss of lubrication as *grip*, *dryness*, *structure.* In a ceviche, that grip is the backbone — it is what makes the dish taste firm and defined rather than merely sour, and it is why the best ceviches have a clean, almost tannic edge and not just acidity.




Acid tomatillo — a frontier plant bred toward brightness so defined it reads as structure, not sourness. Here it does the work a squeeze of lime only gestures at.

Our green of choice for the acid cook is a tomatillo built for exactly this — the *Acid* line, from the Extended-Nightshades tier of our roadmap, bred toward a brightness so defined it reads as structure rather than sourness. We are candid, as throughout, that this is a plant we are building toward rather than one on the shelf today; it stands here for a target the finished library will let you cook with, and until then a good ripe tomatillo plus lime approximates its job. The idea it carries is precise: a plant whose organic-acid and husk-polyphenol profile is tuned so that its astringency reads as clean architecture — IFI-A around 900 — giving a ceviche its firm finish without the one-note sourness of lime alone. The lime still does the denaturing; the tomatillo supplies the backbone the lime lacks.

## Sea Bass Ceviche, Acid Tomatillo

*Serves 4 · 25 minutes · 15 of them spent waiting*

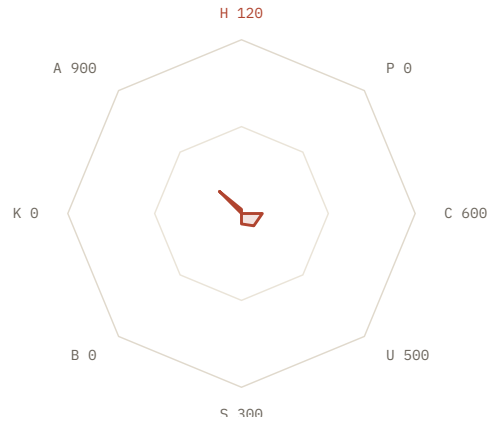
| | |
|---|---|
| 400 g | very fresh sea bass or corvina, in 1 cm dice |
| 4 | Acid tomatillos, finely chopped |
| 3 | limes, juiced |
| 1/2 | Contradiction cucumber, diced |
| 1 tbsp | engineered spearmint, sliced |
| | flaky salt · a pinch of mild chili (IFI-H 120) |

### Make it

1. Toss the fish with the lime juice and a good pinch of salt. Leave it 12–15 minutes, until the edges turn opaque but the centers stay just translucent — the acid is cooking from the outside in, and you want to stop it before the center goes chalky.
2. Fold in the tomatillo, cucumber, and a small pinch of chili.
3. Rest two minutes more, then lift the fish from most of its liquor onto cold plates. Finish with spearmint.

**Why it works** — The Acid tomatillo's IFI-A 900 is brightness as backbone, holding the whole plate firm; the cucumber and spearmint lay a cool floor (IFI-C 600); a pinch of chili sits at IFI-H 120, barely there, just enough to make the cool read cooler; and the fish's own sweetness shows at IFI-S 300 where the acid gives it an edge to lean on. The acid cooks; the plants frame.

IFI PROFILE




| | |
|---|---|
| IFI-H | 120 |
| IFI-P | 0 |
| IFI-C | 600 |
| IFI-U | 500 |
| IFI-S | 300 |
| IFI-B | 0 |
| IFI-K | 0 |
| IFI-A | 900 |

The second acid cook is louder and leaner — a shrimp aguachile where the acid is pushed, the cool is pushed, and a genuine thread of heat runs through, so the dish snaps rather than soothes. It is the same denaturing science, dialled toward exhilaration.

## Shrimp Aguachile Verde

*Serves 4 · 20 minutes · bright, cold, and awake*

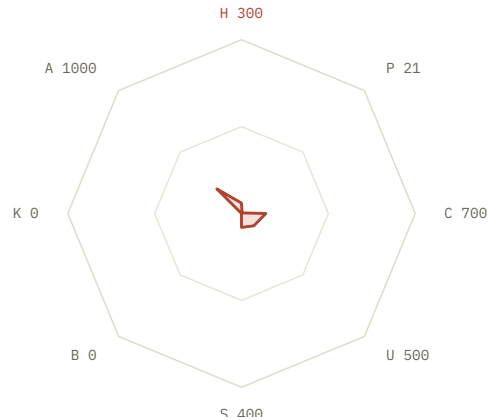
| | |
|---|---|
| 400 g | raw shrimp, peeled, butterflied, very cold |
| 4 | Acid tomatillos |
| 4 | limes, juiced |
| 1/2 | Contradiction cucumber, plus more sliced to serve |
| 1 tbsp | engineered spearmint |
| 1 tsp | mild green chili, to taste (IFI-H 300 band) |
| | flaky salt · thin-sliced red onion |

### Make it

1. Blend the tomatillos, lime juice, half the cucumber, spearmint, chili, and salt into a loose, bright green liquor. Keep it ice-cold.
2. Lay the butterflied shrimp flat on cold plates and pour the aguachile over to just cover.
3. Leave 8–10 minutes — the shrimp firm and turn opaque at the edges. Strew with sliced cucumber and red onion and eat at once, cold.

**Why it works** — Pushed on three axes at once: IFI-A 1,000 from the tomatillo and lime for a hard bright backbone, IFI-C 700 of cooling cucumber and spearmint to keep it from burning, and a real IFI-H 300 of green chili laddered up because the leaner shrimp and the fierce acid can carry it. This is the acid cook at its most alive — the one plate in this part of the book that is meant to wake you rather than settle you, and a clean demonstration that "cooking without fire" need not mean cooking without excitement.

## IFI PROFILE




| | | |
|---|---|---|
| IFI-H | | 300 |
| IFI-P | | 21 |
| IFI-C | | 700 |
| IFI-U | | 500 |
| IFI-S | | 400 |
| IFI-B | | 0 |
| IFI-K | | 0 |
| IFI-A | | 1,000 |



PART IV OF VI

# The Savory Center

glutamate × ribonucleotide · the restored tomato · kokumi and the invisible axis · the clear broth

# Chapter 9 · Umami Meets Umami — *two sources of one axis, in one pot*

This is the chapter the whole book leans on, because it is where our platform and the sea do the same thing from two directions and meet in the middle of a bowl. Everything Chapter 1 established as mechanism now becomes dinner: free glutamate and a 5′-ribonucleotide, arriving together on TAS1R1·TAS1R3, where the second does not add to the first but multiplies it. A little glutamate and a little inosinate, together, taste like a great deal of both. The sea brings one half; we grow the other.

Shellfish, recall, bring their ribonucleotides (AMP, and the inosinate that accumulates post-mortem) and their seam of succinate. What they do not bring in quantity is free glutamate — and glutamate is the half that our tomato work was built to supply. Here is the piece of the library that matters most to a seafood cook, and it is a story of restoration rather than addition. The tomato is one of our easiest and largest hosts — **2,040** constructs, axes spanning sweetness, umami, and the composites — but the engineering did not invent anything foreign to the fruit. It *gave back* what a century of shipping-first breeding had quietly bred out.



The restored tomato — IFI-U lifted from roughly 300 to 2,600 through the plant's own GAD and GDH1 routes. Not a flavor added, but a flavor grown back in.

The mechanism is worth naming because it is the cleanest example in the library of engineering as *recovery.* Free glutamate in a ripening tomato is built and balanced by the plant's own nitrogen metabolism — principally **glutamate decarboxylase (GAD)**, which consumes glutamate to make GABA, and **glutamate dehydrogenase (GDH1)**, which sits at the hinge between glutamate and α-ketoglutarate in the amino-acid pool. Breeding for shelf life, uniform ripening, and shipping durability dragged the free-glutamate pool down as a side effect; a supermarket tomato can read as low as IFI-U ~300, a pale shadow of what the fruit can carry. By tuning the GAD/GDH1 balance

toward glutamate accumulation in the ripe fruit, we restore free glutamate to roughly three times that of a shipping tomato — **IFI-U ~2,600** — without touching anything that was not already the tomato's own chemistry. It is the tomato that tastes *like a tomato should,* and for seafood it is precisely the missing half of the chord.

Put the restored tomato in a pot with mussels and the arithmetic of Chapter 1 becomes flavor you can taste expanding. The mussels open and release their liquor — inosinate, AMP, succinate, salt — into a base already loud with the tomato's grown-back glutamate. On the receptor, the ribonucleotide stabilises the glutamate-bound flytrap; the $EC_{50}$ for the combined signal drops far below either component's; the broth tastes deeper than the sum of what went in. This is the single dish in the book where we let umami run high on purpose, because here it is not seasoning — it is the whole point.

It is worth dwelling on what "grown back in" actually required, because it is the library's cleanest case of engineering as restoration rather than addition. Free glutamate in a ripening tomato is not stored; it is the moving balance of a flux — made and consumed continuously by the fruit's nitrogen metabolism, with glutamate decarboxylase (GAD) drawing it down toward GABA and glutamate dehydrogenase (GDH1) shuttling between glutamate and α-ketoglutarate. Decades of selection for shipping durability and uniform ripening nudged that balance toward consumption, and the free-glutamate pool fell as a quiet side effect, dragging IFI-U from the fruit's native ~2,600 toward the ~300 of a supermarket tomato. We did not borrow a glutamate gene from elsewhere; we re-weighted the plant's own GAD/GDH1 balance toward accumulation in the ripe fruit, and the savor came back. The tomato that tastes like a tomato should is simply the tomato allowed, again, to keep what it always made.

## Mussels, Tomato and Garlic Broth

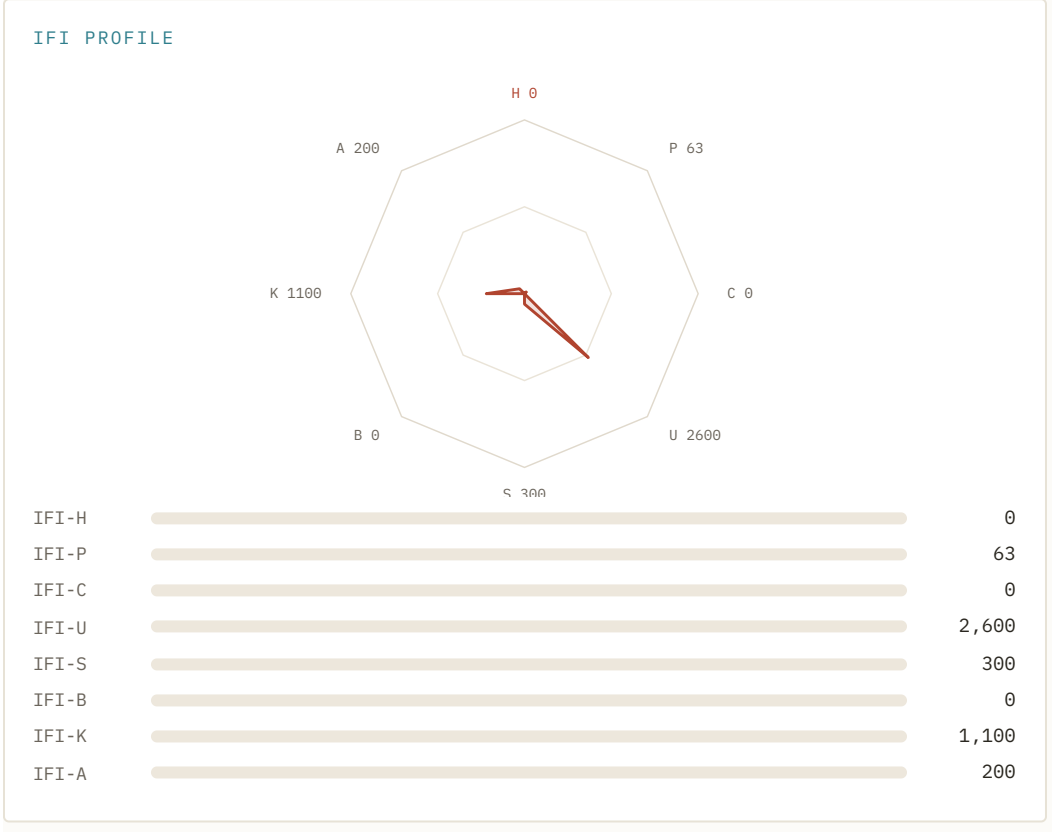
*Serves 4 · 30 minutes · the synergy, in a bowl*

```
1  kg      mussels, scrubbed and debearded
4          restored tomatoes, grated (or the Volcanic 'Caldera' line, for
heat)
6  cloves  engineered garlic, sliced
3  tbsp    olive oil
200 ml     dry white wine
1  tbsp    engineered oregano · flaky salt
```

### Make it

1. Soften the garlic slowly in the oil until gold and sweet — do not brown it. Add the grated tomato and oregano and let it cook down to a thick, glossy base, about five minutes.
2. Pour in the wine, bring to a hard simmer, and tip in the mussels. Cover.
3. Shake the pan; in three or four minutes the shells open and release their liquor into the tomato. Discard any that stay shut.
4. Salt carefully — the mussels are already saline — and bring the pot to the table with bread.

**Why it works** — The restored tomato's grown-in glutamate (IFI-U ~2,600 on its own) meets the mussels' native inosinate and succinate on the same receptor, and the response multiplies to a broth that reads a full IFI-U 2,600 on the plate. The garlic supplies body — IFI-K 1,100 of kokumi — so the broth tastes cooked-all-day with no stock in sight. A low allium pungency (IFI-P 63) runs underneath. No heat, unless you reach for the Volcanic 'Caldera' tomato in place of the restored one, which carries its own IFI-H up the ladder for those who want the broth to bite.




The second dish holds the synergy but strips it to clarity — a tomato "dashi," where the restored tomato is treated like kombu, steeped rather than cooked, and the clams supply the inosinate in a near-clear amber broth. It is the same chord played *pianissimo.*

## Clams in Tomato Dashi

*Serves 4 · 25 minutes · the synergy, whispered*

| | | |
|---|---|---|
| 24 | | small clams, purged |
| 4 | | restored tomatoes, very ripe |
| 1 | strip | kombu |
| 700 | ml | water |
| 1 | tsp | engineered-koji paste |
| 1 | tbsp | engineered chives, sliced · flaky salt |

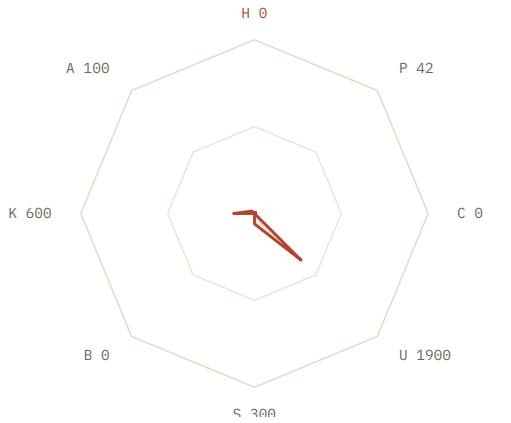
### Make it

1. Grate the tomatoes and strain the pulp through a sieve to collect the clear, savory "water," pressing gently. Reserve.
2. Steep the kombu in the cold water ten minutes, then warm slowly to just below a simmer and lift it out before it boils.
3. Whisk in the clear tomato water and the koji. Add the clams and cover until they open, about three minutes.
4. Lift the clams into bowls, pour the near-clear broth over, and strew with chives.

**Why it works** — The clear tomato water carries the glutamate without the pulp's body; the clams bring inosinate and succinate; the kombu adds a third thread of glutamate; the koji rounds it. Umami

runs clean and high (IFI-U 1,900) with almost nothing else on the plate — proof that the synergy does not need richness to read deep. The chives lay a faint green pungency (IFI-P 42) across the top.

IFI PROFILE




| | |
|---|---|
| IFI-H | 0 |
| IFI-P | 42 |
| IFI-C | 0 |
| IFI-U | 1,900 |
| IFI-S | 300 |
| IFI-B | 0 |
| IFI-K | 600 |
| IFI-A | 100 |

# Chapter 10 · The Invisible Axis — *kokumi, and richness without fat*

There is an axis you have been tasting your whole life without a name for it. Call a broth "round," a sauce "complete," a dish "long" on the finish — you are reaching for kokumi, the hardest of the eight to describe because it is not, strictly, a taste at all. Kokumi adds no flavor of its own. It takes the flavors already present and gives them *body, continuity, and mouthfulness* — it makes a thin thing feel thick, a brief thing feel lingering, a collection of tastes feel like one integrated whole. For seafood, where we are forever trying to add completeness without adding weight, it is the most useful axis in the book after umami itself.

The receptor is **CaSR**, the calcium-sensing receptor — the same receptor the body uses in the parathyroid gland to monitor blood calcium, deployed also on the taste cells. CaSR is activated by calcium and, crucially for flavor, by a family of **γ-glutamyl peptides:** small peptides carrying a glutamate linked through its side-chain (γ) carboxyl rather than the usual backbone. The archetype is **glutathione** (γ-Glu-Cys-Gly), the cell's workhorse antioxidant tripeptide; even more potent on CaSR is the peptide **γ-Glu-Val-Gly.** When these bind CaSR on the taste cells, they do not generate a "kokumi taste" — they modulate the signalling of the other taste pathways, amplifying the perceived intensity and, especially, the *persistence* of sweet, salty, and umami sensations. The dish does not get a new note; its existing notes get longer and rounder.

The structure–activity story behind that is unusually clean, which is why the platform can tune kokumi by the number. CaSR, like the sweet and umami receptors, is a class-C GPCR built around a large Venus-flytrap domain — but it is an unusually permissive one, evolved to sense calcium against a noisy biological background, and it reads a whole family of γ-glutamyl peptides with a graded potency. Glutathione (γ-Glu-Cys-Gly) is the familiar one; γ-Glu-Val-Gly is several times more potent; γ-Glu-Cys and a handful of others fill in the ladder. Their common feature is the γ-linkage — the glutamate tethered through its side-chain carboxyl rather than its backbone — which is precisely what the receptor's pocket recognises and what ordinary α-peptides lack. Because potency tracks sequence so predictably, we can choose *which* peptides a host accumulates, and therefore how loud, and how clean, its kokumi reads.



Engineered baker's yeast — a kokumi host, built to concentrate the γ-glutamyl peptides that move CaSR. Body without butter.

This is why our kokumi work lives in **yeast** (**240** constructs, axes U and K) and **garlic** (**560** constructs, axes K and P): both are natural reservoirs of γ-glutamyl peptides, and both can be tuned to carry more. Yeast builds glutathione and related peptides as part of its ordinary redox housekeeping; we select and engineer strains that accumulate the kokumi-active peptides and deliver them as a clean extract. Garlic carries γ-glutamyl-S-allyl-cysteine and its relatives — the same γ-glutamyl chemistry, which is part of why garlic makes almost everything taste more complete. On the Index these read as IFI-K, and the number is a measure of how much continuity and body the ingredient lends, calibrated against a CaSR reference.

The practical magic for a seafood cook is this: kokumi lets you build the sensation of richness with a fraction of the fat. A spread, a sauce, a broth that would normally need butter or cream or a long reduction to feel "finished" can be brought to the same roundness with a teaspoon of engineered yeast extract and no added fat at all. The fish stays clean and light; the dish still feels complete. We did not set out to make these dishes leaner — we set out to make them taste whole — and it turned out those were the same instruction.

## Seared Scallops, Kokumi Butter and Chive

*Serves 4 · 20 minutes · completeness, with almost no fat*

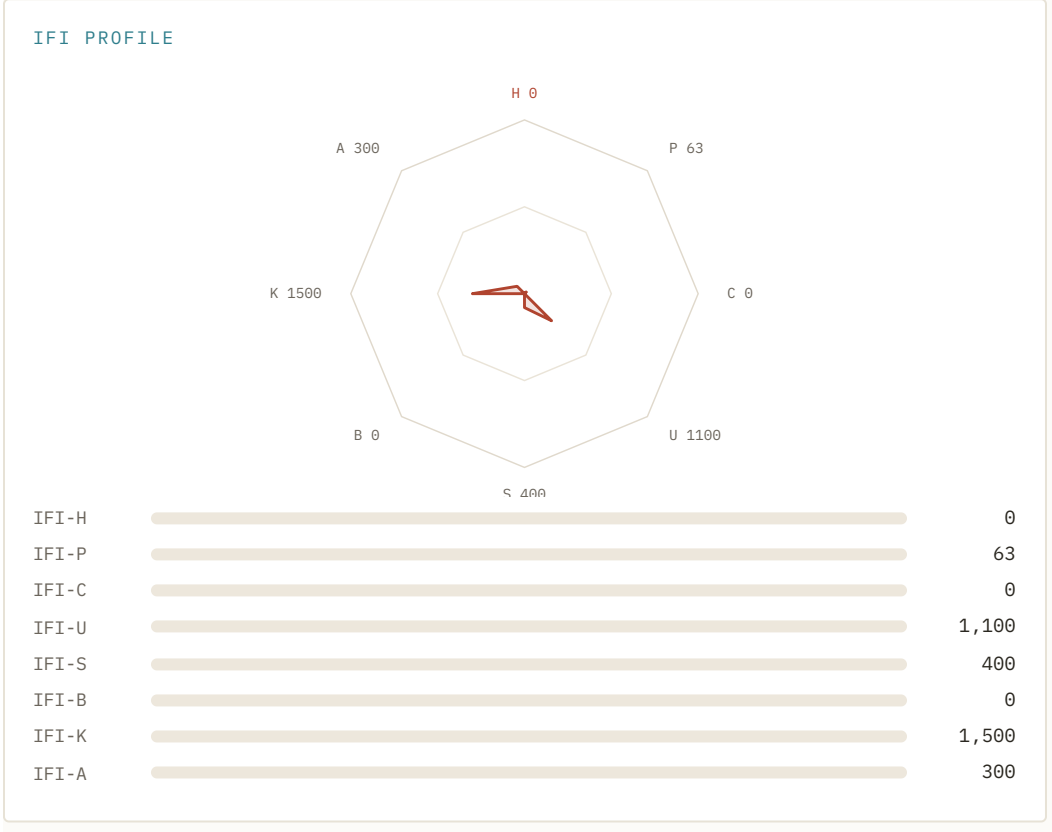
```
12          large sea scallops, patted very dry
1  tbsp     olive oil
20 g        butter (yes, a little — but only a little)
1  tsp      engineered-yeast extract
1           lemon · 1 tbsp  engineered chives, sliced
            flaky salt
```

**Make it**

1. Heat a heavy pan until nearly smoking. Film with the oil. Season the scallops and lay them down without crowding; do not move them. Sear 90 seconds until a deep crust forms, then flip for 30–45 seconds more. Lift them out — they should be barely set in the middle.
2. Off the heat, add the small knob of butter to the warm pan and whisk in the yeast extract until it melts into a glossy, savory emulsion. A squeeze of lemon.

3. Spoon the kokumi butter over the scallops and strew with chives.

**Why it works** — Just 20 grams of butter for four people, yet the sauce reads as a rich beurre — because the engineered yeast's IFI-K 1,500 lends the continuity and body that fat usually supplies, moving CaSR to stretch the scallop's own sweetness (IFI-S 400) and the seared umami (IFI-U 1,100) across a long finish. The chives give a green pungent lift (IFI-P 63); the lemon, a clean astringent edge. This is the invisible axis made visible: the plate feels luxurious and eats light.




The second kokumi dish takes the axis into its subtlest possible vehicle — a savory steamed custard, almost weightless, that would collapse into thin egg-water without the body the engineered yeast lends it.

## Clam Chawanmushi, Kokumi Custard

*Serves 4 · 30 minutes · a savory custard, barely set*

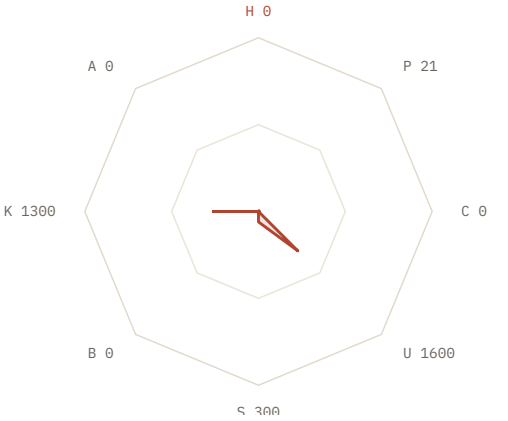
| | |
|---|---|
| 3 | eggs |
| 400 ml | clear dashi or Clear Clam Broth (Chapter 11), cooled |
| 1 tsp | engineered-yeast extract |
| 12 | small clams, steamed open, meat reserved |
| 1 tsp | light soy |
| | engineered chives, to finish |

### Make it

1. Whisk the eggs gently — no foam — then stir in the cooled dashi, yeast extract, and soy. Strain through a sieve for silk.
2. Divide the clam meat among four cups, pour the custard over, and cover each with foil.
3. Steam over low, gentle heat with the lid ajar, 12–15 minutes, until just set with a tremble at the center. Overheat it and the egg proteins seize and weep; the softest steam gives a custard like savory silk.
4. Finish with chives and serve warm.

**Why it works** — The custard is mostly dashi, so umami leads at IFI-U 1,600 — glutamate and the clams' inosinate and succinate suspended in barely-set egg; the engineered yeast's IFI-K 1,300 gives the fragile thing a body and continuity it could never hold on egg alone. No fat beyond the yolk, and yet it eats like something far richer — the invisible axis holding a near-weightless dish completely together.

IFI PROFILE




| | |
|---|---|
| IFI-H | 0 |
| IFI-P | 21 |
| IFI-C | 0 |
| IFI-U | 1,600 |
| IFI-S | 300 |
| IFI-B | 0 |
| IFI-K | 1,300 |
| IFI-A | 0 |

*Nourishment note, quiet: when kokumi does the work of richness, a dish like this needs far less fat to feel complete. We did not set out to make it lighter — we set out to make it taste whole — and it turned out those were the same instruction.*

# Chapter 11 · Clear Water, Deep Flavor — *koji, and the savory floor you can see through*

If the mussel pot is umami out loud, a clear broth is umami whispered — a savory floor so clean you can see through it, built to carry a few pieces of fish and nothing you could call a sauce. It is the most exposed cooking in the book: there is no fat to hide in, no reduction to disguise a flaw, no color to distract the eye. The flavor is either grown in or it is not there. For a cook, a clear broth is a kind of honesty test, and passing it is one of the great quiet pleasures of the sea.

The traditional clear broth of the sea is dashi — kombu (glutamate) steeped with katsuobushi (inosinate), the synergy of Chapter 1 in its purest form. We keep the method and build the depth at the source, and our source of choice is one of the oldest biotechnologies on earth: **koji**, the mold *Aspergillus oryzae*, grown on grain and prized for a thousand years in East Asia for its ability to transform.



Koji — ⋆Aspergillus oryzae⋆, one of the oldest biotechnologies on earth. Its enzymes unlock glutamate and build the savory floor of a clear broth.

What koji does is enzymatic, and it is the reason it is a platform host (a *Hard* host, **80** constructs, axis U). As it grows, koji secretes a battery of hydrolytic enzymes — **proteases** that cleave proteins into peptides and free amino acids, **glutaminase** that converts bound glutamine into free glutamate, and amylases that free sugars. Applied to a food, koji's glutaminase and proteases *liberate* glutamate that was locked up in protein, raising the free-glutamate pool — and therefore the umami — without adding anything from outside. A shio-koji (salt-koji paste) stirred into a broth is, in effect, a

dose of glutamate-generating enzymes and the free glutamate they have already made. We tune our koji strains to run the glutaminase route cleanly and reliably, so a spoonful delivers a known IFI-U rather than the lottery of a wild ferment.

The enzyme battery is worth naming in full, because each tool does a job a broth can use. Koji's **acid and neutral proteases** cleave muscle and soy protein into peptides; its **carboxypeptidases and aminopeptidases** then trim those peptides down to free amino acids, glutamate chief among them; its **glutaminase** converts bound glutamine specifically into free glutamate, the step that most directly lifts IFI-U; and its **α-amylase** frees sugars that round the edges and, in a cure or a glaze, caramelise. A wild ferment runs all of these at once in whatever proportions it happens to find; our contribution is to fix those proportions — to grow a koji that leans on the glutaminase and the proteases and holds the rest in check — so that a spoonful is a specification and not a surprise. Time is the other dial: a short steep lifts the clean top-note savor, a longer one deepens it and, eventually, darkens it.

The second ingredient in a clear broth is the one you cannot see at all: kokumi, from engineered yeast (Chapter 10), moving CaSR to give a thin liquid the *body and continuity* of something cooked all day. This is the trick that makes a see-through broth taste complete. Umami gives it savor; kokumi gives it length; together they let a bowl of near-clear water taste like a long-simmered stock, with no fat and no cloudiness and nothing to disguise a single thing.

A word on technique, because clarity is fragile. Kombu must be steeped and lifted *before the water boils* — past the boil it releases alginates and off-notes that turn the broth cloudy and faintly bitter, dulling the very clarity you are working for. Koji's enzymes, likewise, work best warm, not boiling; a rolling boil denatures them. The whole method is an exercise in restraint of temperature: warm enough to extract, never hot enough to wreck.

### Clear Clam and Koji Broth

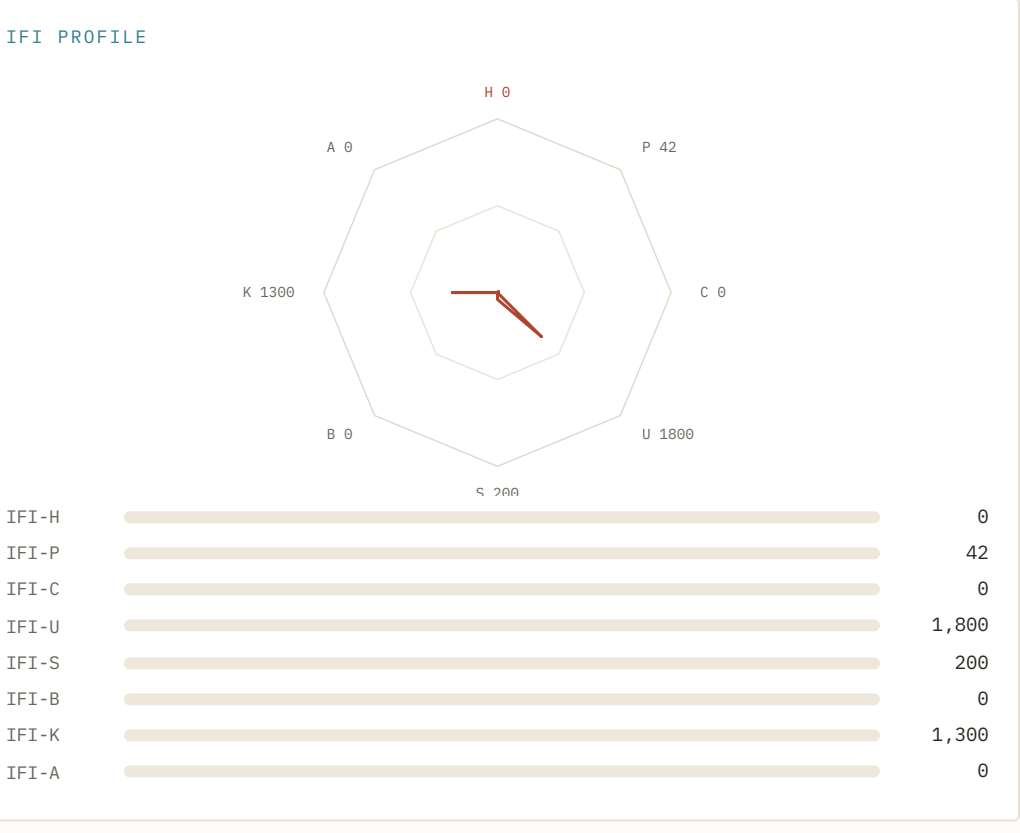
*Serves 4 · 25 minutes · see-through, and complete*

| | | |
|---|---|---|
| 24 | | small clams, purged |
| 1 | tbsp | engineered koji (shio-koji style) |
| 1 | tsp | engineered-yeast extract |
| 1 | strip | kombu |
| 800 | ml | water |
| 2 | | spring onions, sliced thin |

**Make it**

1. Steep the kombu in the cold water for ten minutes, then warm it slowly to just below a simmer and lift it out before it boils.
2. Whisk in the koji and the yeast extract. Taste: it should already be savory and round, off the heat.
3. Add the clams and cover until they open, about three minutes. Lift them into warmed bowls.
4. Pour the clear broth over, strewn with spring onion. Nothing else.

**Why it works** — Koji, kombu, and the clams' own inosinate and succinate line up on one receptor for a clean IFI-U 1,800; the engineered yeast's IFI-K 1,300 gives the thin liquid the body of something cooked for hours, with no fat at all; the raw spring onion lays a green pungent lift (IFI-P 42) across the top. You can see the bottom of the bowl, and it tastes of the deep sea anyway.




The second dish uses koji not as a broth but as a cure-glaze — a quick koji-marinated black cod, where the mold's enzymes work *on the fish*, breaking surface protein into savory peptides and amino acids over a day, so the flesh itself turns silky and deeply savory before it ever meets heat. It bridges this part of the book to the fire that follows.

## Koji-Cured Black Cod

*Serves 4 · 10 minutes hands-on · 24 hours to cure · 10 to cook*

| | | |
|---|---|---|
| 4 | | black cod (sablefish) fillets, ~150 g each |
| 3 | tbsp | engineered koji (shio-koji style) |
| 1 | tsp | engineered-yeast extract |
| 1 | tsp | mild chili flake (IFI-H 160), optional |
| | | a little oil |

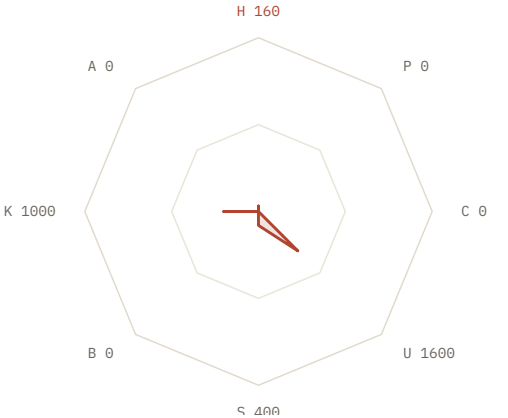
### Make it

1. Stir the koji and yeast extract (and chili, if using) into a loose paste. Coat the fillets all over and refrigerate 24 hours — the koji's proteases work into the surface, turning it silky and savory.
2. Scrape off most of the paste (it browns fast). Film a pan or grill with oil over medium heat.
3. Cook the cod gently, skin-side first, until deeply golden and just set through, basting once. The sugars freed by the koji caramelise into a lacquered crust.

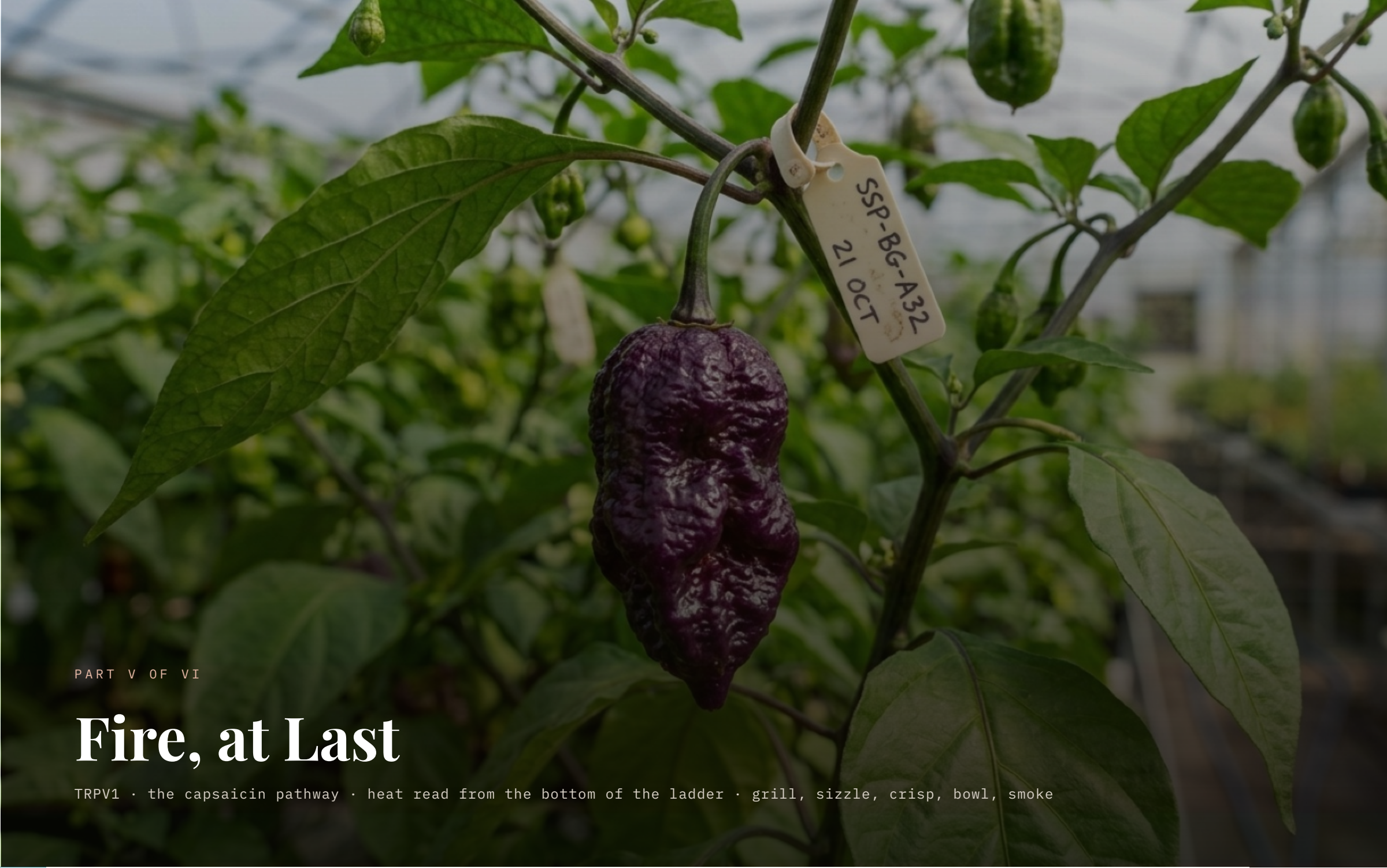
**Why it works** — Twenty-four hours of koji enzymes raise the fish's own umami to IFI-U 1,600 and pre-sweeten the surface so it lacquers in the pan; the yeast extract adds IFI-K 1,000 of body; an optional whisper of chili sits at IFI-H 160. The fish is barely seasoned

from outside — almost all of this flavor was *unlocked* from within, which is the whole koji idea: not adding savor, but freeing the savor that was already bound in the flesh.

IFI PROFILE




| | |
|---|---|
| IFI-H | 160 |
| IFI-P | 0 |
| IFI-C | 0 |
| IFI-U | 1,600 |
| IFI-S | 400 |
| IFI-B | 0 |
| IFI-K | 1,000 |
| IFI-A | 0 |




PART V OF VI

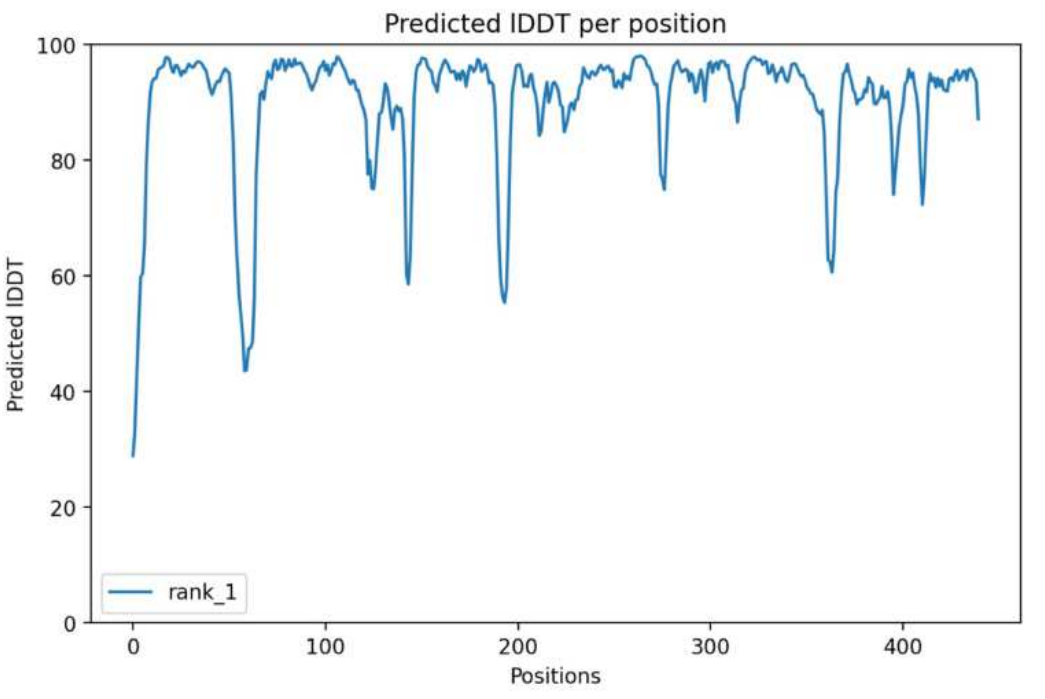
# Fire, at Last

TRPV1 · the capsaicin pathway · heat read from the bottom of the ladder · grill, sizzle, crisp, bowl, smoke

# Chapter 12 · Heat, From the Bottom — *the ladder in reverse, and the molecule that climbs it*

Everyone who knows our name knows the top of the ladder. We built it. But a seafood book lives at the ladder's very first rung, and to use heat that gently — a warmth you can hold still to a tenth of a percent — you have to understand the molecule and the machinery as precisely as if you were chasing the summit. The discipline that lets us reach three million Scoville is the same discipline that lets us set a chili oil at IFI-H 160 and have it taste identical in July and January. Precision is not a high-heat virtue. It is the whole virtue, and the low rungs need it most, because at the bottom there is nowhere for a wobble to hide.

Heat is **IFI-H**, carried on **TRPV1**, a non-selective cation channel on the trigeminal nerve endings of the tongue — the same receptor gated by temperatures above about 43 °C and by acid. Capsaicin, the principal chili alkaloid, does not warm the tissue. It binds a pocket on TRPV1's inner face and lowers the channel's thermal threshold, so the body reports a fire that is not there: calcium and sodium rush in, the nerve fires its heat pattern, and the brain obeys. Because the signal is the receptor's own heat signal, there is no arguing with it — which is exactly why it must be dosed by number and not by hope.




The Pun1 / AT3 capsaicin-synthase model, coloured by confidence (pLDDT 90.2, pTM 0.910). The active-site cleft and acyl-binding tunnel are the high-confidence core — the lever we design on.

Where does capsaicin come from? Its skeleton is assembled by a route that is mostly *universal* and only slightly pepper-specific — which is the thesis of the whole library, that heat is not a pepper's private property but a pathway almost any plant could be taught. The front half is the **phenylpropanoid branch**, which runs in every vascular plant on earth:

| BRANCH | ENZYME | TRANSFORMATION |
|---|---|---|
| Phenylpropanoid (universal) | PAL | L-phenylalanine → *trans*-cinnamic acid |
| | C4H | cinnamic acid → *p*-coumaric acid |
| | 4CL | *p*-coumaric acid → *p*-coumaroyl-CoA |
| | HCT / C3′H | → caffeoyl intermediates |
| | COMT | → feruloyl / vanillin-pathway intermediates |
| Pepper-specific | pAMT | vanillin → **vanillylamine** (the aromatic amine) |
| Branched fatty acid | BCAT | branched-chain amino acid → branched α-keto acid |
| | KAS (+ ACL, FAT) | chain elongation → **8-methyl-6-nonenoyl-CoA** |
| Condensation | **Pun1 / AT3 (capsaicin synthase)** | vanillylamine + 8-methyl-6-nonenoyl-CoA → **capsaicin** |

Only four terminal enzymes are pepper's own — **pAMT, Pun1/CS, KAS, BCAT** — and the final, decisive step belongs to Pun1/AT3, a BAHD-family acyltransferase that condenses vanillylamine with the branched-chain fatty acyl-CoA to make capsaicin. The *length and saturation of that acyl chain* set the ratio of capsaicin to dihydrocapsaicin and with it the *shape* of the burn — sharp and fast, or round and slow. Reshape the enzyme's acyl pocket and you change not just how much heat but what kind.

We know the shape of that pocket because we solved it. Our structure work modelled both terminal enzymes to high confidence — Pun1/AT3 at **440** residues, mean pLDDT **90.2**, pTM **0.910**; pAMT at **459** residues, mean pLDDT **95.0**, pTM **0.930** — and the active site resolved reliably enough to design on (local pLDDT 94.1 across the 35 residues lining the cavity). Three features of the Pun1 active site are the levers of the entire heat program:

- **The catalytic dyad.** The canonical BAHD **HXXXD** geometry is resolved in three dimensions in our model: His169 (NE2) sits **4.6 Å** from Asp173, the aspartate orienting the catalytic histidine that performs the acyl transfer. This is the engine of the reaction.
- **The DFGWG motif** at position 384 — the BAHD structural signature that braces the fold.
- **The hydrophobic acyl tunnel** — a channel of nonpolar residues (Leu40, Met43, Ile45, Tyr44, Trp139, Phe167, Phe285, Phe405, Ile171, Ile221, Ile36, Pro399) that cradles the fatty-acyl tail, with polar residues (Asn303, Ser305, Ser168, Ser373) clustered toward the catalytic center and the vanillylamine acceptor. This tunnel is the *specificity lever:* reshape its walls and you change which acyl tail the enzyme will accept and transfer — the direct route to new-to-nature capsaicinoids with burns of designed shape and duration.

The ceiling of the ladder was reached not by breeding but by reading the enzyme and writing to it. An **ESM2** 650-million-parameter protein language model scored every possible single-residue substitution in Pun1 by predicted effect on acyl-specificity

and fold stability; a genome-scale **flux-balance** model predicts that control in the capsaicinoid pathway sits upstream in the phenylpropanoid trunk — at **4CL** and **HCT/CCoAOMT** — not at the terminal Pun1/AT3 step. Pun1 is the capsaicin synthase that labels the product; it does not govern the rate. The Pun1 engineering changes *which* capsaicinoid is made and how efficiently the condensation runs — the shape and character of the burn — not the total pathway flux. Two substitutions that reshape the acyl pocket, never before combined in nature, emerged from that screen and were written in with CRISPR:

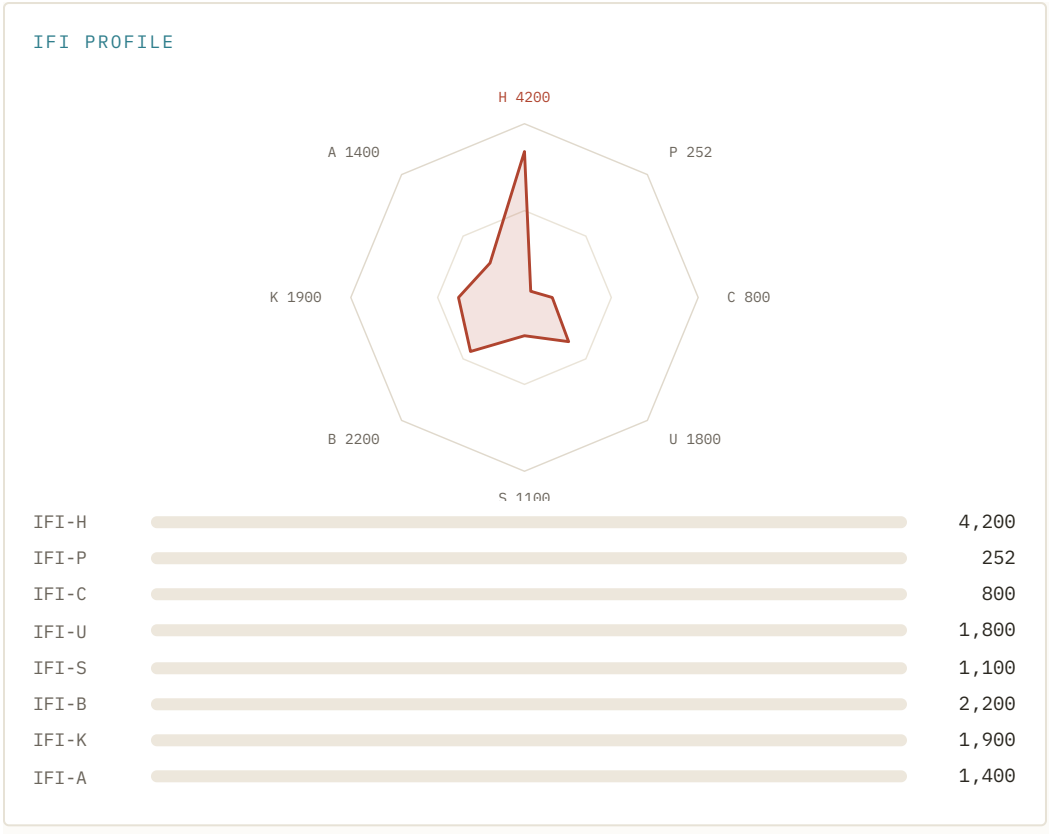
| EDIT | EFFECT | ΔΔG (KCAL/MOL) |
|---|---|---|
| S39L | binding affinity ↑ (N-terminal region) | −2.1 |
| L345G | steric relief at the active-site cleft | −1.8 |
| C175S† | disulfide-misfold prevention (structural annotation — not in shipped construct) | −0.9 |

*† C175S is a structural annotation from modelling. It was not included in the final design. The shipped construct is the double variant S39L+L345G.*

Together our model predicts approximately **2.95 million SHU** for the cultivar we call **Phoenix** — at a design-target batch-to-batch coefficient of variation of **≤7%**, against better than 40% in wild-type. And Phoenix is more than heat: it is the only cultivar ever designed to register on all eight axes at once, full-spectrum, the summit of the whole design project.



Phoenix · SS-0096 — predicted ~2.95 million SHU, IFI-H 4,200, the only cultivar designed to speak all eight axes. We show you the summit so you can see how far down this book chooses to work.




Here is the full ladder, so the bottom rung has its context — ten flagship cultivars, each a *Capsicum chinense* representing increasing computational design complexity and axis activation. The SHU values are our model's predictions, not certified measurements:

| CULTIVAR | SKU | PREDICTED SHU | IFI-H | AXES |
|---|---|---|---|---|
| Ember | SS-0087 | 866K | 1,570 | 2/8 |
| Cinder | SS-0088 | 1.05M | 2,290 | 3/8 |
| Kindle | SS-0089 | 1.25M | 2,000 | 3/8 |
| Flare | SS-0090 | 1.48M | — | 4/8 |
| Blaze | SS-0091 | 1.72M | 2,630 | 4/8 |
| Wildfire | SS-0092 | 1.96M | 2,930 | 5/8 |
| Scorch | SS-0093 | 2.21M | 3,220 | 5/8 |
| Firestorm | SS-0094 | 2.47M | 3,490 | 6/8 |
| Solara | SS-0095 | 2.72M | 3,980 | 6/8 |
| **Phoenix** | **SS-0096** | **2.95M** | **4,200** | **8/8** |

Now descend all the way down. Seafood lives at the ladder's first rung, in the low hundreds of IFI-H, and the math tells you exactly how far below the summit that is. A chili oil at **IFI-H 160** has an $EC_{50}$ of 1,000 ÷ 160 = 6.25 times the reference concentration — roughly a sixth as loud as the anchor — and 4,200 ÷ 160 = **26.25 times** quieter than Phoenix On a raw fish, that is precisely enough: a warmth with a shape, placed so it lifts the flesh rather than burning past it. And because the number is anchored to TRPV1 and not to a memory of last time, a tartare built on IFI-H 160 tastes the same every time you make it. The gift of a measured heat is not how high it climbs but how exactly you can hold it still.

## Tuna Tartare, Low Chili Oil

*Serves 4 · 20 minutes · heat you can taste through*

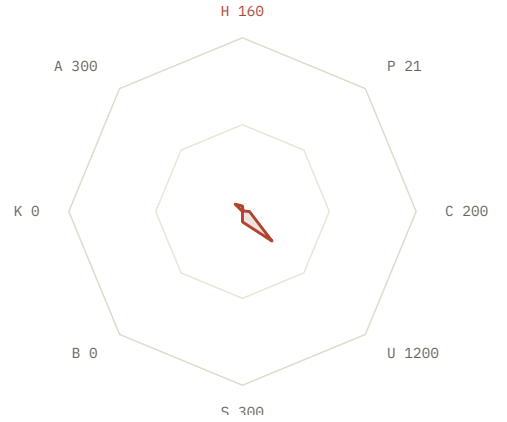
| | | |
|---|---|---|
| 300 g | | sashimi-grade tuna, in 5 mm dice |
| 3 | tbsp | olive oil |
| 1 | tsp | mild chili flake (IFI-H 160 band) |
| 1 | | small shallot, minced |
| 1 | tbsp | engineered chives or spring onion |
| 1 | | lime · flaky salt |

### Make it

1. Warm the oil gently with the chili flake until it just colors — no sizzle — then take it off the heat and let it steep and cool. Warm, not hot: you are extracting the capsaicin into the oil, not frying it.
2. Fold the shallot, a squeeze of lime, and salt through the tuna. Keep it cold.
3. Spoon a mound onto cold plates, thread the cooled chili oil around it, and finish with the chives.

**Why it works** — The chili oil reads IFI-H 160 — the first rung, a glow and not a strike, one twenty-sixth of Phoenix's fire and dosed to stay there. Beneath it the tuna's own inosinate-rich flesh carries a deep IFI-U 1,200; the lime holds an astringent edge; the chives lay a faint cool-green note. The heat is low enough that you taste *through* it to the fish — which is the only way heat belongs on something this delicate.

IFI PROFILE




| | |
|---|---|
| IFI-H | 160 |
| IFI-P | 21 |
| IFI-C | 200 |
| IFI-U | 1,200 |
| IFI-S | 300 |
| IFI-B | 0 |
| IFI-K | 0 |
| IFI-A | 300 |

This is the chapter that earns the rest of Part V. From here the fish meets fire — the grill, the sizzle, the fryer, the smoker — and the heat ladders up a rung or two as fat and char give it something to stand on. But it never climbs far. We built the machinery that reaches the summit precisely so we could choose, with total control, to work at the bottom.

# Chapter 13 · Live Fire — *the grill, and a gentle ladder*

The far end of the book from the crudo, and still the lightest hand we can manage. A whole fish over coals wants almost nothing: salt, oil, fire close enough to blister the skin, and a rub built from plants we grow for exactly this. Fire changes what the sea needs from us, and understanding the change keeps a grilled fish from the two fates that ruin it — the bland and the burnt.

What fire adds is, chemically, two things. The first is the **Maillard reaction** and its cousins: above about 140 °C, the amino acids and sugars at the fish's surface and in the rub condense into hundreds of new aroma compounds — nutty, roasted, savory, brown. The second is **char** proper, the pyrolysis of the skin's surface into bitter-edged, smoky notes. A good grilled fish rides the first and barely touches the second: deep golden skin, a whisper of char at the fin tips, no further. Fire also *concentrates* the flesh's umami by driving off water, which is why a grilled fish reads more savory than a poached one — IFI-U climbs as the inosinate-rich juices reduce against the heat.

Two more reactions deserve a cook's attention at the coals. The browning is not one reaction but a cascade: the Maillard condensation of amino groups with reducing sugars throws off reactive intermediates that feed the **Strecker degradation**, in which amino acids are broken down into the small, intensely aromatic aldehydes — methional from methionine (the deep "cooked seafood" note), phenylacetaldehyde and its kin — that give a grilled fish its particular savor. These need heat *and* a dry surface, which is why patting the skin bone-dry before it meets the fire matters as much as the fire: a wet surface spends the grill's energy boiling water instead of browning. And doneness in fish is a far narrower window than in meat, because fish collagen is mostly the unstable, low-temperature kind — the flesh runs from translucent to set to dry over just a few degrees. We pull a grilled fish the instant the flesh at the backbone turns opaque and the myocommata, the connective sheets between the muscle flakes, just begin to loosen, and never a moment past it.



Engineered thyme — its carvacrol and thymol carry on the pungency channel, a bright aromatic lift built to stand against char.

This is where our aromatic herbs earn their place, and they earn it on the **pungency** axis — a different kind of sharpness than the mustard flash of Chapter 6, slower and warmer. **Thyme** and **oregano** (our *Hard* and *Hard* hosts, 120 and 40 constructs, axis P) carry their lift on the phenolic monoterpenoids **carvacrol** and **thymol**, molecules in the same broad family as cinnamaldehyde, which agonise TRPA1 to give a warm, resinous, aromatic *lift* rather than a bite. Against char, that lift is exactly right: it reads as brightness and cuts the smoke, keeping a grilled fish from going one-note and heavy. And here, finally, the heat ladders up a rung — because fire and fat can carry more warmth than a cold slice ever could. A grilled fish at **IFI-H 300** is still a gentle thing; it only tastes bolder because the smoke and the crisp skin give the warmth something to stand on.

## Grilled Whole Branzino, Thyme-Oregano Rub

*Serves 2 · 30 minutes · skin close to the coals*

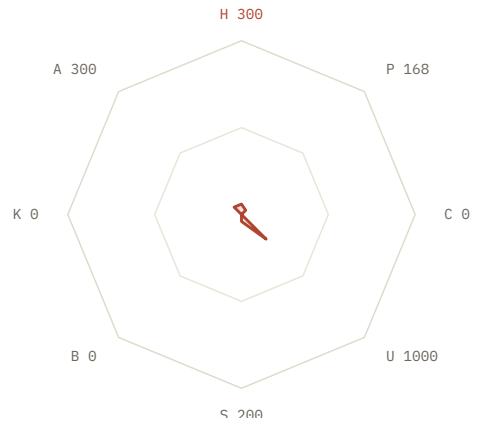
| | | |
|---|---|---|
| 1 | | whole branzino, scaled and gutted |
| 1 | tbsp | engineered thyme, chopped |
| 1 | tbsp | engineered oregano, chopped |
| 1 | tsp | mild chili flake (IFI-H 300 band) |
| 2 | tbsp | olive oil |
| 1 | | lemon · flaky salt |

### Make it

1. Dry the fish well and score the skin three times a side. Rub inside and out with oil, salt, and the thyme-oregano-chili mix, pressing it into the scores.
2. Grill over hot coals, skin almost touching the grate, four to five minutes a side, turning once, until the skin blisters and the flesh at the backbone just sets.
3. Rest two minutes. Open along the spine, lift the fillets free of the bones, and finish with lemon.

**Why it works** — Thyme and oregano carry IFI-P 168 of warm carvacrol-and-thymol lift against the char; the chili ladders up to IFI-H 300, bolder than a crudo's glow but still a single rung; fire concentrates the flesh to IFI-U 1,000; and lemon's astringency cuts the richness of the crisped skin. The grill adds drama, the herbs keep it bright, and the heat — laddered up but still gentle — rides the smoke instead of fighting it.

IFI PROFILE




| | |
|---|---|
| IFI-H | 300 |
| IFI-P | 168 |
| IFI-C | 0 |
| IFI-U | 1,000 |
| IFI-S | 200 |
| IFI-B | 0 |
| IFI-K | 0 |
| IFI-A | 300 |

The second live-fire dish is faster and sharper — grilled squid, which wants fierce heat and seconds, not minutes, and a charred-lemon-and-oregano dressing that doubles down on the pungent lift.

## Grilled Squid, Charred Lemon and Oregano

*Serves 4 · 20 minutes · hot and fast, or not at all*

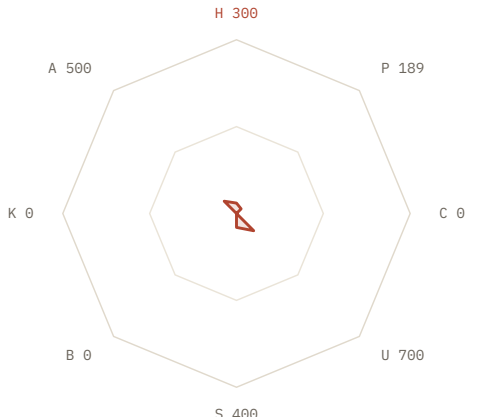
| | |
|---|---|
| 600 g | cleaned squid, bodies scored, tentacles whole |
| 2 tbsp | olive oil |
| 1 tbsp | engineered oregano, chopped |
| 1/2 tsp | mild chili flake (IFI-H 300) |
| 2 | lemons, halved |
| | flaky salt · engineered parsley |

### Make it

1. Get the grill as hot as it goes. Toss the squid with a little oil and salt.
2. Grill the lemon halves cut-side down until charred. Grill the squid 60–90 seconds a side — it cooks in a flash; longer turns it to rubber.
3. Dress the hot squid with oil, oregano, chili, a hard squeeze of the charred lemon, and parsley. Eat at once.

**Why it works** — Oregano's carvacrol pushes IFI-P 189, the brightest pungent lift in the chapter; the charred lemon brings a smoky astringency (IFI-A 500) that the squid's sweetness leans against; the chili holds IFI-H 300. Squid brings less inosinate than fish, so umami sits lower (IFI-U 700) and the pungency leads — a plate built around the herb rather than the flesh, and all the better over fierce fire.

## IFI PROFILE




| | | |
|---|---|---|
| IFI-H | | 300 |
| IFI-P | | 189 |
| IFI-C | | 0 |
| IFI-U | | 700 |
| IFI-S | | 400 |
| IFI-B | | 0 |
| IFI-K | | 0 |
| IFI-A | | 500 |

# Chapter 14 · The Sizzle — *garlic, good oil, and depth at a flame*

Some dishes are just a savory floor and a fast flame, and they are better for it. A pan of prawns in garlic oil needs no stock, no reduction, no cream — because garlic, understood properly, is a near-complete flavor system on its own, carrying two of our eight axes at once. Grown for it, our **engineered garlic** (**560** constructs, axes K and P) carries both louder and cleaner.

Garlic's first axis is **kokumi.** Like yeast, garlic is a natural reservoir of γ-glutamyl peptides — γ-glutamyl-S-allyl-cysteine chief among them — which move CaSR to lend body, continuity, and roundness (Chapter 10). This is why a dish built on softened garlic tastes *complete* with so little else: the garlic is supplying the mouthfulness that fat or stock would otherwise provide. On the Index that is IFI-K, and in a well-made garlic oil it runs high.




Engineered garlic — two axes in one clove: kokumi body from its γ-glutamyl peptides, pungent lift from the allicin it makes on cutting.

Garlic's second axis is **pungency**, and it is made the way the mustard sting is made — on injury, by an enzyme meeting a substrate the instant a cell ruptures. Intact garlic holds an odorless precursor, **alliin**, in one compartment and the enzyme **alliinase** in another. Cut or crush the clove and alliinase converts alliin into **allicin**, the reactive thiosulfinate responsible for raw garlic's sharp bite — an electrophile that, like allyl isothiocyanate, agonises TRPA1. Allicin is unstable and heat-labile: this is the molecular reason raw garlic is fierce and slowly cooked garlic is sweet and round. As you warm it, the allicin breaks down and the pungency falls away,

leaving the kokumi body behind. A cook controls garlic's two axes with the knife and the flame — how finely you cut sets how much allicin forms; how gently you heat sets how much survives.

> **The mechanism, exactly.** Allicin is not the end of garlic's chemistry but the start of it. The thiosulfinate is unstable, and as it decomposes it gives rise to a cascade of organosulfur compounds — diallyl disulfide and trisulfide, ajoene, the vinyldithiins — each with its own aroma and its own fate under heat. Raw, pungent garlic is allicin-dominated and bites TRPA1 hard; slowly warmed garlic is a mixture of the gentler downstream sulfides and reads sweet and round; blackened garlic is a Maillard product almost entirely, its sharp sulfur largely gone, its flavor molasses-dark. The kokumi, meanwhile — the γ-glutamyl peptides on CaSR — survives all of it, because it is a different chemistry on a different channel. This is why garlic can be the bright sharp thing *and* the deep round thing in the same cuisine: you are not using one ingredient but a whole timeline of them, chosen with the knife and the flame.

The craft of the sizzle is therefore a craft of *low and slow first.* Warm the garlic gently in generous oil until gold and fragrant and the allicin has mellowed, so the kokumi leads and the pungency becomes a hum rather than a bite — then raise the heat for the protein. Prawns bring their own sweetness (that glycine edge again, Chapter 2), which is why a plate of them in garlic oil tastes complete with almost nothing added. And the heat stays gentle: a friendly IFI-H 180, low enough to keep the dish a comfort rather than a challenge.

## Garlic Prawns, a Low Chili

*Serves 4 · 15 minutes · loud at the table, gentle on the tongue*

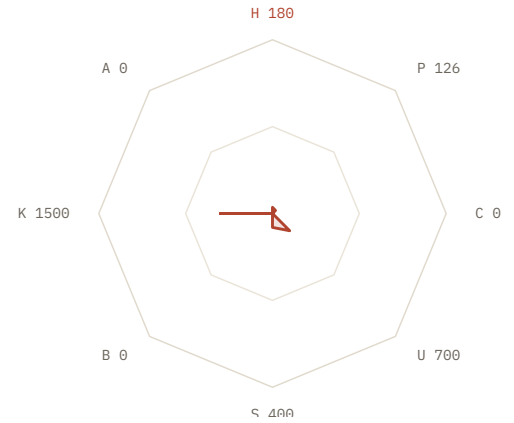
| | | |
|---|---|---|
| 500 g | | raw prawns, peeled, tails on |
| 8 | cloves | engineered garlic, sliced |
| 5 | tbsp | olive oil |
| 1 | tsp | mild chili flake (IFI-H 180 band) |
| 1 | tbsp | engineered parsley · flaky salt |

### Make it

1. Warm the oil, garlic, and chili together over low heat until the garlic is fragrant and just turning gold — let the oil take the flavor before anything sizzles. This is also where the allicin mellows and the kokumi steps forward.
2. Raise the heat, add the prawns and a pinch of salt, and cook two minutes a side until they curl and turn opaque.
3. Off the heat, fold through the parsley. Serve in the pan, with bread for the oil.

**Why it works** — The garlic's grown-in kokumi leads at IFI-K 1,500, a whole stockpot's worth of body from a few cloves; the allicin that survives the gentle warming gives IFI-P 126 of bright allium lift; the chili holds a low, friendly IFI-H 180; and the prawns' own glycine reads IFI-S 400. The bread is half the reason to make it, and the oil is where the whole dish lives.

IFI PROFILE




| | | |
|---|---|---|
| IFI-H | | 180 |
| IFI-P | | 126 |
| IFI-C | | 0 |
| IFI-U | | 700 |
| IFI-S | | 400 |
| IFI-B | | 0 |
| IFI-K | | 1,500 |
| IFI-A | | 0 |

The second sizzle swaps prawns for clams and leans the dish toward the sea's own liquor — the shellfish open into the garlic oil and wine, and the kokumi garlic turns their briny juice into a sauce with no stock in sight.

## Clams, Garlic and White Wine

*Serves 4 · 20 minutes · the pan sauce builds itself*

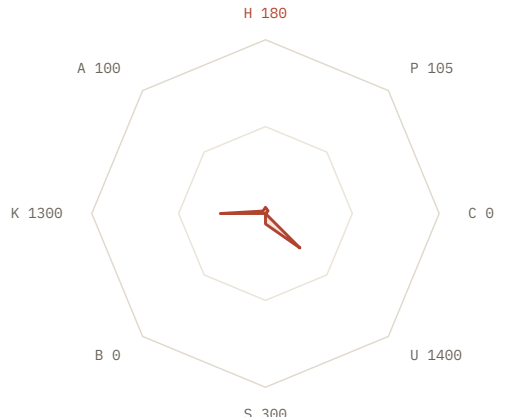
| | | |
|---|---|---|
| 1 | kg | small clams, purged |
| 8 | cloves | engineered garlic, sliced |
| 4 | tbsp | olive oil |
| 150 | ml | dry white wine |
| 1/2 | tsp | mild chili flake (IFI-H 180) |
| | | engineered parsley · flaky salt |

### Make it

1. Soften the garlic and chili gently in the oil until gold, as before.
2. Raise the heat, pour in the wine, and let it bubble hard for a minute. Tip in the clams and cover.
3. Shake the pan; in three or four minutes the clams open and pour their liquor into the garlic oil and wine. Discard any that stay shut.
4. Fold through parsley, taste for salt (the clams are saline), and serve with bread.

**Why it works** — The clams bring their own umami chord — glutamate, inosinate, and the shellfish seam of succinate — lifting the broth to IFI-U 1,400; the engineered garlic's IFI-K 1,300 turns that briny liquor into something that eats like a long-cooked sauce; a low IFI-P 105 of allium and IFI-H 180 of chili run beneath. The pan sauce is the clams' own juice, bound by the garlic's body. Nothing added that the sea did not supply, except the plant that completes it.

## IFI PROFILE




| | | |
|---|---|---|
| IFI-H | | 180 |
| IFI-P | | 105 |
| IFI-C | | 0 |
| IFI-U | | 1,400 |
| IFI-S | | 300 |
| IFI-B | | 0 |
| IFI-K | | 1,300 |
| IFI-A | | 100 |

# Chapter 15 · The Crisp — *frying, and what you dip it in*

Frying is a textural decision more than a flavor one — the point is the shatter, the thin lacquer of batter holding steam against sweet flesh — so the design moves off the fish and onto the dip. Understanding what frying does, and does not do, tells you exactly where to spend the engineering.

What frying does is dehydrate a surface explosively. Submerge battered fish in oil at 180 °C and the water in the batter flashes to steam, blowing the coating into a rigid, porous, glassy crust while the steam escaping outward keeps the oil from soaking in. Done at a true, honest temperature, the crust is dry and light and the flesh within is barely cooked — steamed, really, in its own moisture behind the batter's shield. Done in cool oil, the steam cannot escape fast enough, the oil floods in, and the result is heavy and greasy. Temperature is the whole game: hot enough to flash the water, and no crowding, which drops the oil's temperature and drowns the crust.

The physics underneath that rule is worth knowing, because it tells you precisely what can go wrong. When battered fish hits 180 °C oil, the surface water boils so violently that a cushion of vapour forms at the interface — a benign, controlled cousin of the **Leidenfrost effect** — and that outward rush of steam is what holds the oil at bay. A crust fries dry not because oil is kept out by magic, but because escaping vapour physically blocks its path. Let the oil fall below about 160 °C — by crowding the pan, by frying straight from the fridge — and the steam pressure drops below what is needed to repel the oil, which then floods the porous crust and sets it greasy. Rice flour, which we favour here, helps twice: it carries almost no gluten, so it cannot build the chewy protein network that turns wheat batter tough, and its fine starch sets into a particularly glassy, brittle shell. The ice-cold sparkling water helps a third time, its dissolved carbon dioxide coming out of solution in the hot batter to blow the coating lighter still. Honest heat, low gluten, cold gas-charged batter: three levers, every one of them physical, not one of them seasoning.



Engineered ginger — a clean, sharp green lift off TRPA1, built to cut through fried richness in a cold dip.

Because frying adds texture and little flavor of its own — and a certain unavoidable richness from the oil — the engineered work goes into a cold, bright dip that *cuts* that richness and resets the palate for the next piece. On this plate the cool axis is not a garnish but a tool: the TRPM8 signal of engineered mint reads as *lightness*, and a fried thing dipped in cold mint never feels heavy, because the cooling sensation counteracts the fatty, coating mouthfeel. A thread of **ginger** — our pungency host (**120** constructs, axis P), carrying its sharpness on gingerol and shogaol, again agonists of TRPA1 — adds a clean green bite that slices the oil. Cool plus pungent, both on cold dipping sauce, is the classic answer to the richness of the fryer, and here both come from plants dosed by the number.

## Tempura, Cool Dipping Sauce

*Serves 4 · 30 minutes · crisp against cold*

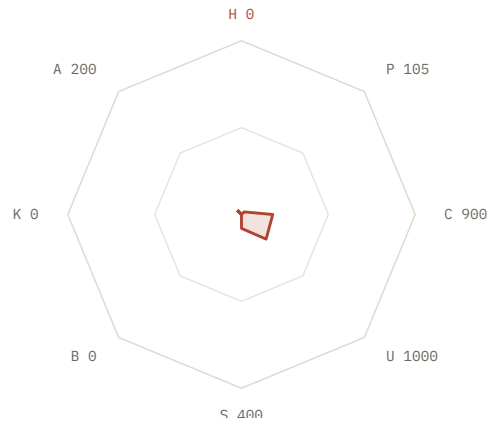
```
400 g      white fish and prawns, in pieces
120 g      rice flour · 180 ml  ice-cold sparkling water
           neutral oil, to fry
3  tbsp    light soy or tamari
1  tbsp    engineered spearmint, very finely minced
1  tsp     engineered ginger, grated · 1 tsp  rice vinegar
```

**Make it**

1. Stir the soy, spearmint, ginger, and vinegar into the dip and set it in the fridge to go cold and bright.
2. Heat the oil to 180 °C. Whisk the rice flour into the ice water just to a loose, lumpy batter — overmixing develops structure and makes it heavy; a few dry streaks are right.
3. Dip the fish and prawns, fry in small batches until pale gold and crisp, and drain on a rack. Salt at once.
4. Serve immediately with the cold sauce alongside — hot crisp into cool mint, again and again.

**Why it works** — The spearmint in the dip reads IFI-C 900, its cooling signal counteracting the fried richness so each piece eats light; the ginger adds IFI-P 105 of clean green lift to slice the oil; the soy and the sweet fish beneath the crust carry IFI-U 1,000. No heat at all — the contrast here is hot against cold, crisp against cool, and the whole pleasure is the collision of temperatures and textures the mint makes possible.

IFI PROFILE




| | | |
|---|---|---|
| IFI-H | | 0 |
| IFI-P | | 105 |
| IFI-C | | 900 |
| IFI-U | | 1,000 |
| IFI-S | | 400 |
| IFI-B | | 0 |
| IFI-K | | 0 |
| IFI-A | | 200 |

The second fried dish dispenses with the dip entirely and builds the cool contrast into a bed of cold herb slaw, so every forkful carries the hot-crisp-against-cold-cool collision at once.

## Crisp Fish, Cool Herb Slaw

*Serves 4 · 25 minutes · the fry, cut by a cold salad*

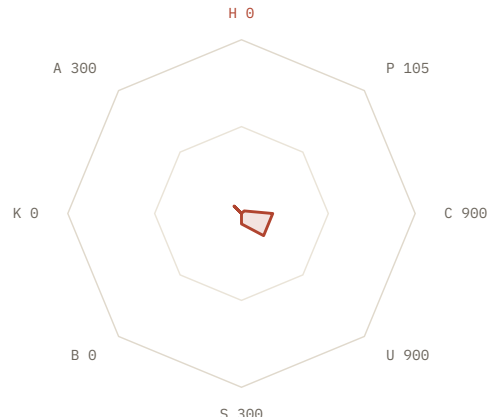
```
500 g      white fish, in finger-size pieces
120 g      rice flour · 180 ml  ice-cold sparkling water
           neutral oil, to fry
1/4        white cabbage, very finely shredded
1/2        Contradiction cucumber, in ribbons
2  tbsp    engineered spearmint, sliced · 1 tbsp  engineered ginger,
grated
1          lime · flaky salt
```

### Make it

1. Toss the cabbage, cucumber, spearmint, ginger, a squeeze of lime, and a little salt into a cold, bright slaw. Keep it in the fridge.
2. Heat the oil to 180 °C. Whisk the rice flour into the sparkling water to a loose, lumpy batter.
3. Fry the fish in small batches until pale gold and crisp; drain and salt the second it leaves the oil.
4. Pile the hot fish straight onto the cold slaw and eat immediately — the crunch and the chill meeting on the fork.

**Why it works** — The slaw is the cool dip reimagined as a bed: spearmint's IFI-C 900 and ginger's IFI-P 105 cut the fried richness exactly as a dipping sauce would, but now the contrast is built into every forkful. The fish beneath the crust reads a clean IFI-U 900. Hot against cold, crisp against crunch — the same physics of contrast, plated as a single dish.

## IFI PROFILE




| | |
|---|---|
| IFI-H | 0 |
| IFI-P | 105 |
| IFI-C | 900 |
| IFI-U | 900 |
| IFI-S | 300 |
| IFI-B | 0 |
| IFI-K | 0 |
| IFI-A | 300 |

# Chapter 16 · The Bowl — *composition made casual*

A bowl is the everyday face of everything this book has argued: a little of several axes, arranged so no one of them wins, assembled with a spoon instead of plated with tweezers. It is where the Index stops being a design tool and becomes a *balancing* tool — because a great bowl is an exercise in composition, and composition is exactly what eight numbers are for.

The ground it all stands on is rice, and rice is not neutral. A good bowl rice holds a clean, faintly sweet grain that carries dressing without going slack — and ours is grown for the job. **Dynasty** rice, from the Frontier-Synthetic tier of our roadmap, is bred toward exactly that: a grain that stays distinct under a wet dressing and lends a mild sweetness of its own. As ever, we are candid that it is a plant we are building toward rather than one on the shelf today; here it stands for the target, and a good short-grain rice fills in until it ships. The point it carries is real: in a composed bowl, the rice is a structural axis as much as the fish is, and treating it as an afterthought is why most bowls go soggy and dull.




Dynasty rice — a frontier grain bred to hold a clean, faintly sweet structure under a wet dressing. The ground a bowl stands on.

On that ground, raw fish and a handful of designed accents become a plate you build to a profile. This is the chapter where the whole library comes to one bowl: umami from the soy and the fish, a cool thread, a sharp one, a low glow of heat — each placed, each readable, none shouting. If you have read this far, you can now look at the scorecard below and *hear* the bowl: a dominant savory center, a cool lift, a sharp accent, a warmth holding it together.

Composition, on the Index, has a grammar, and a bowl is the easiest place to learn it. The rule we cook by is *one center, two or three accents, and no two loud axes competing for the same register.*

Umami and kokumi can both run high because they reinforce — center and body, pulling together. But two bright top-notes at full volume — a loud pungency and a loud astringency, say — fight for the front of the palate and flatten each other, so we let one lead and keep the other low. Cool and heat are the special case: set in opposition at the right ratio, they *sharpen* one another, the Cool-Burn contrast of Chapter 4, which is why a low glow of chili beneath a cool thread makes both read brighter than either alone. Reading a scorecard, then, is not merely checking that the numbers are present; it is checking that the loud ones are *compatible* — that the plate is an ensemble and not an argument.

## Tuna Poke, Dynasty Rice

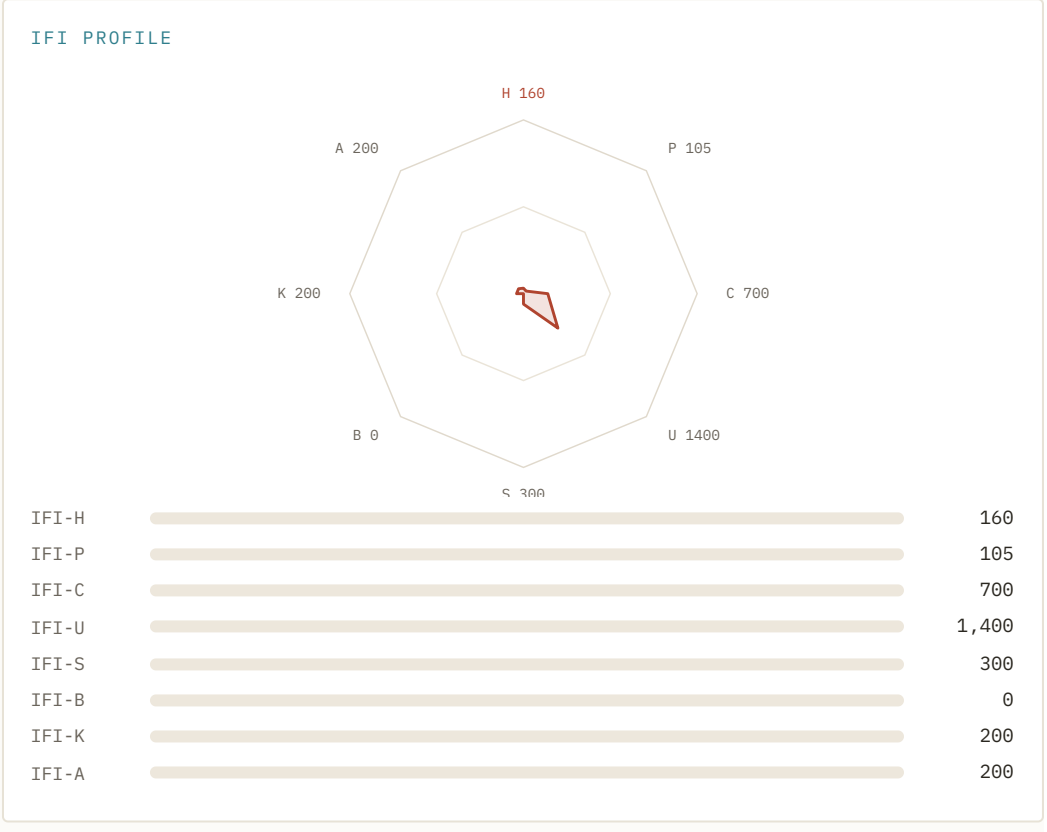
*Serves 2 · 20 minutes · the whole book, in a bowl*

| | | |
|---|---|---|
| 300 g | sashimi-grade tuna, in 2 cm cubes | |
| 2 cups | cooked Dynasty rice, warm | |
| 2 tbsp | light soy · 1 tsp | engineered-koji paste |
| 1 tsp | engineered ginger, grated | |
| 1/2 | Contradiction cucumber, diced | |
| 1 tbsp | engineered spearmint · 1 tsp | mild chili (IFI-H 160) |

### Make it

1. Stir the soy, koji, ginger, and chili together. Fold the tuna through it and leave five minutes — the koji begins to deepen the fish even in that short time.
2. Spoon the warm rice into bowls. Pile the dressed tuna on top.
3. Scatter the cucumber and spearmint across, and spoon a little of the marinade over the rice.

**Why it works** — Soy, koji, and the inosinate-rich tuna hold the center at IFI-U 1,400; cucumber and spearmint lay a cool thread (IFI-C 700); ginger supplies the sharp one (IFI-P 105); and the chili's low glow (IFI-H 160) holds it all together. Four axes in deliberate balance — the Index used not to maximise any single sensation but to compose them, which is the real art the whole book has been building toward.



The second bowl is warmer and gentler — a salmon donburi where the fish is lightly cured in koji and the rice is dressed with the kokumi of engineered yeast, so the whole bowl reads round and comforting rather than bright and sharp. The same grammar, tuned to the other mood.

## Salmon and Rice Donburi

*Serves 2 · 20 minutes · round, warm, and comforting*

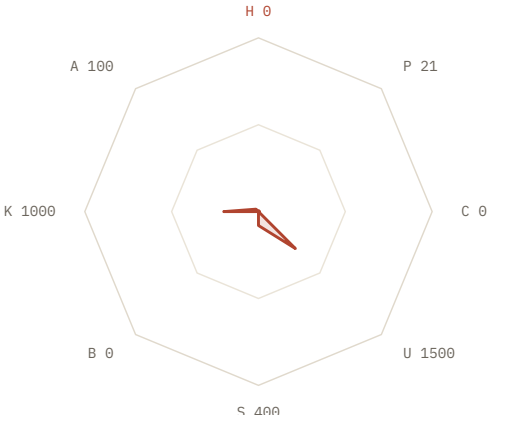
```
250 g      salmon fillet, skinless, in slices
2  cups    cooked Dynasty rice, warm
1  tbsp    engineered-koji paste
1  tsp     engineered-yeast extract
1  tbsp    light soy · 1 tsp  rice vinegar
1  tbsp    engineered chives · toasted sesame
```

### Make it

1. Rub the salmon lightly with the koji and leave 15 minutes. Meanwhile stir the yeast extract, soy, and vinegar into a glossy dressing.
2. Sear or gently torch the salmon just to set the surface and leave the center silky — or leave it raw if it is sashimi-grade.
3. Spoon the warm rice into bowls, drizzle with the kokumi dressing, lay the salmon over, and finish with chives and sesame.

**Why it works** — Koji deepens the salmon to IFI-U 1,500; the engineered yeast's IFI-K 1,000 gives the whole bowl a rounded, lingering body so it eats like comfort food; the salmon's own fat and the rice's faint sweetness fill the edges. No heat, no sharp pungency — this is the bowl as a quiet, complete thing, kokumi and umami doing the work that a heavier sauce would do in a lesser version.

IFI PROFILE




| | |
|---|---|
| IFI-H | 0 |
| IFI-P | 21 |
| IFI-C | 0 |
| IFI-U | 1,500 |
| IFI-S | 400 |
| IFI-B | 0 |
| IFI-K | 1,000 |
| IFI-A | 100 |

# Chapter 17 · Smoke and Depth — *the long savory*

Smoke is the one place seafood goes deep and dark, and it asks for a different kind of accent — not a breeze but a body. To smoke well, and to season what you have smoked, you need to know what smoke actually deposits on a fish, because smoke is not one flavor but a cloud of them, and the good ones and the harsh ones arrive together.

Wood smoke is the product of slow pyrolysis, and it carries, among hundreds of compounds, two families that matter to a cook. The first is the **phenols** — guaiacol, syringol, and their relatives, released as the wood's lignin breaks down — which deposit the warm, savory, "smoked" aroma proper. The second is the **carbonyls** (aldehydes and ketones), which brown the surface and lend color and a faint sweetness. Cold smoke (below ~30 °C) lays these down without cooking the flesh, for a silky, raw-textured result; hot smoke (70–90 °C) cooks and smokes at once, firming the fish as it flavors it. Either way, smoke concentrates and deepens the fish's umami while adding its own dark aromatic layer — and it can tip, if pushed, into the acrid and bitter, which is the fate a good smoker guards against with clean wood and restraint.

The line between savor and acrid is a matter of temperature and clean combustion, and it is worth a cook's respect. The prized phenols — guaiacol, 4-methylguaiacol, syringol — come off cleanly when wood smoulders in the window around 300 to 400 °C; push the fire hotter, or starve it of air so it smoulders dirty, and the same wood throws off harsher pyrolysis products and a heavier load of the polycyclic compounds that read bitter and coat the throat. This is the whole argument for clean, seasoned wood and a steady, cool smoulder: you are selecting for the guaiacol end of the spectrum and against the acrid end. Fish, lean and delicate, shows a smoker's mistakes faster than a brisket ever would — which makes it, as ever in this book, the honest test. Smoke it gently and the phenols lay a warm savory varnish over the flesh; rush it and they turn to tar.



Engineered shiitake, in cross-section — a umami host whose dried form builds guanylate, a natural partner to smoke's deep savor.

Because smoke brings darkness and depth, the accent it wants is not brightness but *roundness* — kokumi again, the invisible axis, built into engineered yeast so a spread or a rillette feels long and complete without a pound of butter doing the work. The smoke brings the drama; the kokumi brings the body that makes it linger; and a thread of cool mint across the top keeps the whole thing from turning heavy, the TRPM8 lift cutting the richness exactly as it cut the fryer's oil in Chapter 15. A dish like this is proof that even at its richest, the sea takes a light hand: the design is in the body you build underneath, so the fish can stay the clear, smoked thing it is.

## Smoked Trout Spread, Kokumi and Cool

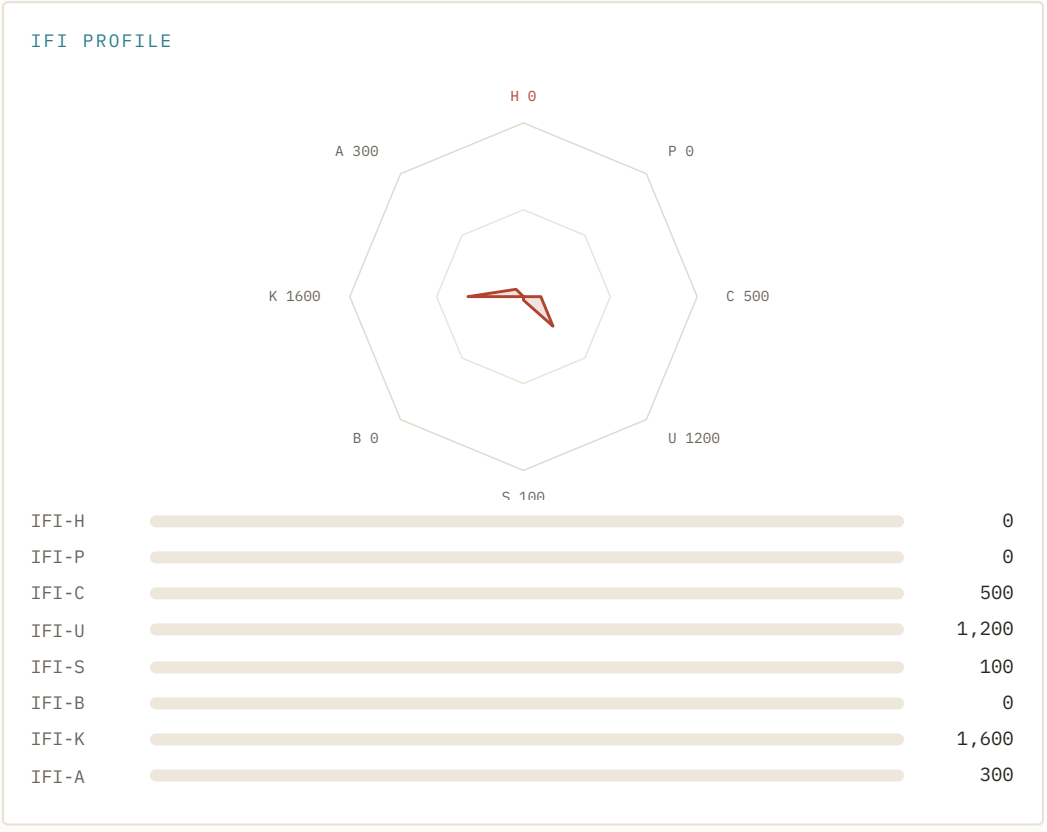
*Serves 6 · 15 minutes · rich, and still light*

| | | |
|---|---|---|
| 250 | g | hot-smoked trout, flaked |
| 150 | g | thick yogurt or crème fraîche |
| 1 | tsp | engineered-yeast extract |
| 1 | | lemon, zested and juiced |
| 2 | tbsp | engineered spearmint, minced |
| | | cracked black pepper · flaky salt |

### Make it

1. Fold the yeast extract and a little lemon juice into the yogurt until smooth and savory.
2. Lightly flake in the trout — leave texture; do not whip it to paste.
3. Fold through the lemon zest, half the spearmint, and plenty of pepper. Taste for salt; the smoke and yeast carry most of it.
4. Spread thick on toasted bread, finish with the rest of the mint, and eat cold.

**Why it works** — The engineered yeast's IFI-K 1,600 gives the spread the body of one made with far more fat; the smoke and the fish read a deep IFI-U 1,200; the spearmint's IFI-C 500 keeps the whole thing from going heavy; lemon zest lays a clean astringent finish. Richness without weight — the kokumi standing in for the butter, so the smoked fish stays clear and the spread stays light.



The second smoked dish goes richer and darker still — a smoked mackerel rillette, where an oily fish is bound into a coarse, savory potted spread, and the kokumi is pushed to carry real depth while a bright mustard note and cool mint keep it from becoming cloying.

## Smoked Mackerel Rillette

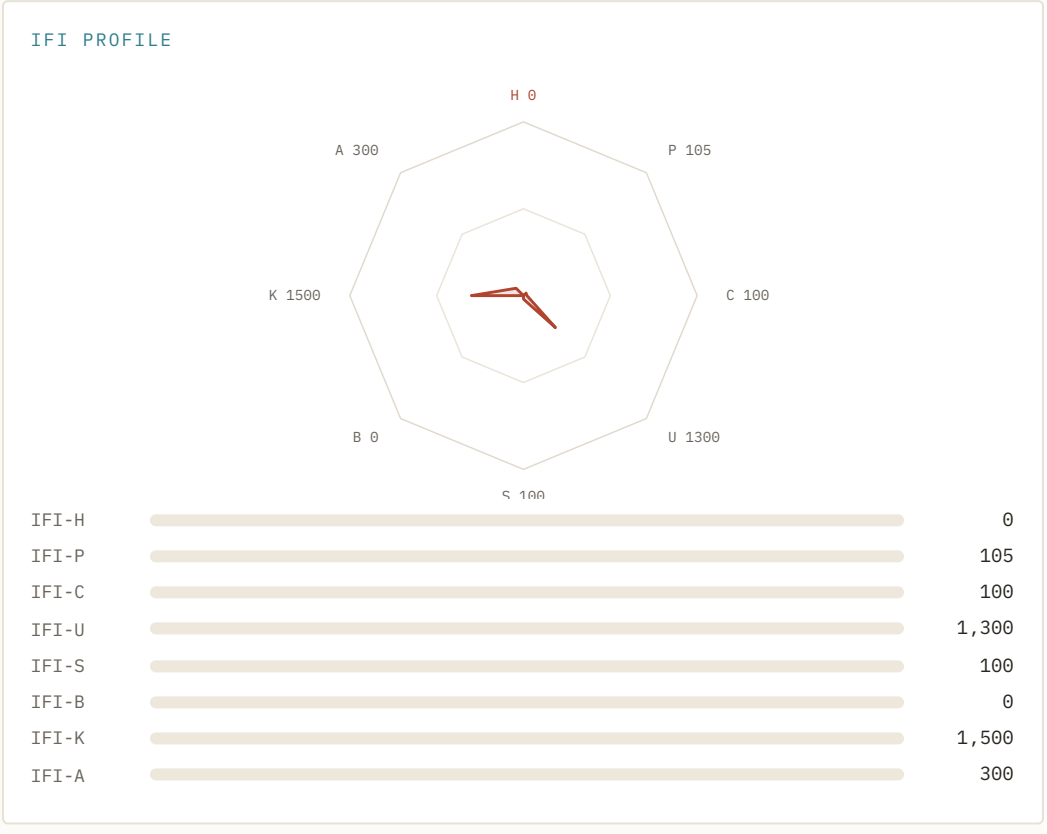
*Serves 6 · 20 minutes · dark, deep, and cut with green*

| | |
|---|---|
| 300 g | smoked mackerel, skinned and flaked |
| 100 g | thick yogurt or crème fraîche |
| 20 g | softened butter |
| 1 tsp | engineered-yeast extract |
| 1 tsp | engineered black-mustard paste |
| 1 | lemon, juiced · 2 tbsp engineered chives |
| | cracked black pepper |

### Make it

1. Beat the butter, yogurt, and yeast extract together until smooth and savory.
2. Fold in the flaked mackerel, mustard paste, lemon juice, chives, and plenty of pepper, keeping it coarse.
3. Pack into a jar or bowl, smooth the top, and chill an hour. Serve cold with toast and cornichons.

**Why it works** — The oily mackerel and smoke drive a big IFI-U 1,300; the engineered yeast's IFI-K 1,500 binds it into something that eats rich and long on just 20 grams of butter; a hit of black-mustard paste adds IFI-P 105 of bright pungency to slice through the oil; chives and lemon lift the finish. The darkest, deepest dish in the book — and even here the design is in the body underneath and the green cut on top, so the fish stays itself.





PART VI OF VI

# The Everyday, and the Reference

a weeknight fillet, scored · the seafood pantry · every plant in this book, by the number

# Chapter 18 · The Everyday Table — *a weeknight fillet, scored*

Most nights are not crudo and coals. Most nights are a fillet, a hot pan, and fifteen minutes, and the whole argument of this book has to survive that too — or it was only ever a Sunday argument. It does survive, and the reason it survives is the thesis in miniature: the design lives in the pantry, not the technique. You are not cooking harder on a Tuesday. You are reaching for plants that already carry what the dish needs.

This is the quiet payoff of the entire library. A weeknight cook does not have time to build depth — no stockpot, no cure, no cold-smoke. But a weeknight cook can keep a good engineered garlic, a jar of mild chili at a *known* IFI-H, and a bright herb grown for lift, and with those three the fifteen-minute fillet carries real intention. The garlic brings kokumi body (a stockpot in a clove, Chapter 14); the chili brings a measured, repeatable warmth that is the same every time because it is anchored to TRPV1 (Chapter 12); the herb and the lemon bring brightness. The pantry does the work the clock will not allow.

**The thesis, in a cupboard.** It is worth saying plainly what the whole library is *for*, because a weeknight fillet is where it either proves itself or does not. A conventional cook builds flavor with time — stocks, cures, reductions, long-browned aromatics — because time is how you coax depth out of ingredients bred for yield and shipping rather than for taste. Our wager is to move that depth upstream, into the plant, so the cook need not manufacture it on a Tuesday: a garlic that already carries a stockpot's kokumi, a tomato that already carries the savor a long reduction would build, a chili dosed to a known warmth so no tasting-and-adjusting is required. The engineered pantry is not a shortcut around technique; it is technique, performed once in the greenhouse so the kitchen can be quick. The fifteen-minute fillet that still scores on four axes is the entire company, folded into a cupboard.



The mild chili of a weeknight — a pepper read at the very bottom of a ladder that climbs to three million Scoville, dosed to a known IFI-H so the Tuesday plate is as exact as the Sunday one.

This is the recipe we actually make most, scored like all the rest, because a weeknight plate deserves intention as much as a feast does — and because scoring it proves the point. The humble pan-seared fillet reads on four axes, every one of them placed, none of them the product of long labor. Intention, it turns out, is a pantry decision.

## Pan-Seared Fillet, Garlic and Lemon

*Serves 2 · 15 minutes · the one we make most*

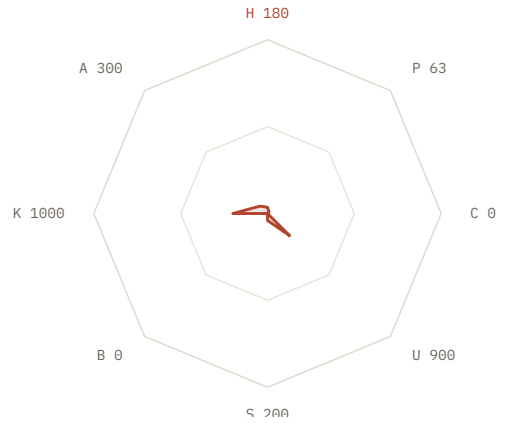
```
2          firm white fillets (cod, hake, bass)
2  tbsp    olive oil
3  cloves  engineered garlic, sliced
1/2 tsp    mild chili flake (IFI-H 180)
1          lemon · 1 tbsp  engineered parsley · salt
```

### Make it

1. Dry the fillets hard and salt them. Heat the oil until it shimmers.
2. Lay the fish in skin-side (or presentation-side) down and leave it — three to four minutes — until a deep crust forms and it releases on its own. Flip for one minute more.
3. Lift the fish out. Off the heat, swirl the garlic and chili in the warm pan just until fragrant, then the lemon juice.
4. Spoon the pan sauce over, strew with parsley, and eat.

**Why it works** — The garlic's IFI-K 1,000 is a weeknight's whole stockpot, bought in a clove; the chili holds a low, known IFI-H 180, the same warmth every single time; lemon's astringency wakes it up; and the seared fish itself reads IFI-U 900. Fifteen minutes, four axes, no shortcuts taken — because the depth was grown into the pantry long before Tuesday arrived.

IFI PROFILE




| | |
|---|---|
| IFI-H | 180 |
| IFI-P | 63 |
| IFI-C | 0 |
| IFI-U | 900 |
| IFI-S | 200 |
| IFI-B | 0 |
| IFI-K | 1,000 |
| IFI-A | 300 |

The second weeknight dish is even more hands-off — a sheet-pan cod roasted on a bed of the restored tomato and olives, where the oven does the work and the engineered tomato supplies the umami that a quick-cooked dish usually lacks.

## Sheet-Pan Cod, Tomato and Olive

*Serves 4 · 25 minutes · the oven does the work*

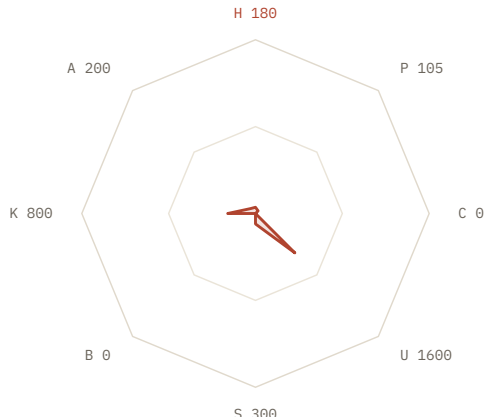
```
4          cod or pollock fillets, ~150 g each
4          restored tomatoes, quartered
100 g      good olives, pitted
4  cloves  engineered garlic, sliced
3  tbsp    olive oil
1/2 tsp    mild chili flake (IFI-H 180) · engineered oregano · salt
```

### Make it

1. Heat the oven to 220 °C. Toss the tomatoes, olives, garlic, oil, chili, and oregano on a sheet pan and roast 10 minutes until the tomatoes slump and release their juice.
2. Nestle the salted cod into the pan, spoon some of the hot tomato over it, and roast 10–12 minutes more until the fish just flakes.
3. Finish with more oregano and the pan juices.

**Why it works** — The restored tomato's grown-in glutamate meets the cod's own inosinate as it roasts, lifting the pan to IFI-U 1,600 — the Chapter 1 synergy, achieved by an oven and a sheet pan; the garlic adds IFI-K 800 of body; oregano lays IFI-P 105 of bright lift; the chili holds its low 180. A whole composed plate from one pan and twenty-five minutes, carrying more savory depth than its effort has any right to — because the depth was engineered into the tomato, not coaxed out by the cook.

## IFI PROFILE




| | | |
|---|---|---|
| IFI-H | | 180 |
| IFI-P | | 105 |
| IFI-C | | 0 |
| IFI-U | | 1,600 |
| IFI-S | | 300 |
| IFI-B | | 0 |
| IFI-K | | 800 |
| IFI-A | | 200 |

# Chapter 19 · The Pantry, Scored — *every plant in this book, by the number*

A cookbook that scores its plates owes you a scored pantry. Here, gathered in one place, is every engineered plant these recipes reach for — what it carries, which axis it speaks, how hard it was to build, and the role it plays on the plate. This is the reference you can cook from directly: want more cool, more savory depth, more bright pungency on a dish of your own? The axis column tells you which plant to reach for, and the chapter column tells you where to see it work.

Everything below resolves against the same shared library as the rest of the Scoville Splice shelf, so a number here is the same number in *The Iyengar Flavor Index* or *Umami* or *Pungency* — one source of truth, forty-odd books, one set of facts.

**Production hosts — live today**

| HOST | CONSTRUCTS | AXIS | DIFFICULTY | ROLE IN THIS BOOK |
|---|---|---|---|---|
| Peppermint | 2,360 | C | Hard | top of the cool axis (IFI-C 2,100) — oysters, mignonette |
| Black mustard | 2,790 | P | Hard | the wasabi flash — AITC via sinigrin/myrosinase |
| Restored tomato | 2,040 | S · U | Easy | grown-back glutamate (IFI-U ~2,600) — broths, sheet pan |
| Pepper (mild cultivars) | 1,060 | all | Native | the dosed low chili (IFI-H 120–300), anchored to TRPV1 |
| Garlic | 560 | K · P | Moderate | kokumi body + allicin lift — the sizzle, the weeknight |
| Yeast | 240 | U · K | Hard | γ-glutamyl kokumi — spreads, broths, bowls |
| Orange (low-bitter) | 120 | B · C | Hard | zest without the sulk (IFI-B ~2,200) — the cure |
| Ginger | 120 | P | Moderate | clean green lift (gingerol/shogaol) — dips, sashimi |
| Thyme | 120 | P | Hard | thymol lift against char — the grill |
| Watercress | 120 | P | Hard | rooty isothiocyanate — raw oyster |
| Shiitake | 80 | U | Hard | guanylate depth — a partner to smoke |
| Koji mold | 80 | U | Hard | unlocks bound glutamate — clear broths, cures |
| Monk fruit | 80 | S | Hard | clean, brief sweetener — seasons the cure |
| Spearmint | 80 | C | Hard | the soft cool (IFI-C 700) — the book's workhorse |
| Oregano | 40 | P | Hard | carvacrol lift — grill, mussels, sheet pan |
| Onion (alliums) | 40 | K | Moderate | the allium family behind chives and spring onion |

### The roadmap plants — what we are building toward

Four plants in these recipes are concepts from our Beyond-Peppers roadmap rather than hosts you can buy today. We cook with them here because this is a book of intention as much as instruction, and we tell you plainly which is which. Until they ship, the substitutions noted in each recipe stand in.

| PLANT | TIER | AXIS IT WILL CARRY | STANDS IN FOR NOW |
|---|---|---|---|
| Contradiction cucumber | T3 Cross-Family | cool + a buried warmth (C × H) | cucumber + a micro-pinch of mild chili |
| Acid tomatillo | T2 Extended Nightshades | astringency as structure (A) | ripe tomatillo + lime |
| Dynasty rice | T4 Frontier Synthetic | clean, faintly sweet structure (S) | good short-grain rice |
| Volcanic 'Caldera' tomato | T1 Solanaceae Core | umami *and* heat (U × H) | restored tomato + a measured chili |

### The numbers behind the pantry

Every plant above is one expression of a single platform, and the platform's figures are the same across the whole library. We hold them steady on purpose; across forty-odd books, a number that

drifts is the one thing that reads as careless.

| FIGURE | VALUE |
|---|---|
| Engineered constructs | ~19,000 |
| Live / purchasable today | 1,000 |
| Total SKUs | 78,800 |
| Host organisms (live) | 42 |
| Sensory axes | 8 |
| Batch-to-batch consistency (CV) | ≤7% |
| Patents filed | 3 |
| Peer-reviewed papers (Zenodo, CC BY 4.0) | 21 |

That consistency figure is the one a cook feels most. When a recipe in this book says IFI-H 180, it means 180 — not "180 on a good day." The ≤7% coefficient of variation is why the chili oil on your Tuesday fillet tastes like the chili oil on your Sunday tartare, and it is the difference between cooking to a specification and cooking on a hope.

**A note on what these plants are, and are not**

Two honesties belong at the back of a book that engineers food, and we would rather state them plainly than bury them.

These are computational designs; Scoville Splice's cultivars and constructs have not been experimentally validated in a laboratory. The IFI scores, SHU predictions, and pathway descriptions throughout this book reflect computational modelling of designed sequences — not certified lab measurements.

The first is regulatory, and it is simple: engineered food is food, and it is grown and handled under the same rules as any other — ingredient safety established through the ordinary GRAS pathway, and bioengineered content disclosed as the national standard requires. We treat those rules as a floor, not a ceiling, and we would rather over-tell you what is in your food than under-tell you.

The second is about allergens, and it matters more in this book than most, because the sea is one of the great allergen families. Fish and crustacean shellfish are among the major food allergens, and nothing we design changes that — a scallop is still a scallop. Several plants in this pantry touch the allergen list too: soy appears in every recipe that calls for soy or tamari, and sesame garnishes a bowl or two. We engineer flavor; we do not engineer allergens away, and you should cook these dishes with the same awareness of your table's needs that you would bring to any seafood meal.

And a last word on the quiet value that runs under the whole library. Several dishes here lean on kokumi to carry richness with less fat, or on a gentle cure that needs less sugar, and when that happens we have said so in a *nourishment note.* We want to be exact about what those notes are and are not. They are observations about a technique — that body built on CaSR needs less butter to feel complete, that a cure seasoned with clean sweetness can be gentler on the body without losing its balance. They are never a health claim. We make no promise about what any of this does for you beyond the plate. We simply hold, quietly and throughout, that food

is something you give your body with intention — and that designing flavor and designing nourishment have always, for us, been the same act.

# A closing grace · *what the sea taught us about restraint*



The founders at dusk, the greenhouse behind them — a vegetarian family that learned to cook the sea the way it learned to cook anything: on purpose, toward nourishment, with as little as possible between the living thing and you.

We came to the sea as guests, and it taught us the thing our own garden had been trying to teach us all along: that the highest skill is almost always the lightest hand. A fish fresh enough needs a cold plate and a clear head more than it needs a cook. Everything we design — the cooling that never chills, the pungency built to flash and clear, the heat read from the very bottom of a ladder that climbs to nearly three million Scoville, the umami grown back into a tomato so it can meet the umami already waiting in a mussel — all of it exists to let the fish be more completely itself, and never to cover it.

We have tried, across these chapters, to hold two things in one hand that cookbooks usually keep apart: the pleasure and the precision. We do not believe they are opposites. The number under a plate is not a retreat from delight; it is a promise that the delight will survive the trip from our table to yours — that the cool you taste is the cool we meant, the warmth is the warmth we set, the savory depth is the one we grew back into a tomato on purpose. A recipe that can be *repeated* is a kind of generosity, and a scored recipe is the most generous version of it we know how to write.

That is why we scored every plate. Not to make a feeling into a spreadsheet, but because a number, held with care, is a form of respect — for the fish, for the plant, for the person we are cooking for. The computing behind all of this was one pair of hands at a keyboard; the table it comes home to belongs to all of us, and it is from that table, not the lab, that this book is written. We are a vegetarian family who learned to cook the sea the way we learned to cook anything: on purpose, toward nourishment, with reverence for the living thing and as little between it and you as we could manage.

Cook these for the people you love. Keep the hand light. Let the sea do what it already does so well, and bring — exactly, and only — the rest.