

THE SCOVILLE SPLICE LIBRARY · VOLUME XLVII

Engineered Japanese

The fifth taste was named in Japan. *We grew the vocabulary.*

A receptor-level cookbook of washoku — from the synergy folded into a bowl of dashi to the volatile sting of fresh-grated wasabi. The umami axis read through the one cuisine that organized itself around it a century before the receptor was found, and the engineered organisms we tuned to serve it.

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

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Opening essay · The bowl that named a taste

There is a word our family learned late and now cannot cook without. *Umami.* It is Japanese, and it is barely a hundred years old as a named thing, though the sensation it points to is as old as broth. In 1908, a chemist named Kikunae Ikeda stood over a bowl of kombu dashi in Tokyo and refused to accept that its savory depth was only salt and some trick of smell. He boiled down forty kilograms of the dried kelp, chased the taste through crystal after crystal, and pulled out glutamate — a single amino acid, one the body makes by the gram and the tongue reads as *this is nourishing, eat more of this.* He gave the taste a name that means, roughly, *deliciousness itself*, and for most of a century the rest of the world declined to believe him. There were four tastes. Everyone knew that. Sweet, sour, salt, bitter. A fifth was superstition.

The receptor was found in 2000 — a heterodimer, T1R1 bound to T1R3, sitting on the tongue with a cleft shaped exactly to catch a glutamate the way a Venus flytrap closes on a fly. Ikeda had been right for ninety-two years before the biology caught up. We think about that often, in the greenhouse at the hour before the lights come up, because it is the whole shape of our work in one story: a taste felt perfectly and measured not at all, waiting the better part of a century for a number.



Before the lights — the greenhouse at the hour our family's questions get asked. The work was one pair of hands at the keyboard; the table was all of us.

This book is about the cuisine that did not wait. Long before there was a receptor to point to, Japan had built an entire grammar of cooking around umami — had discovered, by palate and patience, not only glutamate but the trick that makes glutamate roar. Kombu carries the glutamate. Katsuobushi — bonito dried until it rings like wood, shaved into pink clouds — carries a nucleotide called inosinate. Put the two in the same warm water for ten minutes and the savory depth does not add; it *multiplies*, seven or eight times over, a supra-additive leap that has a mechanism we can now draw and an equation we can now solve. The Japanese kitchen found that

multiplication in the dark and named its product *dashi*, the mother stock under almost everything else. A nation reorganized its cooking around a receptor it could not see.

So of all the cuisines in this library, this is the one where our two languages — the lush and the exact — are already the same language. We can tell you that a first-draw dashi smells like the sea gone gentle, like the inside of a clean wooden box, like something your body leans toward before your mind has named it; and in the same breath we can tell you it is free L-glutamate at roughly two grams per liter meeting inosinate-5′-monophosphate at a tenth of that, the nucleotide docking an allosteric pocket on T1R1 and dropping the receptor's half-maximal concentration threefold, so that the same molecules speak louder into the same nerve. Both sentences are true. Neither is a decoration on the other. That is the voice we have tried to hold across sixty-four books, and here, for once, the cuisine holds it for us.

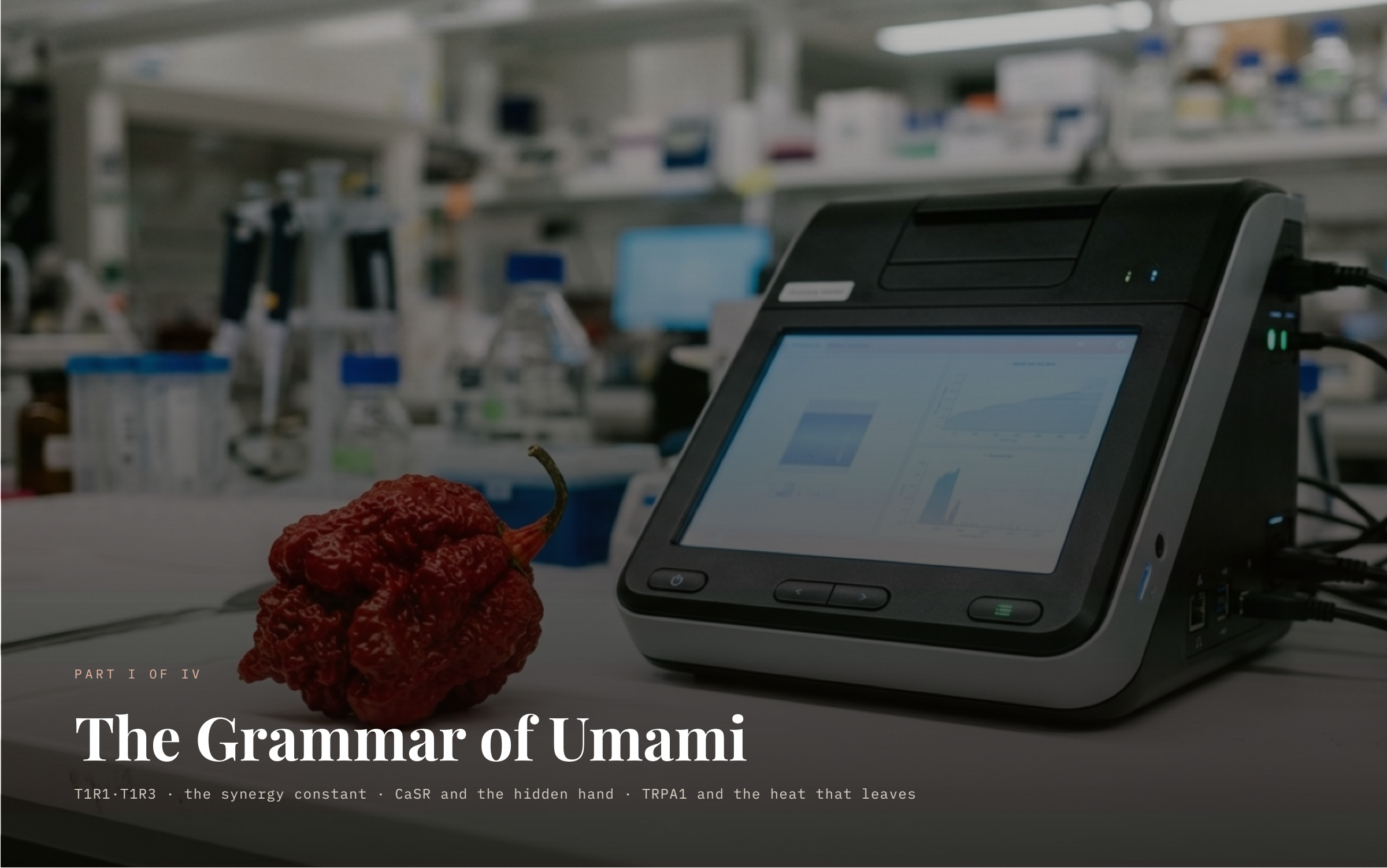
Our part is the plant. Forty-two organisms are validated on the platform today; the soybean that becomes miso and shoyu, the shiitake that dries into guanylate, the tea whose shaded leaves flood with the amino acid theanine, the tomato restored to the savor a supply chain had bred out of it — each is a host we have tuned, construct by construct, to speak one or more of the eight axes of the Iyengar Flavor Index more clearly. We did not invent dashi. We would not dare. What we have done is learn to grow the ingredients of dashi with their best self dialed up and their flaws dialed down — kombu-grade glutamate in a soybean, dried-shiitake guanylate in a mushroom that never had to be left in the sun, the sharp green sting of wasabi in a mustard that will grow where wasabi will not. Every one measured on the same eight axes. Every one grown toward the fullest flavor, and the fullest nourishment, it can carry.

A word on that last clause, because it runs under everything here and we would rather say it plainly once than imply it forever. Umami is the most useful taste a cook who cares about the body has. It is the one that lets you reach for less salt and still be satisfied, because glutamate and sodium share a circuit and a strong savory base makes a smaller pinch of salt taste like a larger one. It is the taste that makes vegetables filling, that lets a bowl of broth and greens land as a meal and not a sacrifice. Japanese cuisine knew this too, in its temple kitchens, in the fully vegetarian *shojin ryori* that built mountains of flavor from kombu, shiitake, soybean, and sesame and never missed the fish. We are a plant-reverent kitchen by instinct and conviction, and this cuisine rewards that instinct more than almost any other. Where fish and dashi and the respect owed to a good piece of mackerel enter these pages — and they do, often, written with the same care as the kelp — they enter as part of the whole, not as an apology and not as an afterthought.

What follows is in four parts. First the grammar: the receptors, the synergy, the math of a taste made loud, the sharp pungent finish that is wasabi's gift and TRPA1's doing. Then the pantry, rebuilt: dashi four ways, koji and its secret enzymology, shoyu and miso, the mushrooms, the tea, the rice — each ingredient as a piece of engineering and a thing to revere. Then the canon: soups, the raw

and cured, the grilled and glazed, the fried, the noodle, the pickle, every dish scored on the eight axes and built, where we could, around a cultivar we designed. And last, the frontier and the table — a kaiseki menu composed the way you would compose a chord, and a closing on *washoku* itself: one soup, three sides, and the quiet arithmetic of feeding a body well.

Pull a square of kombu from the drawer. Run a thumb over the white bloom on its surface — that is not dust; that is glutamate, crystallized out of the kelp as it dried, the fifth taste made visible. We are going to read it to the receptor and back.



PART I OF IV

The Grammar of Umami

T1R1·T1R3 · the synergy constant · CaSR and the hidden hand · TRPA1 and the heat that leaves

Chapter 1 · Umami — *the taste Japan named before the West believed it.*

Set a crumb of monosodium glutamate on a clean tongue and nothing much happens for an instant, and then the back and sides of the mouth fill with a sensation that is not sweet and not salt and has no edges — a roundness, a mouth-filling *presence*, a signal the brain files under *food, real food, the kind with protein in it.* That is a single molecule, L-glutamate, finding a single receptor. Everything in this book is an elaboration of that moment.

The receptor is a heterodimer: two class-C G-protein-coupled receptor subunits, T1R1 and T1R3, latched together at the membrane. (A second umami sensor, the truncated metabotropic glutamate receptor mGluR1, lives in the same tissue and reports the same molecule; the platform anchors the umami axis to both, which is why you will see them paired throughout the library — *mGluR1 / TAS1R1·TAS1R3*.) Each subunit carries, on its outer face, a large bilobed domain that biologists named the Venus flytrap for the obvious reason: it is hinged, and it closes. Glutamate drifts into the cleft of the T1R1 trap, the two lobes swing shut around it, and that mechanical closing is transduced through the membrane as the start of a nerve signal. One molecule, one closing, repeated a billion times a second across the surface of a warm bowl.



The tomato, restored — free glutamate carried back from roughly 90 mg to a sun-ripened 246 mg per 100 g through the native GAD / GDH1 route. The umami organism our platform knows best, and the one a Japanese kitchen uses least and ought to use more.

How *loudly* a molecule speaks is not how much of it a food contains. It is how readily it closes the trap — its affinity, captured by a number called the EC_{50}, the concentration at which the receptor reaches half of its full response. A low EC_{50} means a molecule that activates the receptor at low concentration: a loud molecule. This is the quantity the entire Iyengar Flavor Index is built on. For every axis, the score is the same inversion:

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IFI(c) = 1,000 · EC₅₀(ref) / EC₅₀(c)
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Read it slowly. Put the candidate's EC_{50} in the denominator so that a *lower* threshold — a louder stimulus — yields a *higher* score. Scale against a fixed reference and multiply by a thousand so the result is a number a human can hold. For umami, the reference is the half-maximal activation of the native T1R1·T1R3 by free L-glutamate, which sits near **1.1 millimolar** in our assays. A candidate that activates at half that concentration scores twice as loud. A candidate that needs twice as much scores half.

The underlying curve is the Hill equation, the same sigmoid that governs oxygen on hemoglobin and capsaicin on TRPV1:

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R([S]) = R_max · [S]^h / (EC₅₀^h + [S]^h)
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where R is the receptor response, [S] the stimulus concentration, and h the Hill coefficient — the steepness of the turn-on, near 1.0 to 1.3 for glutamate at this receptor, meaning the response rises smoothly rather than snapping. EC_{50} is simply the [S] at which that fraction equals one-half. Everything downstream — the synergy of the next chapter, the restoration of a tired tomato, the scorecard under every recipe here — is a statement about moving EC_{50} left (louder) or right (softer) on that curve.

Now the food. Free glutamate — not the glutamate bound up inside proteins, which the tongue cannot taste, but the free amino acid liberated by ripening, drying, aging, or fermentation — is distributed across the larder in a pattern the Japanese pantry reads fluently:

INGREDIENT	FREE GLUTAMATE (MG/100 G)	NOTE
Kombu (dried kelp)	~2,240	the white bloom is crystallized glutamate
Nori (dried laver)	~1,380	the toasted sheet around a rice ball
Dried shiitake	~1,060	plus guanylate — see Chapter 2
Soy sauce	~400–1,700	liberated by koji glutaminase
Parmigiano (for scale)	~1,200	the West's accidental kombu
Ripe tomato	~150–250	our platform's umami workhorse
Miso	~200–700	rises with age
Fresh shiitake	~70	drying multiplies it

The number our family keeps returning to is kombu's. Two thousand two hundred milligrams of free glutamate in a hundred grams of a leaf that grew in cold seawater on nothing but sunlight and dissolved nitrogen — a plant that is, by free-glutamate density, among the most savory things on earth, and that no one has to cook, only steep. The genius of the Japanese kitchen was to notice this and to build a stock around it that extracts the glutamate and almost nothing else: no fat, no cloudiness, no fuss. Kombu dashi is close to a pure solution of the fifth taste.

Our platform cannot grow kombu — kelp is not among the forty-two validated hosts, and a marine macroalga is a frontier we have not opened. What we can do is read kombu's trick and write it into

plants that grow on land, in a greenhouse, under control. The restored tomato in the figure above is the clearest case: a fruit bred for shipping and shelf life had lost most of its free glutamate to the truck, dropping toward 90 milligrams, and our design pushes flux toward a vine-ripened 246 through the plant's own glutamate-accumulating route — the glutamate decarboxylase and dehydrogenase steps that sit at the hub of nitrogen metabolism in every green cell. No foreign savor. The tomato's own design, turned back up. We will do the same, in the chapters ahead, to the soybean and the shiitake and the humble mushroom — every one of them an attempt to put more of Ikeda's crystal into a plant you can hold, and to measure, in the clean coin of EC_{50}, exactly how much louder we made it speak.

One molecule. One closing trap. A number for how loud. Hold those three things; the rest of the book is what happens when you have more than one molecule at once.

Chapter 2 · Dashi, solved — *the synergy equation, made liquid.*

Here is the fact that should be more famous than it is. Inosinate — inosine-5′-monophosphate, IMP, the nucleotide that floods into a fish's muscle as it dies and its ATP breaks down — has, by itself, almost no taste. Dissolve pure IMP in water and you will strain to call it savory at all. And yet katsuobushi, which is dried bonito and is almost entirely a vehicle for IMP, is one of the two pillars of Japanese cooking. The resolution of that paradox is the single most important idea in this book, and it is called umami synergy.

Put glutamate and IMP in the same mouthful and the savory intensity does not add — it multiplies. A pinch of glutamate that scores, say, a modest umami on its own, combined with a pinch of inosinate that scores almost nothing on its own, together produce a savoriness many times the sum of the parts. The classic measurement, made by Shizuko Yamaguchi in 1967 and never seriously overturned, is that an optimal mixture tastes roughly **seven to eight times** as intense as the same total mass of glutamate alone. The nucleotide that is nearly tasteless is, in the presence of glutamate, a multiplier.



Dried shiitake — the vegetarian half of the synergy. Drying ruptures the cells and sets ribonuclease loose on the mushroom's own RNA; guanylate climbs from near nothing to ~150 mg/100 g. Guanosine-5′-monophosphate potentiates glutamate even harder than inosinate does.

The mechanism is allostery, and it is beautiful. Recall the Venus flytrap of T1R1, closing on glutamate in its cleft. The ribonucleotides — IMP from fish and meat, guanylate (GMP) from dried mushrooms — do not compete for that cleft. They bind a *second*, adjacent site, on the outer rim of the same flytrap domain, and their binding stabilizes the closed, glutamate-bound conformation. The trap, once shut, is held shut. Functionally, the nucleotide lowers glutamate's EC_{50} — moves the whole Hill curve of Chapter 1 to the left — so that

the same glutamate concentration now sits far higher on the activation curve. The nucleotide is tasteless alone because it does not activate the receptor; it only makes glutamate better at it.

Yamaguchi captured the perceived intensity of a mixture with a relation that still runs under every dashi:

$$y = u + \beta \cdot u \cdot v$$

where u is the glutamate concentration, v the nucleotide concentration (both as a fraction of the total), and β an empirical synergy constant — about **1,218 for IMP** and, remarkably, nearer **2,800 for GMP**, the guanylate of dried shiitake. The product term u · v is the synergy: it vanishes if either partner is absent (multiply by zero and the magic is gone, which is exactly why kombu alone or katsuobushi alone each make only a decent stock, and the two together make dashi) and it swells as both rise toward balance. The curve peaks sharply near a one-to-one ratio of the two partners — which is, not by coincidence, almost exactly the ratio a traditional first-draw dashi arrives at.

Because the Index is built on EC_{50}, and synergy *is* a reduction in EC_{50}, the effect lands directly on the umami score:

$$\text{IFI-U(mixture)} = \text{IFI-U(glutamate)} \cdot (1 + \beta \cdot v) \approx \text{IFI-U(glutamate)} \cdot \text{(potentiation factor)}$$

In the lab, at saturating nucleotide, the potentiation factor approaches an order of magnitude. In an actual bowl of dashi, where IMP is present but not saturating, we measure a threefold-plus reduction in glutamate's effective EC_{50} — enough to carry a kombu-grade glutamate from an IFI-U near 1,400 to an IFI-U of **4,200**. We note that number with a certain reverence, because it is the exact figure Phoenix — the eight-axis superhot that is this library's proof of maximal heat — reaches on the heat axis. The quiet ceiling of umami and the roaring ceiling of heat, the same four digits. A bowl of awase dashi and the hottest engineered pepper on earth, meeting at 4,200 from opposite ends of the tongue.

Let us show the arithmetic plainly, the way the Japanese kitchen performs it by feel:

STOCK	GLUTAMATE SOURCE	NUCLEOTIDE SOURCE	SYNERGY TERM	IFI-U
Kombu dashi	kombu (~2,240 mg/100 g Glu)	—	0	~1,400
Katsuo "dashi"	bonito (~40 mg/100 g Glu)	IMP (~630)	small (little Glu to multiply)	~620
Shiitake dashi	dried shiitake (~1,060)	GMP (~150)	moderate, β≈2,800	~1,600
Awase (ichiban) dashi	**kombu**	**katsuobushi (IMP)**	**large, balanced**	**~4,200**

Read the table as a proof. Kombu alone is good — glutamate with no multiplier. Bonito alone is weak — a strong multiplier with almost nothing to multiply. Put them together and the product term detonates. This is why *awase dashi*, the combined stock, is the

foundation and the single-source stocks are the exceptions. It is also why dried shiitake makes a genuinely satisfying vegetarian stock on its own: the mushroom carries *both* partners — its own glutamate and, thanks to drying, its own guanylate — so the synergy happens inside the single ingredient. A dried shiitake is a one-pot dashi. We will build on that fact for every plant-based bowl in this book.

Now the engineering, because this is where our work meets Ikeda's. If synergy is a reduction in glutamate's EC_{50}, there are two levers a designer can pull: raise the glutamate, or raise the nucleotide. We pull both. In the soybean — a validated host carrying 360 constructs across the umami and kokumi axes — we push free-glutamate accumulation through the GS–GOGAT cycle (glutamine synthetase building glutamine from ammonium, glutamate synthase handing the amine back to make two glutamates) and relieve the feedback that normally caps it, so the bean that becomes miso and shoyu arrives at fermentation already rich in the substrate the koji will liberate. In the shiitake and the button mushroom (validated hosts at 80 and 40 constructs), we lift the purine-pathway flux toward IMP and its oxidation to GMP, and we tune the ribonuclease that drying unleashes, so that the guanylate yield on drying is both higher and — the number that matters to a formulator — *consistent*, inside the platform's standing specification of a batch-to-batch coefficient of variation at or under seven percent. A chef wants the twentieth bowl to taste like the first. Synergy is unforgiving of a wandering nucleotide; we hold it steady.

The dashi in your pot tonight is an analog computer solving Yamaguchi's equation in warm water. Every adjustment a cook makes — a little more kombu, a second handful of bonito, a longer steep — is a move on the u-v surface, chasing the peak of that product term. The Japanese kitchen has been solving it by palate for four hundred years. We have only written down the equation it was already solving, and set about growing better values of u and v to feed into it.

Chapter 3 · Kokumi — *the richness you cannot point to.*

Taste a thin miso soup made with young white miso, and then taste one made with a dark miso aged two years, and the difference is not simply that the second is more savory. It is *rounder*. It arrives earlier, lasts longer, coats more of the mouth, and leaves a sense of body that the first soup, for all its pleasantness, does not. If you try to name the extra thing, you will fail, and your failure is the point. The sensation has a name only because food scientists gave it one — *kokumi*, from the Japanese for "rich taste" — and for a long time it had no receptor and so, officially, did not exist. It was the thing great broths had and thin ones lacked, and no one could say what it was.



Garlic, in cross-section — among the richest plant sources of the γ-glutamyl peptides that drive kokumi. A validated host at 560 constructs across kokumi and pungency; the savory foundation under nearly every cuisine, Japan's included.

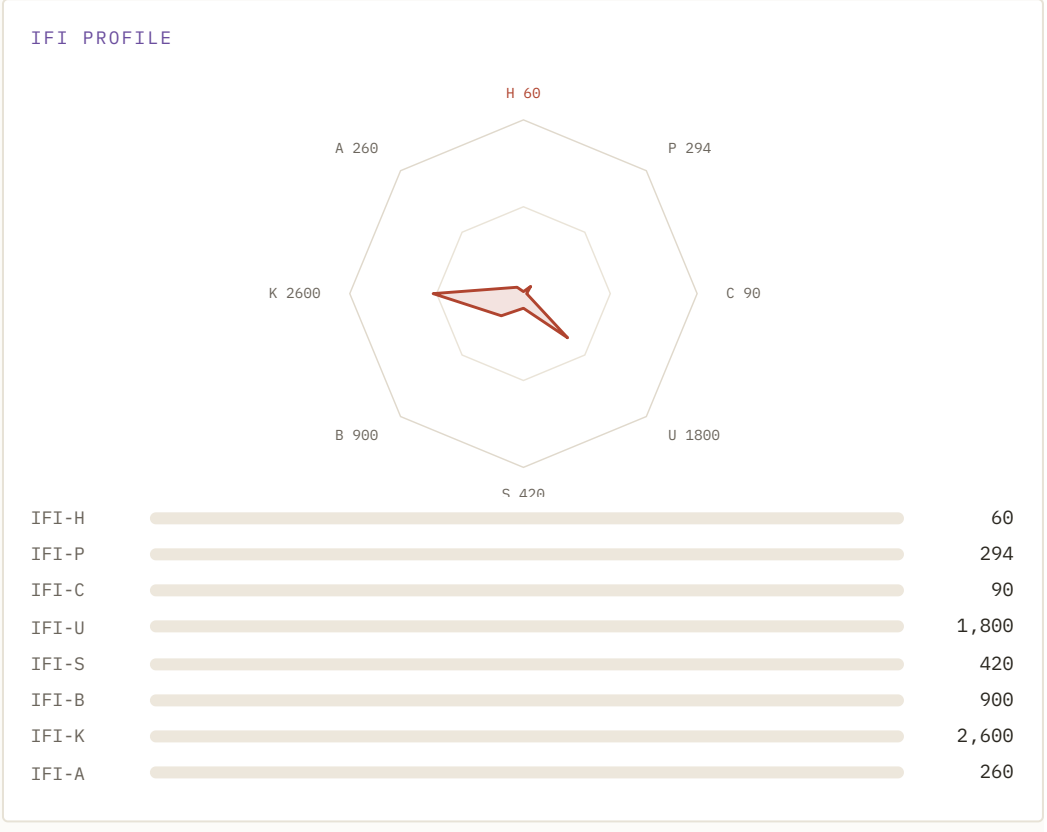
The receptor turned out to be one already famous for an entirely different job. The calcium-sensing receptor, CaSR, sits in the parathyroid gland monitoring blood calcium — and also, it emerged, on the tongue, where it is activated not by calcium but by a family of small peptides: the γ-glutamyl peptides. Glutathione — the tripeptide γ-Glu-Cys-Gly, present in every living cell as an antioxidant — is the archetype; the dipeptide γ-Glu-Val-Gly is a more potent one, and a whole family exists in between. These molecules have no strong taste of their own. What they do is *modulate*: through CaSR, they amplify and prolong the other tastes present — umami, sweet, salt — stretching them across time and across the surface of the mouth. Kokumi is not a flavor. It is a richness applied to flavors. It is the difference between a chord played once and a chord sustained.

The γ-glutamyl bond is the key, and it is an unusual one. Ordinary peptides link the α-carboxyl of one amino acid to the amine of the next; γ-glutamyl peptides link through glutamate's *side-chain* carboxyl instead, a bond built and broken by a specific enzyme, γ-glutamyltransferase. This is why aging matters so much to kokumi: time, and the slow enzymatic churn of fermentation, is what assembles and reshuffles these peptides. A two-year miso is rich because two years of microbial and enzymatic activity have built a deep library of γ-glutamyl peptides that a two-month miso has not had time to write. Soy sauce, likewise, develops its roundness over its long moromi fermentation. Aged garlic — think of the mellow,

almost sweet depth of a long-roasted head, or of black garlic held warm for weeks — is a kokumi powerhouse for the same reason: its γ-glutamyl-S-allyl-cysteine and kin accumulate and transform with time.

Here is where our family's work turns, quietly, toward its oldest value. CaSR responds to glutathione, and glutathione is not only a kokumi agent but the central antioxidant tripeptide of the living cell — the molecule that keeps the plant's own chemistry clean. A food engineered to carry more glutathione is, on the same axis, richer-tasting and more nourishing; the kokumi and the nutrition are the *same molecule*. We say this carefully and without a claim attached: we do not promise the body anything. We only note, with some wonder, that on this one axis the richness you taste and the richness the plant carries for its own survival are written in the same three letters, and that designing for the first tends to deliver the second as a gift we did not have to engineer separately.

So we engineer it. In the garlic above — 560 constructs, kokumi and pungency — and in the onion (a kokumi host at 40 constructs) and the yeast (240 constructs across umami and kokumi, the engine of so much savory depth), we lift the γ-glutamyl peptide pool directly: more substrate glutamate, a tuned γ-glutamyltransferase, relieved feedback on glutathione synthesis. The IFI-K score rises as CaSR's effective EC_{50} for the peptide mixture falls. And because kokumi is a *modulator*, raising it has an effect out of proportion to its own score: a stock with strong kokumi needs less of everything else to satisfy. This is the mechanism underneath one of the quiet facts of good Japanese cooking — that a properly built dashi, rich in both synergistic umami and kokumi, lets a cook salt with a lighter hand and still land a soup that tastes complete. Umami shares a circuit with salt; kokumi stretches whatever salt is there across more of the mouth and more of the meal. Between them, the fifth taste and the richness you cannot point to do real work for a kitchen that would rather not reach for the salt cellar twice.



Aged garlic paste, as a kokumi base — scored high on K for the γ-glutamyl peptides, high on P for the alliin-derived sharpness that long cooking mellows but never erases. A tablespoon folded into a dashi does the work of a pinch more salt and a longer simmer at once.

Chapter 4 · The sharp finish — *wasabi, and the heat that leaves on purpose.*

Everything so far has been round, slow, savory — tastes that fill and linger. Japanese cuisine balances that roundness against its opposite: a heat that is sharp, volatile, and *brief*, a sting that climbs the nose rather than sitting on the tongue, flares for a few seconds, and vanishes. This is wasabi, and understanding why its heat leaves — while a chili's heat stays — is a lesson in two different receptors and the chemistry of volatility.



Black mustard, in cross-section — *Brassica nigra*, which generates exactly the allyl isothiocyanate that gives true wasabi its sting. A validated host at 2,790 constructs across pungency and multi-axis work: our platform's clearest route to the wasabi sensation in a plant that will grow anywhere.

Chili heat is capsaicin on TRPV1 — the subject of this library's first volumes — and capsaicin is a large, oily, non-volatile molecule that embeds in the fatty membranes of the pain nerves and refuses to leave. That is why a chili burn builds and lingers and cannot be rinsed with water: the molecule is lipophilic and stubborn. Wasabi heat is an entirely different compound on an entirely different channel. The molecule is allyl isothiocyanate — AITC — and the channel is TRPA1, the irritant sensor, a cousin of TRPV1 that answers to reactive, pungent, often airborne chemistry: mustard, horseradish, raw garlic's crush, the tear-gas sharpness of cut onion's volatiles. TRPA1 does not merely bind AITC; AITC *reacts* with it, forming a reversible covalent bond to a cysteine residue on the channel's inner face — a genuine chemical modification that springs the channel open. It is a more violent, more chemical gate than capsaicin's, and it is wired to the parts of the trigeminal nerve that serve the nasal passages, which is why wasabi heat shoots upward behind the eyes while chili heat stays in the mouth.

And then it goes. AITC is small and volatile — it evaporates, disperses, and the covalent adduct on TRPA1 reverses — so the burn that was so sharp at second one is gone by second fifteen, washed out and breathed away. This is not a flaw; it is the entire design of

wasabi's role at the table. It is a *finish*, a bright exclamation that clears the palate between pieces of fish and never overstays. Capsaicin commits; AITC visits.

The chemistry of how AITC appears is as elegant as its disappearance. In the intact wasabi root — *Eutrema japonicum*, a demanding semi-aquatic plant that grows in cold running mountain water and almost nowhere a farmer would choose — AITC does not exist. What exists is a stable glucosinolate, sinigrin, kept in one cellular compartment, and an enzyme, myrosinase, kept in another. Nothing happens until the cells are *ruptured* — grated, crushed, chewed — at which point enzyme meets substrate and myrosinase cleaves sinigrin into glucose and an unstable intermediate that rearranges into AITC. This is why wasabi is grated to order against a sharkskin board and used within minutes: you are not cutting a root, you are triggering a reaction, and the product is already beginning to evaporate as it forms. A wasabi grated ten minutes ago is a different, duller thing than one grated ten seconds ago.

The hard truth of the global table is that almost no one outside Japan has ever tasted it. Real wasabi is scarce and costly, and the green paste beside nearly every plate of supermarket sushi on earth is horseradish — *Armoracia rusticana*, a far easier Brassica — plus mustard, plus a dye. Horseradish and mustard make their heat by the identical glucosinolate-myrosinase route; the sensation is a cousin of wasabi's, coarser and without the fleeting sweetness real wasabi carries, but honestly the same chemistry. Which is precisely the opening our platform was built for. We cannot easily grow *Eutrema japonicum* at scale — a mountain-stream crop is not a greenhouse crop. But we can grow its *chemistry*. Black mustard, *Brassica nigra*, is a validated host at 2,790 constructs, and its native glucosinolate is sinigrin — the very same sinigrin, yielding the very same allyl isothiocyanate as real wasabi. White mustard, *Sinapis alba* (a host at 200 constructs), carries a different glucosinolate that yields a less volatile isothiocyanate — the slower, more persistent burn of yellow table mustard. Between the two, the platform spans wasabi's bright volatile sting and mustard's lingering one, and we tune them by pushing glucosinolate accumulation and myrosinase expression on the pungency axis, IFI-P, anchored to TRPA1.

There is a second, gentler pungency in the Japanese repertoire worth naming: *sansho*, the ground pod of a Japanese prickly ash, whose active compound hydroxy-α-sanshool produces not heat but a buzzing, tingling numbness — a light cousin of the Sichuan tingle, acting on touch and potassium channels rather than pure pain. Sansho sits on grilled eel and in the seven-spice *shichimi togarashi*. It is not yet a platform host; we note it as frontier, a paresthetic axis we have not opened. For now, the Japanese sharp finish on our shelves is AITC — wasabi's molecule, mustard's plant, TRPA1's doing — and it is the one accent in this otherwise round and savory cuisine that is designed to arrive loud and leave fast.

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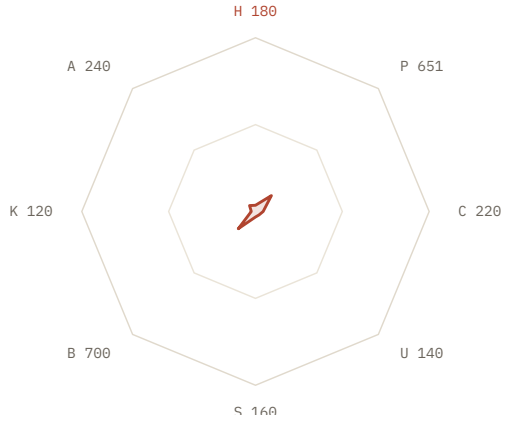


IFI-H		180
IFI-P		651
IFI-C		220
IFI-U		140
IFI-S		160
IFI-B		700
IFI-K		120
IFI-A		240

Fresh-grated wasabi, engineered-mustard base — P at 651 for the AITC sting on TRPA1, everything else low. Note the heat axis near silence: this is pungency, not capsaicin heat. The score is a snapshot; grate it, score it within sixty seconds, and watch the number fall as the molecule breathes away.



PART II OF IV

The Pantry, Engineered

dashi · koji · shoyu & miso · the mushrooms · tea · rice

Chapter 5 · Dashi — *the mother stock, four ways.*

If this book has a single recipe, it is this one, and it is barely a recipe at all. Dashi is the proof of Chapter 2 performed in a pot: glutamate and a nucleotide, extracted into warm water, solving Yamaguchi's synergy equation on your stove. Master the four dashi below and you hold the foundation of nearly everything that follows — the soups, the simmers, the dipping sauces, the custards. Everything in a Japanese kitchen stands on this stock the way everything in a French kitchen stands on its own. The difference is that dashi takes fifteen minutes and almost no fat, and that its depth comes not from reduction and roasting but from a receptor-level trick of synergy that the cuisine discovered centuries before anyone could explain it.



The mother stock begins here — dried shiitake and kombu, the fully plant-based half of the pantry, each a carrier of glutamate and, in the mushroom's case, its own synergistic guanylate. A dashi drawn from these two alone is *shojin* dashi, the temple kitchen's umami, and it owes nothing to the sea's animals.

A word on temperature before the recipes, because it is the one technical thing a dashi cook must respect. Kombu's glutamate extracts best *below* a simmer — around 60 to 80 °C — and if you let kombu actually boil, it releases alginates and other compounds that turn the stock cloudy, slick, and faintly bitter. So kombu is steeped and pulled *before* the boil. Katsuobushi, by contrast, gives up its inosinate fast in hotter water but turns harsh and fishy if simmered long, so it is added off the boil, steeped briefly, and strained. The

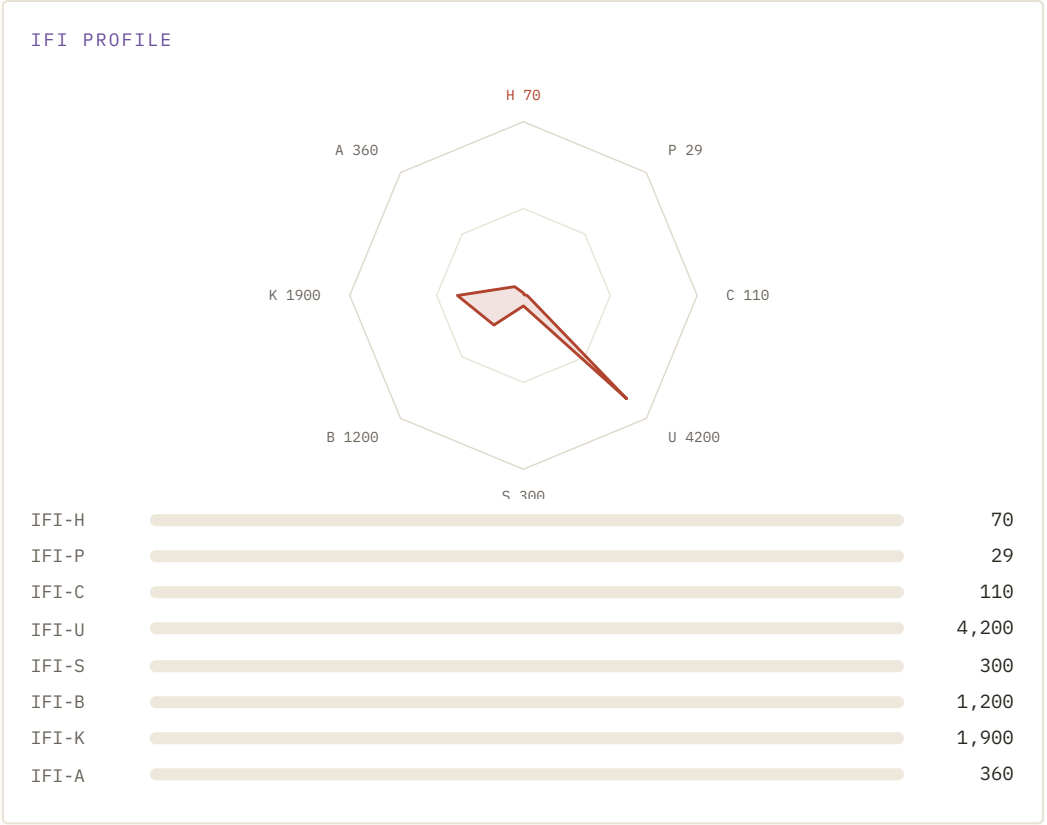
whole technique is a choreography of heat: warm for the kelp, hot-but-brief for the fish, and never a hard rolling boil for either. Hold that, and the rest is patience.

Ichiban dashi — the first draw

The primary stock, clear and delicate, for clear soups and the finest dishes. This is the awase dashi of Chapter 2 — kombu and katsuobushi together, the synergy at full volume.

kombu (dried kelp)	20 g (one 10×10 cm piece)
water	1,000 ml, soft / low-mineral
katsuobushi (bonito)	25 g, loosely packed shavings
time	30 min soak + ~12 min active

1. Wipe the kombu with a barely damp cloth — do not wash off the white bloom; that is glutamate. Soak it in the cold water 30 minutes (or several hours, cold, for a fuller extraction).
2. Bring the pot slowly toward a bare simmer. The instant small bubbles rise at the edges — around 70–80 °C, well before a boil — lift the kombu out. If the water boils with the kombu in it, the stock turns slick; pull it in time.
3. Bring to a brief boil, turn off the heat, and add all the katsuobushi at once. Do not stir. Let it steep 2–3 minutes while the shavings sink.
4. Strain gently through a cloth-lined sieve. Do not press the katsuobushi — pressing squeezes out the harsh, fishy compounds you steeped briefly to avoid. Let it drip. You now hold the clearest, most synergistic stock in the repertoire.



Ichiban dashi — IFI-U 4,200, the synergy ceiling. Taste it warm and unsalted: it is almost shockingly complete, a savoriness that fills the whole mouth from two ingredients and clear water. This is the number to beat and the base to build on.

Niban dashi — the second draw

Thrift, and no waste. The spent kombu and katsuobushi still hold extractable glutamate and inosinate; a second, longer extraction pulls them for a humbler everyday stock — for miso soup, simmered

dishes, anything that will carry its own seasoning.

spent kombu + katsuobushi	from the ichiban draw
water	800 ml
fresh katsuobushi	5 g, to finish
time	~15 min

1. Return the spent solids to the pot with the fresh water. Bring to a gentle simmer and hold 10–12 minutes — a longer, hotter extraction is acceptable now; you are scavenging what remains, and clarity matters less.
2. Off the heat, add the 5 g fresh katsuobushi to lift the inosinate back up. Steep 2 minutes.
3. Strain. Weaker and rounder than the first draw — perfect for a soup that brings its own salt and miso.

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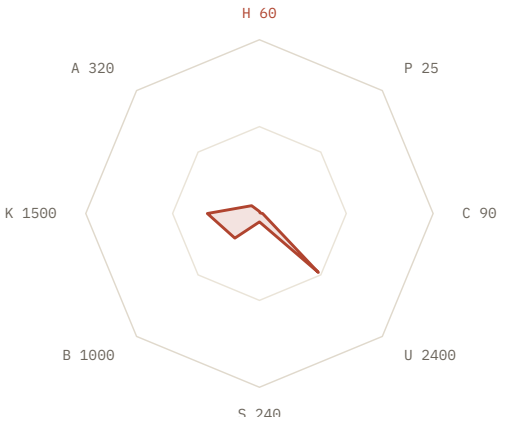


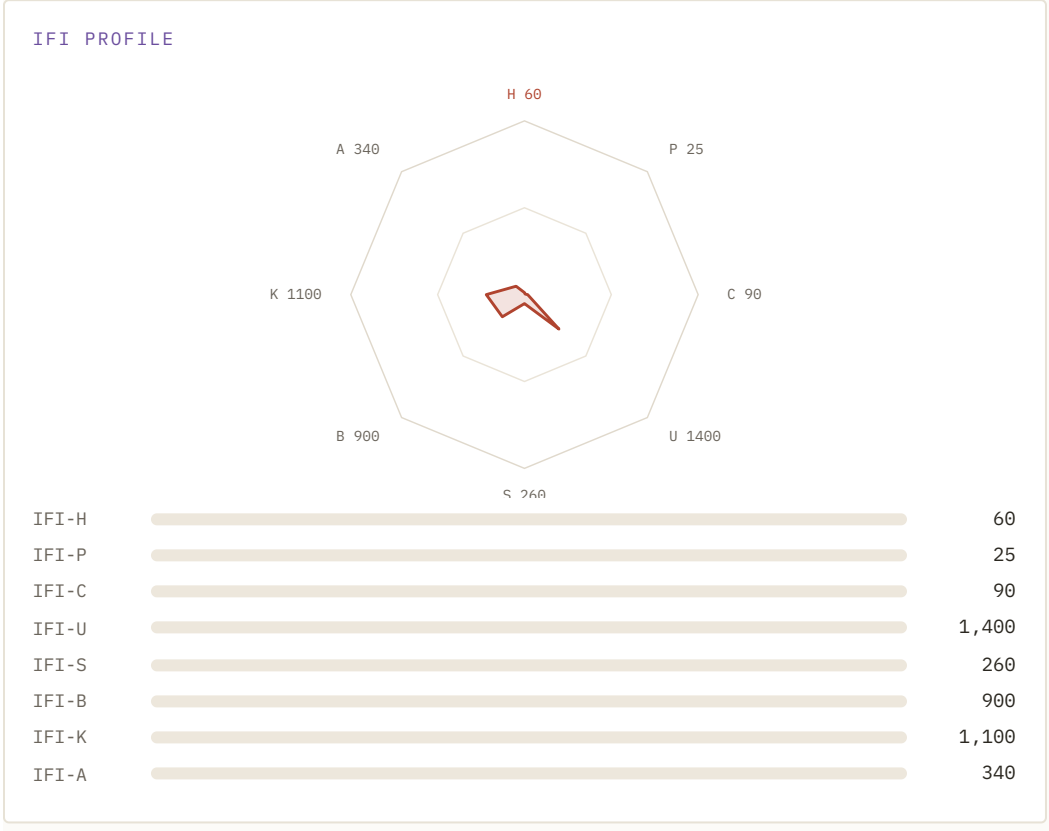
IFI-H	60
IFI-P	25
IFI-C	90
IFI-U	2,400
IFI-S	240
IFI-B	1,000
IFI-K	1,500
IFI-A	320

Kombu dashi — the clean vegetarian base

Glutamate alone, no nucleotide, no synergy — and still a lovely stock. Fully plant-based. The base for anyone avoiding fish, and the gentlest canvas there is.

kombu	30 g
water	1,000 ml
time	3–8 hr cold, or 30 min warm

1. The best kombu dashi is made cold and slow: submerge the kombu in the cold water and refrigerate 3 to 8 hours (overnight is ideal). No heat at all — cold extraction gives the cleanest, sweetest glutamate with none of the cloudiness heat risks.
2. For a same-day stock, soak 30 minutes, then warm gently to 60–70 °C, hold 10 minutes, and pull the kombu before any bubble. Strain.



Glutamate without a multiplier — IFI-U 1,400, honest and clean. To lift it toward the awase ceiling without any animal product, do not add fish; add the mushroom. Which brings us to the fourth dashi, and the one our platform most wants to improve.

Shiitake dashi — the mushroom's one-pot synergy

The vegetarian stock that carries *both* synergy partners in a single ingredient. Dried shiitake holds glutamate *and* guanylate — the GMP liberated when drying ruptures the mushroom's cells and sets its ribonuclease loose on its own RNA — so the synergy of Chapter 2 happens inside the dried cap itself. Combine it with kombu and you rebuild the full awase power with nothing from the sea.

dried shiitake	20 g (4–5 caps), whole
kombu	10 g
cold water	1,000 ml
time	6–12 hr cold

1. Submerge shiitake and kombu in the cold water. Refrigerate 6 to 12 hours — the long cold soak both rehydrates the mushrooms (saving them to cook) and draws a clear, deep stock.
2. Lift out the kombu as the stock comes to a gentle warmth if you heat it; otherwise use it cold-drawn and unheated. Squeeze the shiitake gently over the pot and reserve the caps for a simmer.
3. The result is a vegetarian dashi with real synergy — kombu's glutamate multiplied by the shiitake's own guanylate, β near 2,800.

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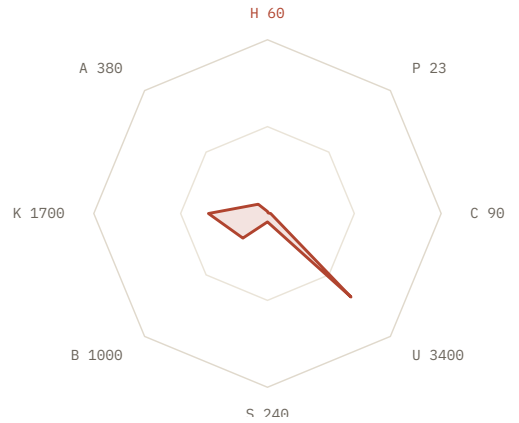


IFI-H		60
IFI-P		23
IFI-C		90
IFI-U		3,400
IFI-S		240
IFI-B		1,000
IFI-K		1,700
IFI-A		380

Shiitake-kombu dashi — IFI-U 3,400, within reach of the awase first draw and entirely from plants. This is the single most important stock in our vegetarian kitchen, and the one we have bent the most engineering toward: our shiitake and mushroom hosts (80 and 40 constructs) are tuned to raise and steady the guanylate yield on drying, so that this plant-based bowl closes more of the gap to 4,200 every season, at a batch-to-batch CV held at or under seven percent. The temple kitchens built mountains of flavor from exactly this. We are trying to make their mountain a little taller.

Chapter 6 · Koji — *the mold that does our enzymology for us.*

Before the soybean can become miso, before rice can become sake or mirin, before anything in the Japanese pantry can ferment into its deep adult self, a mold must get there first. *Aspergillus oryzae* — koji — is the national fungus of Japan, declared so officially, and it is the most important organism in this book that we did not engineer, because in a sense it does our engineering for us. Koji is a secreted-enzyme factory. Grown over steamed rice or soybeans, it sends out a thicket of enzymes that break big, tasteless polymers into small, delicious monomers: proteases that cleave protein into peptides and free amino acids, amylases that cleave starch into sugars, lipases, and — the one that matters most for umami — glutaminase, which converts glutamine into free glutamate.

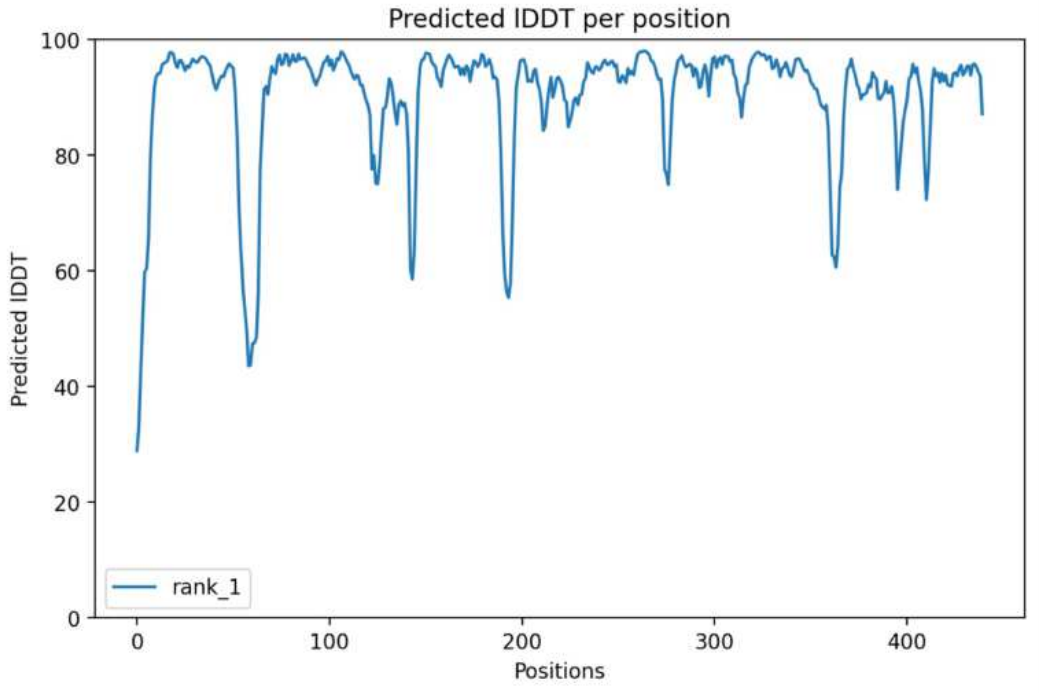


Koji — *Aspergillus oryzae* at work. A validated host at 80 constructs on the umami axis, and the biological engine under miso, shoyu, mirin, and sake. The fuzz on the grain is a living enzyme reactor; its proteases and glutaminase liberate the free glutamate that koji's own substrate could not taste on its own.

Think about what glutaminase does in the frame of Chapter 1. A soybean is full of protein, and protein is full of bound glutamate and glutamine that the tongue cannot taste — glutamate only speaks when it is *free*. Koji's proteases cut the protein chains, releasing amino acids; its glutaminase then converts the released glutamine to glutamate, driving the free-glutamate concentration up and up over the weeks of fermentation. By the end, a paste or a sauce that began as nearly tasteless boiled beans is saturated with free glutamate — Ikeda's crystal, generated in situ by a fungus. Koji is why soy sauce

tastes the way it does. The strains prized for shoyu are specifically those with high glutaminase activity, because glutaminase *is* umami production.

This is also where the platform's core method shows its generality, and we want to be honest about the borrowed figure we are about to show you. Our deepest proof of structure-guided design lives on the heat axis, in the enzyme Pun1 that makes capsaicin — where a protein language model scored every possible single-residue substitution and a handful of edits, never found by breeders, are predicted to lift and steady the output. We show you that proof here not because koji makes capsaicin (it does not) but because the *pipeline* is the same one we point at a koji glutaminase or a soybean glutamine synthetase: model the structure, predict the confident regions, score the mutations, confirm with flux balance which step actually limits the product.



The platform's structure-guided method, shown on its origin enzyme: Pun1/AT3 coloured by pLDDT confidence — the binding domain and active-site cleft resolve with high confidence (warm colours), the flexible termini less so. The same ESM2-plus-flux-balance pipeline that found the heat edits below is the one we turn on a koji glutaminase or a soybean GS–GOGAT enzyme to raise free glutamate.

EDIT (PUN1, HEAT-AXIS PROOF)	EFFECT	ΔΔG (KCAL/MOL)
S39L	binding affinity ↑ (N-terminal)	−2.1
L345G	steric relief, active-site cleft	−1.8
C175S*	disulfide-misfold prevention	−0.9

*C175S is a structural annotation from our modelling; it is not part of the shipped construct. The shipped Pun1 double variant is S39L+L345G only.

The ΔΔG column is the free-energy change on folding stability — negative is stabilizing — and the discipline it represents is the whole point: you do not raise an enzyme's output by brute overexpression and hope; you find the two substitutions that raise catalytic efficiency *and* hold the fold, confirm with a genome-scale flux-balance model that the enzyme you are improving is the true rate limiter and not a bystander, and then make only those edits. On the heat axis, our model predicts this brings peak output from a wandering wild-type to a steadier, more consistent level. On the umami axis, pointed at glutaminase and the glutamate-assimilation enzymes, the same method is what lets us hand koji a soybean that is already primed to be liberated into savor — the substrate pre-loaded for the fungus's knife.

But most of this book does not require you to engineer anything, because koji is a tool any cook can wield. The simplest and most transformative is *shio-koji* — salt-koji — a loose porridge of koji rice, salt, and water, fermented a week on the counter until it becomes a sweet, savory, faintly alcoholic slurry that is, functionally, a bottle of umami-generating enzymes. Rub it on vegetables, fish, or tofu and its proteases go to work tenderizing and its glutaminase goes to work deepening, turning an hour of marination into a shortcut to fermented depth.

Shio-koji

dried rice koji	200 g
sea salt	60 g (30% of koji weight)
water	250 ml, non-chlorinated
vessel	clean glass jar, loosely lidded
time	7–10 days at room temp

1. Crumble the rice koji into the jar, breaking up clumps between your fingers. Add the salt and mix thoroughly — the salt is the preservative that lets this ferment safely on a counter.
2. Pour in the water until the koji is just submerged. Stir to a loose porridge.
3. Lid loosely (it needs to breathe) and leave at room temperature. Stir once a day. Over a week the mixture softens, the rice grains dissolve toward mush, it smells sweet and faintly of banana and alcohol, and a drop on the tongue reads distinctly savory — the glutaminase has been working.
4. When the grains are soft and the aroma is sweet-savory, refrigerate. It keeps for months and deepens as it goes.

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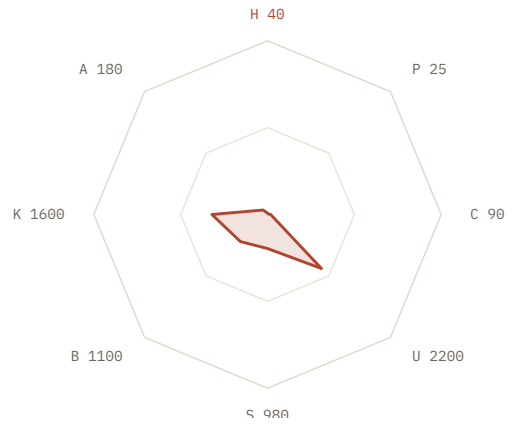

IFI-H	40
IFI-P	25
IFI-C	90
IFI-U	2,200
IFI-S	980
IFI-B	1,100
IFI-K	1,600
IFI-A	180

Shio-koji — a seasoning that is really a jar of enzymes. Note the S at 980: koji's amylases free sugars from the rice, so shio-koji is savory and quietly sweet at once, a double action that makes it the single most useful thing in this chapter. Marinate a block of tofu in it overnight and taste what glutaminase does to a bland protein.

Chapter 7 · Shoyu & miso — *soybean, translated by time.*

Two of the most important flavors on earth are the same three ingredients — soybean, koji, salt — taken down two different roads of time. One becomes a liquid, soy sauce, *shoyu*; the other a paste, *miso*. Both are the soybean translated by koji and patience into something the raw bean could never be, and both are, in the cold language of the Index, machines for generating free glutamate and the γ-glutamyl peptides of kokumi. Our family thinks of them as the two poles of fermented umami — one you pour, one you spoon — and of the soybean as the single most important plant we engineer for this cuisine.



Soybean, in cross-section — a validated host at 360 constructs across the umami and kokumi axes. Nearly tasteless whole and boiled; translated by koji and time into shoyu and miso, the two fermented pillars of Japanese flavor. We tune the bean to arrive at fermentation already rich in the glutamate its koji will liberate.

Follow the soybean into soy sauce and watch the chemistry. Steamed beans and roasted wheat are inoculated with koji and grown until the grain is furred with mold — this is the *koji* stage, the enzyme-loading. The furred mass is then mixed into a strong brine to make *moromi*, a thick mash that ferments slowly for months, sometimes years. In the brine, two more organisms join the koji's enzymes: a salt-tolerant lactic acid bacterium, *Tetragenococcus halophilus*, which acidifies and deepens, and a salt-tolerant yeast, *Zygosaccharomyces rouxii*, which produces alcohol and, crucially, the aromatic compounds that make soy sauce smell like soy sauce. Chief among them is a molecule with an unlovely name and a glorious smell: HEMF, 4-hydroxy-2(or 5)-ethyl-5(or 2)-methyl-3(2H)-furanone, a caramel-savory furanone that is one of the signature aromas of fermented shoyu and is found at meaningful levels almost nowhere else. The koji's glutaminase, meanwhile, has spent those months doing what it does: converting glutamine to free glutamate, driving the umami up. The finished sauce is pressed from the spent mash — a dark, glutamate-rich, aromatic liquid that is umami you can pour.

Miso takes the soybean the other way. Steamed beans are mashed with koji (grown on rice for most miso, on barley for others) and salt, packed into a vessel, and left to ferment — weeks for a pale young

miso, years for a dark aged one. The variable that matters most is the *ratio of koji to bean* and the *time*, and together they set everything:

MISO	KOJI RATIO	FERMENT TIME	COLOUR & CHARACTER	UMAMI / KOKUMI
Shiro (white / Saikyo)	high	weeks–2 months	pale, sweet, mild	moderate U, low K
Shinshu (yellow)	medium	~1 year	amber, balanced, all-purpose	high U, medium K
Aka (red)	low	1–2 years	dark red-brown, deep, salty	high U, high K
Hatcho (all-soy)	very low	2–3 years	near-black, intense, chocolatey	very high U, very high K

Read the table as a timeline of the Maillard reaction and the γ-glutamyl library. A white miso is young and high in koji, so it is sweet (the koji's amylases freed sugars) and pale (little time for browning) and gentle. A dark Hatcho miso is old and low in koji, so it is intensely savory (years of glutaminase), deeply colored (years of slow, cold Maillard browning between the freed sugars and amino acids), and rich with kokumi (years of γ-glutamyl peptide assembly, as Chapter 3 described). The darkening *is* the deepening; color and depth rise together because the same slow reactions drive both.

This is where our soybean engineering earns its place. Fermentation can only liberate what the bean brought. A soybean richer in the glutamate precursors — pushed, as Chapter 2 described, through a relieved GS–GOGAT cycle — hands koji more raw material, so the finished miso or shoyu reaches a higher umami at the same age, or the same umami at a younger age. A soybean richer in glutathione and the γ-glutamyl substrates hands the ferment a deeper kokumi library to draw on. Three hundred sixty constructs, aimed squarely at these two axes, at the front of a fermentation that then does the rest of the work for us. We are not replacing the koji or the time. We are improving the bean they start from.

A note on compliance and the body, because soy invites both. Soybean is one of the major regulated food allergens, and nothing we do changes that — an engineered soybean is a soybean and is labeled and handled as one; the proteins a sensitive person reacts to are not the proteins we tune. The free glutamate these ferments generate is chemically identical to the glutamate in a tomato or in your own blood; the body cannot tell fermented glutamate, added glutamate, and endogenous glutamate apart, because there is nothing to tell apart — it is one molecule, and it is generally recognized as safe. We make no health claim for miso or shoyu beyond the obvious one a cook already knows: that a strong fermented umami base lets you salt a dish with a lighter hand and still call it seasoned. Shoyu and miso are themselves salty, so this is a swap, not a free lunch; but a soup built on deep dashi and finished with a measured spoon of miso needs less additional salt than a thin soup chasing flavor with the shaker. Umami does salt's work at a lighter touch. That is not a claim. It is Chapter 1, applied at the stove.

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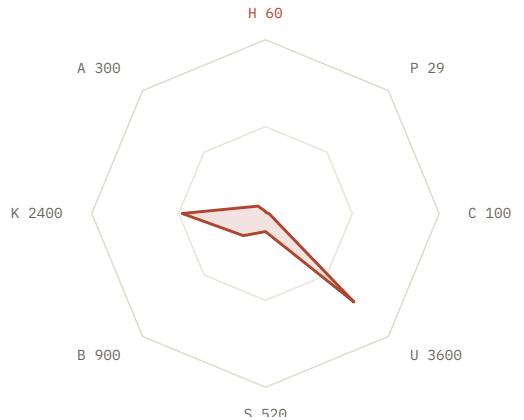

IFI-H		60
IFI-P		29
IFI-C		100
IFI-U		3,600
IFI-S		520
IFI-B		900
IFI-K		2,400
IFI-A		300

A one-year Shinshu miso, scored straight from the crock — U 3,600 and K 2,400, the balanced center of the miso world. Thin a tablespoon of this into warm dashi off the heat (never boil miso — it dulls the aroma and kills the live character) and you have, in ninety seconds, the most-eaten soup in Japan.

Chapter 8 · Shiitake & the mushrooms — *guanylate, and the gift of drying.*

We return to the mushroom because it deserves a chapter of its own, for one remarkable fact: the shiitake is the only common ingredient in this book that improves, as an umami source, by being *killed and dried.* A fresh shiitake is pleasant and mild — a little glutamate, almost no guanylate. A dried shiitake is a powerhouse. The transformation is not concentration alone; it is a chemical event triggered by the drying itself, and understanding it tells you exactly how to cook the mushroom.



Shiitake — a validated host at 80 constructs on the umami axis. The one ingredient here that gets better by dying: drying ruptures the cells, ribonuclease digests the mushroom's own RNA, and guanylate — nearly absent in the fresh cap — climbs to around 150 mg per 100 g. A dried shiitake carries both halves of the synergy inside one ingredient.

Here is the mechanism. The guanylate that makes dried shiitake so synergistic — GMP, the β≈2,800 partner of Chapter 2 — is not sitting around in the living mushroom. It is locked up inside RNA, the mushroom's own ribonucleic acid, as part of long polymer chains that the tongue cannot taste. The living cell also contains ribonuclease, the enzyme that cuts RNA into single nucleotides — but enzyme and substrate are kept apart by the cell's compartments while the mushroom lives. Drying breaks the compartments. As the cells die and their membranes fail, ribonuclease meets RNA and digests it, liberating free 5′-GMP — the guanylate — along with other nucleotides. The drying *creates* the synergist. And it is temperature-sensitive in a way a cook can exploit: the ribonuclease works fastest in a warm window, so the guanylate yield is highest when a dried shiitake is rehydrated *slowly in cold or cool water* and then warmed gently, giving the enzyme time to work on any remaining RNA before heat denatures it. Dump a dried shiitake into boiling water and you denature the ribonuclease before it finishes and leave guanylate on the table. Soak it cold overnight, as the shiitake dashi of Chapter 5 instructs, and you collect all of it.

This is also the biosynthetic step our platform targets. Our shiitake and button-mushroom hosts (80 and 40 constructs) are tuned on two fronts: raising the purine-pathway flux that fills the mushroom

with RNA and nucleotide precursors in the first place, and tuning the ribonuclease so that drying liberates more guanylate, faster, and — the formulator's number — more *reproducibly*, inside the platform's ≤7% batch CV. A mushroom whose guanylate yield wanders from batch to batch wrecks the synergy of a bowl built on it; we hold it steady. The ambition is a dried cap that carries dried-shiitake guanylate without the loss and inconsistency of sun-drying — the synergist, dialed up and locked down.

The mushroom's great gift to this cuisine, and to our vegetarian kitchen in particular, is that it makes the sea optional. The awase dashi of Chapter 2 reaches its 4,200 by pairing kombu's glutamate with a *fish's* inosinate. The shiitake offers a second road to the same place: kombu's glutamate paired with a *mushroom's* guanylate, every bit as synergistic, entirely from plants. For the temple kitchens that cooked without any animal product, the dried shiitake was not a substitute for bonito — it was its own first-class route to depth, and the vegetarian dashi it anchors is not a compromise but a cuisine. We cook from it constantly, and we have aimed real engineering at making it richer, because a world that wants more of its umami from plants should have a louder mushroom to get it from.

A dish that shows the mushroom's synergy at its most elegant is *chawanmushi* — a savory steamed custard, barely set, the texture of a cloud, in which dashi is the entire flavor and the egg is only the structure that holds it. Here the synergy is doubled: a dashi that already carries the kombu-katsuo multiplication, deepened further by dried shiitake steeped in it and by the custard's own concentration.

Chawanmushi — savory steamed custard

ichiban or shiitake dashi	400 ml, cooled to lukewarm
eggs	3 large (~150 g), beaten gently
light soy sauce (usukuchi)	1 tsp
mirin	1 tsp
sea salt	1/4 tsp
dried shiitake	2 caps, rehydrated, thin-sliced
+ per cup, any of:	a prawn, ginkgo nut, a sliver of chicken or kamaboko, a spring of mitsuba

1. Combine the lukewarm dashi with the beaten eggs in a 1 part egg to roughly 2.5–3 parts dashi ratio — this ratio is the whole secret of the silk; too much egg and it rubbers. Add soy, mirin, salt. Strain the mixture through a fine sieve for glassy smoothness. Skim any foam.
2. Divide your garnishes — the rehydrated shiitake, and whichever morsels you are using — among heatproof cups. Pour the custard mixture over, filling each cup about four-fifths full.
3. Steam over *low* heat with the lid slightly cracked (a bamboo steamer is ideal) for 12–15 minutes. Low and slow is essential: a hard steam boils the custard into bubbles and toughness. The custard is done when it barely trembles and a skewer draws clear liquid, not raw egg.

4. Serve warm, with a last sliver of mitsuba or a drop of yuzu if you have it. Eaten with a spoon; it should wobble.

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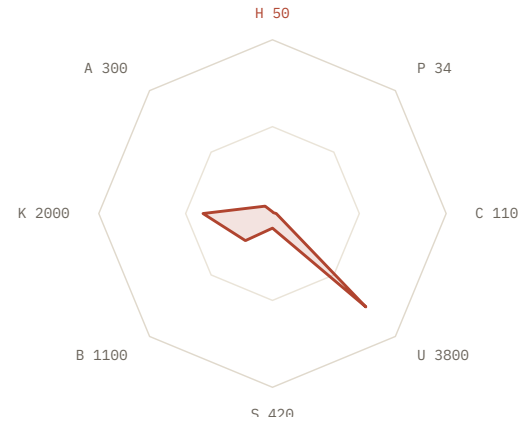

IFI-H	50
IFI-P	34
IFI-C	110
IFI-U	3,800
IFI-S	420
IFI-B	1,100
IFI-K	2,000
IFI-A	300

Chawanmushi — U 3,800, nearly the awase ceiling, delivered in something that barely holds its shape. The dish is almost pure dashi given just enough egg to be eaten with a spoon; it is the clearest argument in the book that umami, not richness or fat, is what makes food feel nourishing. A vegetarian version, built on the shiitake-kombu dashi and garnished with mushroom alone, loses almost nothing on the U axis.

Chapter 9 · Tea & matcha — *theanine, the umami you drink.*

There is umami you sip. A fine Japanese green tea — a shaded *gyokuro*, or a well-made *matcha* — carries a savory, brothy roundness under its vegetal brightness that is unmistakably the fifth taste, and it comes from an amino acid most plants do not make in quantity: L-theanine, a close relative of glutamate. Theanine is why a great green tea tastes of more than astringency and grass; it is the savory sweetness, the mouth-filling calm, the thing a connoisseur means by *the broth* of a tea. And it is the clearest example in this book of a single plant speaking three axes at once — umami from theanine, astringency from catechins, bitterness from caffeine and more catechins — a chord we can engineer note by note.



Tea, in cross-section — a validated host at 280 constructs across the umami, zero-bitter, and astringency axes. The shaded leaf floods with theanine, the umami amino acid; the sun-grown leaf converts that theanine to catechin astringency. We tune the balance directly, lifting theanine and attenuating the catechin bitterness that shading alone cannot fully tame.

The biochemistry of theanine is a quiet marvel and the reason for one of the oldest techniques in tea. Theanine is synthesized in the *roots* from glutamate and ethylamine, then transported up into the leaves. In sunlight, the leaf's enzymes convert theanine onward into catechins — the polyphenols responsible for astringency and much of green tea's bitterness. So theanine and catechin stand at a fork: light pushes the balance toward catechin, shade holds it at theanine. This is the entire logic of *gyokuro* and *tencha* (the leaf that is ground into matcha): the plants are covered with shade cloth for the weeks

before harvest, starved of light, so that theanine accumulates and does not convert. A shaded tea is a high-theanine, low-catechin tea — more umami, less astringency. The farmer has been performing a flux-balance intervention with a tarp for four hundred years.

We perform it in the plant. Across the tea host's 280 constructs — umami, zero-bitter, astringency — we push theanine accumulation (raising the root synthesis and the leaf transport) and, separately, attenuate the catechin and caffeine bitterness on the IFI-B axis, which is anchored to the bitter receptor TAS2R38. Note what that lets us do that shading alone cannot: shading raises theanine but can only so far lower the catechins that are already a mature plant's nature. By tuning bitterness attenuation directly — 20 to 65 percent, in the platform's validated range — we can hold a tea's umami high *and* its astringency gentle without starving it of the light it needs to grow. The result on the three-axis scorecard is a tea with the brothy depth of a top gyokuro and a softened edge, the catechin astringency present enough to structure the sip but quieted below the pucker. We are, in effect, moving the whole three-note chord: theanine up, catechin down, caffeine's bitterness attenuated, each a separate lever on a separate axis of the same leaf.

Matcha deserves a note of its own, because it is the one tea you *eat* rather than steep — the whole leaf, stone-ground to a powder and whisked into suspension, so you consume the theanine, the catechins, and the caffeine entire, nothing left in a spent leaf. This is why matcha's umami is so pronounced and its potential bitterness so real: there is no dilution, no discarding. Good matcha is almost entirely a theanine-and-umami experience with the catechins held in check by shading and grade; poor matcha is a catechin-and-caffeine bitterness. The engineering target is obvious and we have aimed at it — a tea leaf whose ground-whole-leaf profile is theanine-forward and bitterness-attenuated, so that even a modest grade whisks up closer to the ceremonial ideal.

Usucha — thin matcha, whisked

matcha (ceremonial grade)	2 g (about 1 heaping chashaku scoop, ~1 tsp)
water	70 ml, cooled to 70–80 °C (never boiling)
tools	bamboo whisk (chasen), warmed bowl

1. Sift the matcha into the warmed bowl to break up every clump — matcha clumps are the enemy of a smooth bowl, and sifting is not optional.
2. Heat the water and let it fall to 70–80 °C. Boiling water scorches matcha, pulling out harsh catechin bitterness and flattening the theanine sweetness; the temperature is the single most important variable, and most bitter matcha is simply matcha drowned in water too hot.
3. Pour the water over the powder. Whisk briskly in a light W or M motion — not a round stir — for 15–20 seconds, keeping the whisk near the surface, until a fine, even foam rises and no liquid tea shows through.
4. Drink at once, turning the bowl, while the foam holds. The first sip is umami and a vegetal sweetness; the finish is a clean, brief astringency that readies the mouth for the next thing. That arc —

savory open, astringent close — is the tea doing on the palate exactly what a good wasabi does for a plate: resetting it.

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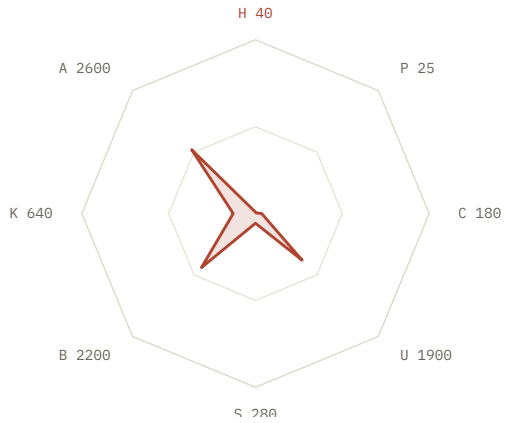


IFI-H	40
IFI-P	25
IFI-C	180
IFI-U	1,900
IFI-S	280
IFI-B	2,200
IFI-K	640
IFI-A	2,600

Usucha from engineered, bitterness-attenuated tea — U 1,900 from theanine, A 2,600 from the whole-leaf catechins that give matcha its structure, and B at 2,200: that B is the attenuation score, the measure of how far we have quieted the catechin and caffeine bitterness that an un-tuned leaf would push past comfort. Read the three high numbers together and you are reading the chord of a great matcha: broth, structure, and a bitterness held exactly where it belongs.

Chapter 10 · Rice — *the grain we built the meal around.*

Everything else in this book is, in a sense, a way of making rice taste better. That is not a diminishment of the other dishes; it is the architecture of the Japanese meal, where rice — *gohan*, a word that also simply means *meal* — is the center and everything else is positioned around it. The miso soup, the grilled fish, the pickle, the simmered vegetable: these are *okazu*, accompaniments, and their saltiness and depth are calibrated against the plain, faintly sweet neutrality of the rice they are eaten with. To understand Japanese cooking you must understand that the blank grain is not a background. It is the thing being seasoned, at a remove, by everything else on the tray.



Rice, in cross-section — the grain the whole meal is built around. Japonica's high amylopectin is the molecular source of the clingy, glossy texture Japanese rice is prized for; the endosperm starch is the canvas every other dish on the tray is seasoning. On the platform, engineered rice is a frontier concept — the Dynasty line — not yet a validated host.

The texture that defines Japanese rice is a matter of two starches in a ratio. All rice endosperm is starch, and that starch is two molecules: amylose, a long straight chain of glucose, and amylopectin, a bushy branched one. Their ratio sets everything about how a cooked grain behaves. High-amylose rice (the long-grain *indica* of a pilaf or a biryani) cooks dry, separate, fluffy — the straight amylose chains retrograde and firm up, keeping grains apart. High-amylopectin rice (the short-grain *japonica* of Japan) cooks moist, glossy, and clingy — the branched amylopectin holds

water and stays soft and sticky, so the grains adhere in tender clumps you can lift with chopsticks or press into sushi. Japanese *japonica* is bred for low amylose and high amylopectin precisely for that cling. Push amylopectin to its extreme and you reach *mochigome*, glutinous sweet rice, so high in amylopectin that it pounds into the chewy paste of mochi. The whole spectrum of rice texture, from a fluffy pilaf to a sticky mochi, is a single knob: the amylose-to-amylopectin ratio.

RICE TYPE	AMYLOSE	TEXTURE	ROLE
Indica (long-grain)	22–28%	dry, separate, fluffy	pilaf, biryani
Japonica (short-grain)	15–18%	moist, glossy, clingy	the Japanese staple; sushi
Mochigome (glutinous)	~0–2%	sticky, chewy, pounds to paste	mochi, sekihan

The cooking is a controlled gelatinization: heat and water swell the starch granules until they burst and set into the familiar tender grain, which is why rinsing (to remove loose surface starch and prevent gumminess), the right water ratio, and a *rest* off the heat (to let the moisture equalize through each grain) all matter so much. A pot of Japanese rice is a starch-physics experiment with a narrow window of perfection.

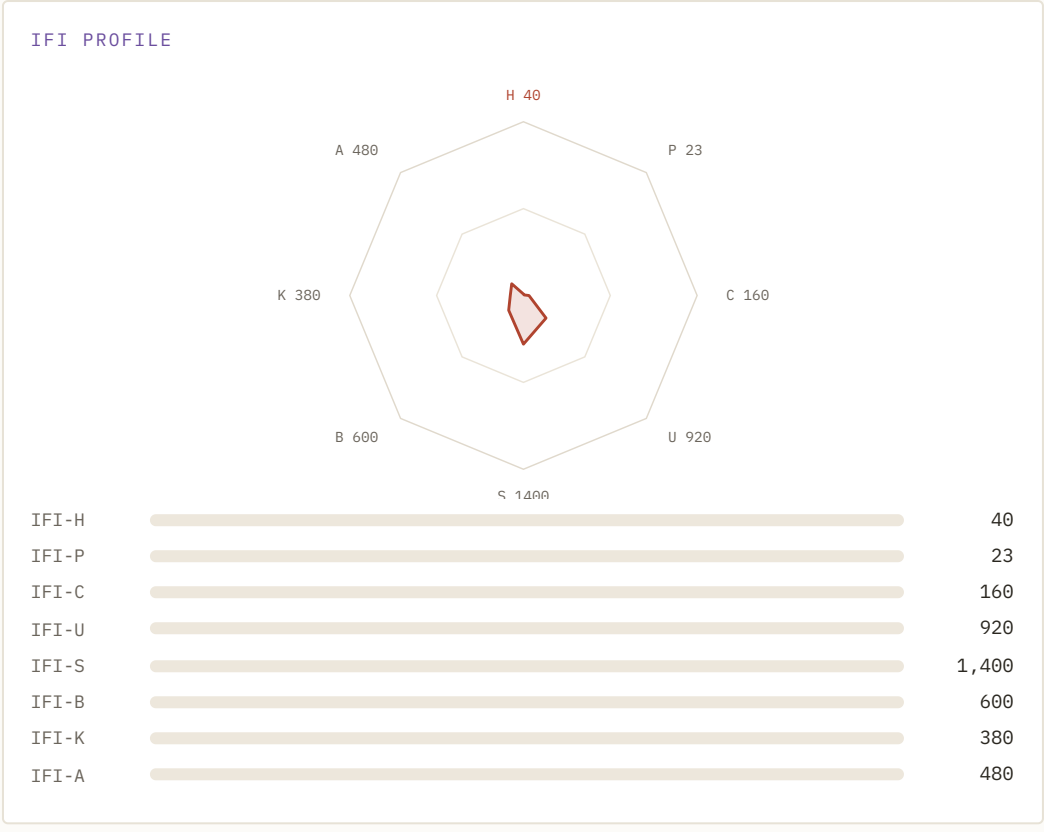
On the platform, rice is a frontier, and we will be honest about that rather than imply more than is true. Rice is not among the forty-two validated hosts; engineered rice lives on the roadmap as a concept — the *Dynasty* line, a tier-four synthetic-pathway ambition measured in years, not seasons. What that line imagines is not a spicier or sweeter rice for its own sake but a grain engineered on the axes that matter to the whole meal: more of its own umami and kokumi so the center of the tray carries flavor rather than only receiving it, and — this is the nourishment frontier, named plainly and claimed as nothing more than an intention — a grain grown to hold more of what the body can draw from it. For now, rice in this book is the one great ingredient we revere without having engineered, and we are content to leave it so while the Dynasty work is only a concept. Some things you build toward slowly, and the staple of half the world is a thing to approach with patience.

The one preparation of rice that is itself a seasoned dish — and the foundation of sushi — is *shari*, sushi rice, where plain cooked japonica is dressed while warm with a vinegar seasoning. Here the rice stops being a blank center and becomes a flavor in its own right: faintly sweet, faintly tart, salted, glossy, cooled to body temperature so it reads as tender rather than hot.

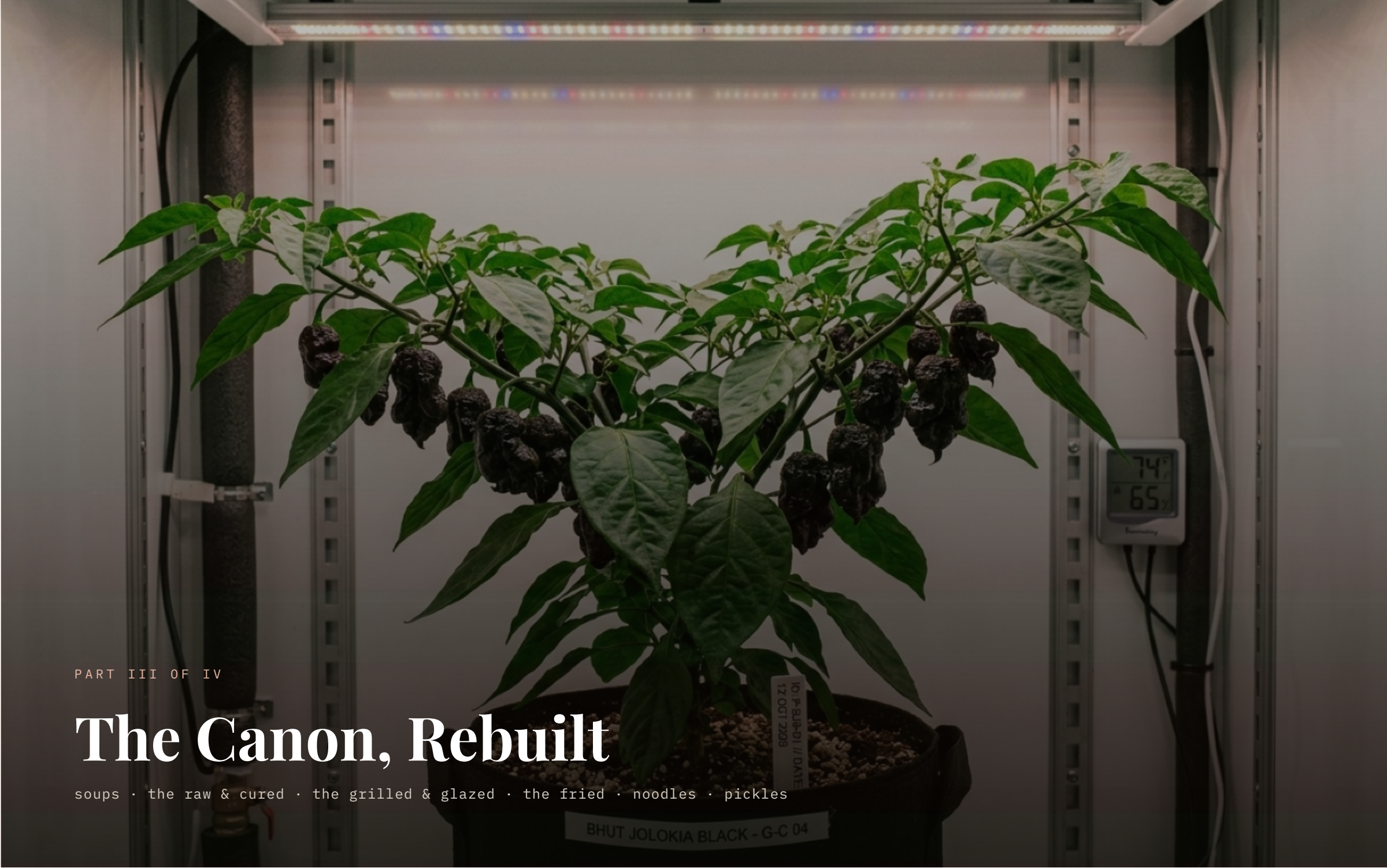
Shari — seasoned sushi rice

```
japonica short-grain rice   300 g (about 1.5 rice-cooker cups)
water                       330 ml (1 : 1.1 by volume, rinsed rice)
— sushi vinegar (awasezu) —
rice vinegar                60 ml
sugar                       2 tbsp
sea salt                    1 tsp
kombu                       a 3 cm square (optional, for umami)
```

1. Rinse the rice in several changes of cold water, swirling and draining, until the water runs nearly clear — this removes surface starch and is the difference between distinct, glossy grains and a gummy mass. Drain well and let it sit 20–30 minutes before cooking.
2. Cook the rice (rice cooker or a heavy lidded pot: bring to a boil, drop to low, 12 minutes, then rest off the heat, covered, 10 minutes — do not lift the lid during the rest; the rest is where the amylopectin finishes setting).
3. Meanwhile, warm the vinegar, sugar, salt, and optional kombu just until the sugar dissolves — do not boil off the vinegar's brightness. Discard the kombu (which has now lent a little glutamate to the seasoning).
4. Turn the hot rice out into a wide, non-metal bowl (a wooden *hangiri* is traditional and wicks moisture). Pour the vinegar over a rice paddle to distribute it, and fold — never stir or mash — with a slicing, cutting motion while fanning the rice to cool it quickly. The fanning gives sushi rice its characteristic sheen and keeps it from going mushy.
5. Use at body temperature. Warm shari against cool fish is the correct and deliberate contrast of a piece of nigiri.



Shari — S 1,400 for the vinegar's sugar and the rice's own sweetness, U lifted toward 920 by the kombu in the seasoning and the rice's native glutamate, A 480 for the clean acetic tartness. This is the seasoned center that every piece of sushi is built on; its job is to be delicious enough to matter and quiet enough to let the fish or the vegetable speak. Balance, as always in this cuisine, is the whole art.



PART III OF IV

The Canon, Rebuilt

soups · the raw & cured · the grilled & glazed · the fried · noodles · pickles

Chapter 11 · Soups & simmered things — *miso, suimono, the gentle pot.*

Now we cook from the pantry we have built. And we begin where the Japanese day begins, with soup — because a bowl of soup, in this cuisine, is not a starter or a comfort but a structural element of the meal, the *shiru* of *ichiju-sansai*, "one soup, three sides," the template that has organized the Japanese table for centuries. Two soups define the range: the everyday miso soup, cloudy and warming and different in every household, and the formal clear soup, *suimono* or *osuimono*, a transparent and exacting thing in which a perfect dashi is shown off naked with two or three beautiful objects suspended in it. The first is home; the second is restraint raised to ceremony. Both are dashi, seasoned two ways.



Eggplant — a validated host, and one of the great vehicles for miso. The flesh drinks a simmering liquid like a sponge and gives back its own silken body; in *nasu dengaku* it meets a sweet miso glaze, in a miso soup it turns to custard. The Dark Matter eggplant line on our roadmap imagines this fruit with real heat folded in.

The technical heart of miso soup is a rule we have met before and now state as law: *never boil the miso.* Miso is a living, aromatic ferment, and a hard boil drives off its delicate aroma compounds, dulls its flavor, and can turn its texture grainy. So the sequence is always the same — build and heat the dashi, cook any hard ingredients (daikon, potato) in it until tender, then pull the pot *off the boil* and thin the miso into the hot-but-not-boiling liquid through a small sieve or against the back of a ladle, so it disperses without

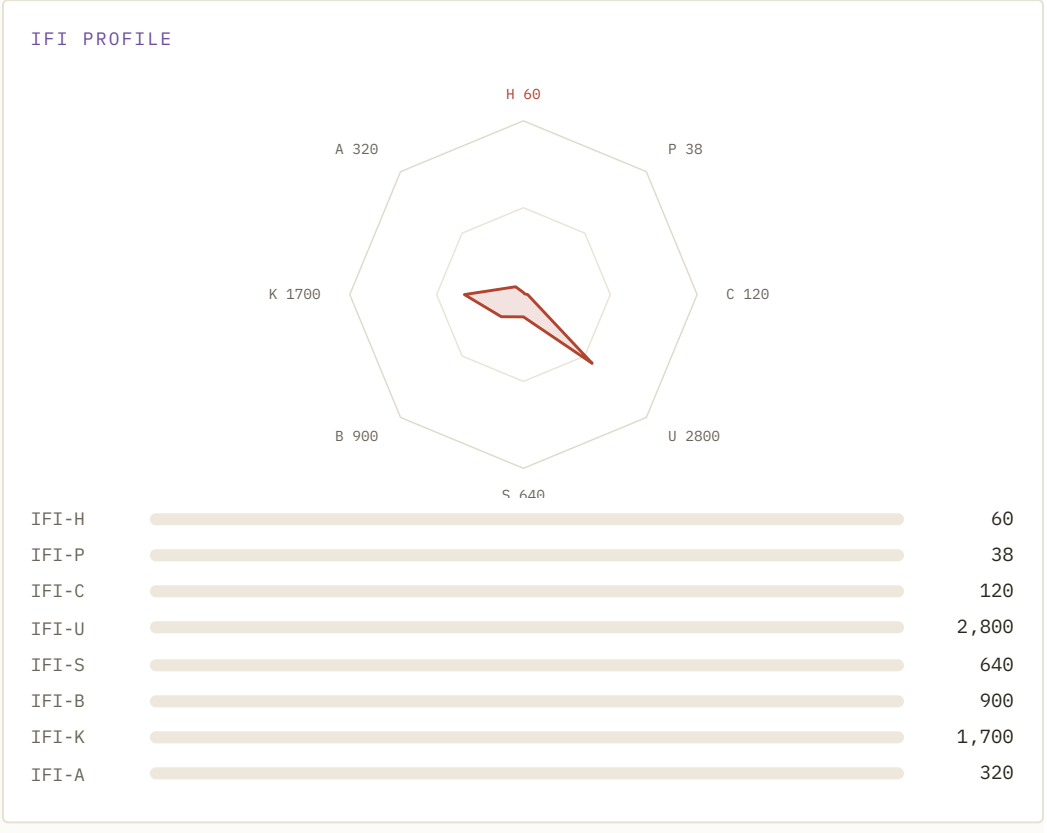
clumping. Add soft ingredients (tofu, wakame, scallion) at the very end, warm them through, and serve. The miso goes in last, off the heat, every time.

Within that rule is infinite variation, because miso soup is a canvas. The *kind* of miso sets the base character (sweet white, balanced yellow, deep red — Chapter 7's table); the dashi sets the depth; and the garnish, the *mi*, sets the season and the household. A winter miso soup might carry daikon and deep red miso; a summer one, silken tofu, wakame, and pale white. What follows is the balanced everyday version, the one eaten more than any other dish in this book, and then its formal opposite.

Everyday miso soup

niban or shiitake dashi	600 ml
miso (yellow Shinshu)	3 tbsp (~55 g), or to taste
silken tofu	150 g, cut in 1.5 cm cubes
dried wakame	1 tbsp, rehydrated 5 min, drained
scallion	1, thin-sliced on the bias

1. Heat the dashi to a bare simmer. If using any firm vegetable, cook it here until tender.
2. Lower the tofu cubes in gently and warm them through — 1 minute, no boil, so they do not toughen.
3. Pull the pot off the heat. Place the miso in a small sieve or ladle held in the liquid and work it through with chopsticks until fully dispersed. Taste; adjust.
4. Add the drained wakame and the scallion. Serve immediately, while the aroma is at its peak — miso soup is at its best in the first two minutes and fades after, which is why it is made to order and not held.



Osuimono — a clear soup, for show

The formal counterpart: a flawless ichiban dashi, seasoned only with a whisper of salt and light soy, carrying two or three exquisitely chosen objects in a bowl you can see the bottom of. There is

nowhere to hide. If the dashi is less than perfect, this soup announces it.

ichiban dashi	600 ml, your best
usukuchi (light soy)	2 tsp
sea salt	1/2 tsp, scant
— to suspend, chosen for beauty —	
a prawn, or a cube of silken tofu	
a leaf of mitsuba or a sliver of yuzu peel	
a single blanched vegetable, cut with care	

1. Warm the dashi gently and season it *subtly* — salt and light soy only, tasting until it is savory and barely salted. The light soy (usukuchi) is used because it seasons without darkening; a clear soup must stay clear.
2. Warm the suspended ingredients separately (a prawn poached, tofu heated in a little of the dashi) so the soup stays limpid.
3. Arrange the objects in a warmed lidded bowl with an eye to composition — this is as much flower-arranging as cooking — and ladle the clear hot dashi over. Float the yuzu or mitsuba last, for aroma.
4. Serve lidded; the diner lifts the lid to a rising curl of citrus-and-sea steam. The soup is drunk from the bowl, the solids eaten with chopsticks.

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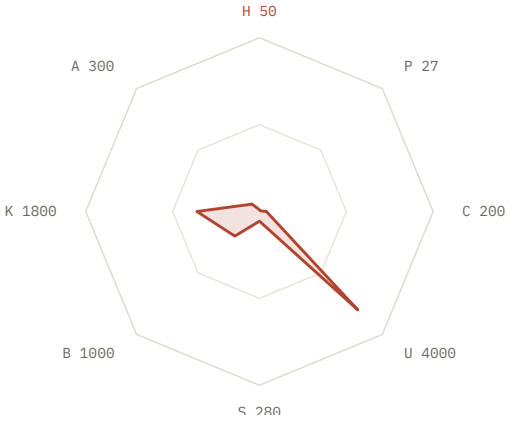

IFI-H	50
IFI-P	27
IFI-C	200
IFI-U	4,000
IFI-S	280
IFI-B	1,000
IFI-K	1,800
IFI-A	300

Osuimono — U 4,000, nearly the awase ceiling, and almost nothing else. This is the dish that proves the thesis of the whole book: that a cuisine which organized itself around umami can build a complete, elegant, memorable course out of clear stock and three beautiful things, needing neither fat nor heat nor richness to satisfy. The C at 200 is the yuzu's cool volatile lift across TRPM8 — a tiny grace note of coolness over the warm savory depth. Restraint, scored.

Chapter 12 · Raw & cured — *sashimi, sushi, and respect as a technique.*

Here we come to the dishes that frighten cooks raised in other traditions, and to a principle that our plant-reverent kitchen holds just as firmly for a fish as for a vegetable: that the highest technique is sometimes the lightest. Sashimi — raw fish, sliced and served with almost nothing — and sushi — that fish or vegetable on seasoned rice — are cuisines of *subtraction*, where the cook's skill is spent not on transformation but on selection, cutting, and the exact calibration of two or three accents around an ingredient left mostly alone. To cook this way is to stake everything on the quality of the thing itself, and to treat it with a seriousness that is, in the deepest sense, reverence. We write the fish here with the same care we write the kelp, because the cuisine does.



Daikon radish — a validated host at 40 constructs on the zero-bitter axis. Shredded into the fine threads of *tsuma* beneath a slice of sashimi, it is texture, palate-cleanser, and a gentle peppery counterpoint at once; its own mild pungency comes from the same isothiocyanate chemistry as wasabi, in a quieter key.

Consider what actually happens when you eat a piece of sashimi with its traditional accompaniments, in the frame of this book's receptors. The fish itself delivers umami — free glutamate, and in a fish aged a day or two, a rising tide of inosinate (the same IMP of dashi, forming in the muscle post-mortem). A dab of real wasabi delivers the sharp, fleeting AITC sting on TRPA1 that both excites the palate and, not incidentally, has genuine antimicrobial properties that the tradition exploited long before it was measured. A dip in soy

sauce delivers a wave of fermented glutamate and kokumi that *synergizes* with the fish's own inosinate — the soy's glutamate multiplied by the fish's IMP, dashi's equation performed on the tongue instead of in a pot. And the shredded daikon, the *tsuma* beneath the slice, cleanses and resets with its crisp texture and faint isothiocyanate pepperiness. Four ingredients, four receptors, one bite — the whole grammar of Part I compressed into a single mouthful of something barely cooked. This is not simple food. It is food of extraordinary technical and sensory sophistication *disguised* as simplicity, which is the highest form of the art.

The cutting is a real technique, worth a paragraph. Sashimi is sliced with a single long pull of a very sharp single-bevel knife — never sawed — because a clean severed cell wall tastes different from a crushed one: a torn surface weeps, oxidizes, and turns the delicate flesh dull and slick, while a cleanly cut face stays bright and holds its texture. The angle and thickness are matched to the fish: a firm white fish is cut thin and on a slant to coax tenderness from it; a fatty tuna is cut thicker to give its richness something to stand on. This is knife-work as flavor engineering, the cut itself a variable in how the ingredient meets the tongue.

Our platform's contribution to this most ingredient-dependent of cuisines is, fittingly, at the edges — in the accompaniments and the one cooked element, the rice. The engineered-mustard wasabi of Chapter 4 brings true AITC to tables that have only ever had dyed horseradish. The daikon above, tuned on the zero-bitter axis, can be grown milder or sharper to suit. The soy sauce, built on our engineered soybean, brings a deeper synergistic glutamate to the dip. And the shari of Chapter 10 is the seasoned foundation. We do not engineer the fish; a wild mackerel at its peak is a thing we would only diminish by touching. What we can do is make everything *around* it a little better, and then get out of the way. That, too, is a kind of respect — knowing which part of a dish is yours to improve and which part to leave alone.

A vegetarian table loses less here than you would expect, because the grammar transfers. A piece of nigiri can carry a marinated shiitake, a sweet simmered squash, a sheet of grilled eggplant, a block of the koji-cured tofu of Chapter 6 — each an umami object on seasoned rice, each dressed with the same wasabi and soy and daikon, each performing the same four-receptor chord with a plant where the fish would be. *Inari* (sweet fried-tofu pouches around rice), *kappa* (cucumber), *oshinko* (pickle) rolls: the raw-and-cured tradition has always had a fully vegetable wing, and it is not a concession but a cuisine. We cook from it with pleasure and without apology.

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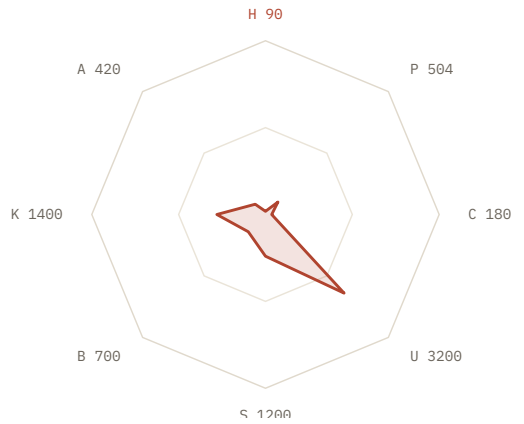

IFI-H		90
IFI-P		504
IFI-C		180
IFI-U		3,200
IFI-S		1,200
IFI-B		700
IFI-K		1,400
IFI-A		420

A piece of mackerel nigiri with the full accompaniment — P 504 from a proper wasabi dab, U 3,200 from the fish's inosinate synergizing with the soy's glutamate and the rice's kombu-seasoning, S 1,200 from the shari. Read the scorecard and you are reading a chord built across four receptors in a single bite — the argument of this book in one piece of nigiri. Rebuild it on a koji-cured shiitake and the U barely moves; the P and S hold; only the source changes.

Chapter 13 · Grilled & glazed — *yakimono, dengaku, the lacquer of sugar and fire.*

Fire changes the rules. Everything in this book until now has been extraction, fermentation, synergy — the slow, cool chemistry of umami. The grill brings the hot chemistry: the Maillard reaction, that vast cascade between amino acids and sugars at high heat that builds hundreds of new roasted, savory, complex aroma compounds found nowhere in the raw ingredient, and caramelization, the browning of sugar itself into bitterness and depth. *Yakimono*, the grilled dishes, are where Japanese cooking turns loud — and where it characteristically disciplines that loudness with a glaze, a lacquer of sweet and savory that both flavors the surface and catches the fire's browning into a glossy, blistered skin.



Eggplant again, in specimen — the canonical canvas for *dengaku*, the sweet-miso glaze. Scored, oiled, and grilled until the flesh collapses to silk, then lacquered with sweetened miso and flashed under the broiler until the sugars blister. Fire's Maillard chemistry over fermentation's umami: the two halves of flavor, on one skewer.

The signature glaze is *dengaku miso* — miso sweetened with sugar and mirin and loosened with a little dashi or sake, painted onto grilled vegetables, tofu, or fish and flashed under high heat until it bubbles and chars at the edges. In the frame of this book it is a designed object: the miso brings fermented umami and kokumi (Chapter 7), the mirin and sugar bring sweetness *and* the sugar for the Maillard reaction and caramelization at the surface, and the high heat builds the roasted aroma compounds that lacquer the whole

thing together. The glaze is sweet, savory, and deeply browned at once — three chemistries (fermentation, caramelization, Maillard) stacked on one surface. It is also a lesson in restraint: the glaze is a thin lacquer, not a sauce; it accents the grilled vegetable beneath, it does not drown it.

The other great glazed form is *teriyaki* — *teri* meaning the glossy shine the glaze gives. True teriyaki is not a bottled marinade but a technique: a reduction of soy sauce, mirin, sake, and a little sugar, simmered to a syrup and brushed onto grilling fish or vegetables in coats, each coat caramelizing before the next, building a layered glossy lacquer. The *teri*, the shine, comes from the reduced sugars and the glaze's thickening; the flavor is the by-now-familiar stack of fermented glutamate (soy), sweetness (mirin and sugar), and Maillard browning. Teriyaki done honestly — reduced in the pan, brushed in coats — is a world away from the sticky sweetness the word has come to mean abroad.

Nasu dengaku — miso-glazed grilled eggplant

Japanese eggplant	2 (or 1 large globe), halved lengthwise
neutral oil	2 tbsp
— dengaku miso —	
red or yellow miso	4 tbsp
mirin	2 tbsp
sugar	1 tbsp
sake	1 tbsp
dashi	1–2 tbsp, to loosen
— to finish —	
toasted sesame seeds; thin-sliced scallion	

1. Score the cut face of each eggplant half in a close crosshatch, cutting into but not through the flesh — this helps it cook through and drink the glaze. Brush generously with oil.
2. Grill, broil, or pan-sear cut-face down first, then skin-side, until the flesh is completely soft and collapsing — eggplant must be fully cooked to reach its silken texture; underdone eggplant is spongy and bitter. This can take 10–15 minutes; do not rush it.
3. Meanwhile, whisk the miso, mirin, sugar, and sake in a small pan and warm gently, loosening with dashi, until it is a thick, spreadable, glossy paste. Do not boil hard.
4. Turn the eggplant cut-face up, spread the dengaku miso thickly over the soft flesh, and flash under a hot broiler (or a kitchen torch) for 1–2 minutes until the glaze bubbles, blisters, and chars at the edges — this final high heat is where the Maillard and caramelization happen; it is the whole point.
5. Finish with sesame and scallion. Serve hot, the flesh scooped from the skin with the glaze.

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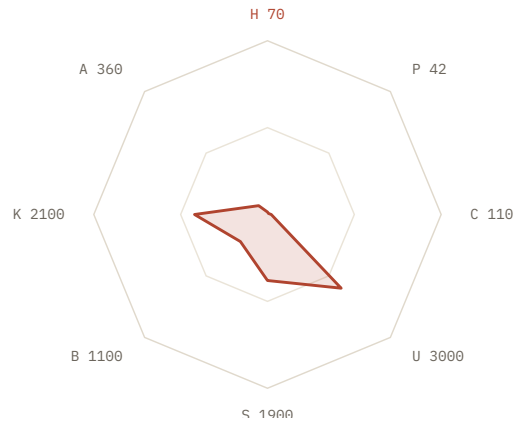

IFI-H	70
IFI-P	42
IFI-C	110
IFI-U	3,000
IFI-S	1,900
IFI-B	1,100
IFI-K	2,100
IFI-A	360

Nasu dengaku — U 3,000 and K 2,100 from the miso, S 1,900 from the mirin and sugar, all lacquered over a vegetable cooked to custard. Read the high S and high U together: this is the swicy principle's gentle cousin, sweet-and-savory rather than sweet-and-hot, and it is one of the most satisfying things a vegetable can be made into. The eggplant brings almost no flavor of its own — it brings texture and a sponge for the glaze — which is exactly why it is the canonical dengaku canvas.

Chapter 14 · Fried & crisp — *tempura, karaage, the weightless crust.*

Japanese frying is defined by a paradox: it is a cuisine of extraordinary lightness that happens to be submerged in hot oil. *Tempura* — seafood and vegetables in a gossamer batter, fried so briefly and at such a precise temperature that the crust shatters like glass and the ingredient inside is barely cooked, still bright and almost raw at the center — is the opposite of heavy fried food, and achieving that weightlessness is a matter of real physics, exactly controlled. Where the grilled dishes were about building flavor with fire, the fried dishes are about building *texture* with fire, and then letting the pure ingredient and a clean dipping sauce carry the flavor.



Pepper, in cross-section — the whole Capsicum genus made legible. A validated host at 1,060 constructs and the platform's native organism; a shishito or a mild green pepper, tempura-fried whole, is one of the gentlest ways heat enters the Japanese table. For a hotter accent, a trace of an engineered cultivar in the tentsuyu lifts a tempura dinner without ever reaching a superhot's register.

The science of a weightless tempura crust is the science of keeping gluten from forming and water from lingering. The batter is flour and cold water (and sometimes egg), and the three rules of it all serve one goal — a crust that is crisp, not bready. First, *cold*: ice-cold water, and often chilled flour, because cold slows the development of gluten, the protein network that would otherwise make the crust tough and chewy. Second, *barely mixed*: the batter is stirred only a few strokes and left visibly lumpy, because overmixing develops that

same gluten; a smooth batter makes a heavy crust. Third, *fresh and fast*: the batter is made at the last second and the frying is brief and hot — around 170–180 °C — so that the water in the thin batter flashes to steam and escapes (the furious bubbling of good tempura frying is water leaving), leaving behind a dry, porous, shatteringly crisp shell, while the ingredient inside, protected by that shell, barely cooks. A weightless tempura is a controlled dehydration: get the water out of the crust fast, before the oil soaks in and before the inside overcooks.

Karaage — Japanese fried chicken, marinated in soy, sake, ginger, and garlic, dredged in potato starch, and double-fried — is the other great fried form, and its lesson is the double fry: a first fry at moderate heat to cook through, a rest, then a second fry at high heat to crisp and color. The potato starch (rather than wheat flour) gives a characteristically light, craggy, glass-crisp crust, because pure starch has no gluten to toughen and fries drier than flour. The marinade — soy's glutamate, ginger's and garlic's pungency, sake's depth — seasons the meat through; this is a dish where the Japanese pantry's umami goes *inside* the ingredient before it is fried. We write it, as ever, with full respect for the bird; a well-made karaage is a serious thing.

Vegetable tempura with tentsuyu

— to fry —	
assorted vegetables:	shiitake, Japanese eggplant, shishito pepper, sweet potato, lotus root, shiso leaf, etc.
— batter —	
cake/low-protein flour	100 g, chilled, + extra for dusting
ice water	160 ml, ice-cold
egg yolk	1 (optional, for colour & crispness)
— tentsuyu (dipping sauce) —	
dashi	200 ml
light soy sauce	50 ml
mirin	50 ml
grated daikon & ginger	to serve
oil for frying	to 175 °C

1. Make the tentsuyu first: warm the dashi, soy, and mirin together to a simmer, then cool. Serve with a mound of grated daikon and ginger stirred in at the table — the daikon's enzymes and fresh pungency cut the richness of the fried food.
2. Prep the vegetables dry; pat off every drop of surface water (water is the enemy of crisp). Dust each piece lightly with flour so the batter grips.
3. At the last moment, make the batter: whisk the yolk into the ice water, then add the chilled flour and stir only 8–10 strokes with chopsticks. Leave it lumpy. Do not let it rest — use it now.
4. Heat the oil to 175 °C (a drop of batter should sink slightly then rise and sizzle). Dip each vegetable in the batter, let the excess fall away, and slip it into the oil. Fry in small batches — crowding drops the temperature and makes greasy tempura — for 1–3

minutes until the crust is pale gold and the furious bubbling has quieted (quieting bubbles mean the water is gone and the crust is dry).

5. Lift to a rack (never paper-line in a pile; tempura steams itself soggy) and salt lightly. Serve at once with the tentsuyu. Tempura waits for no one.

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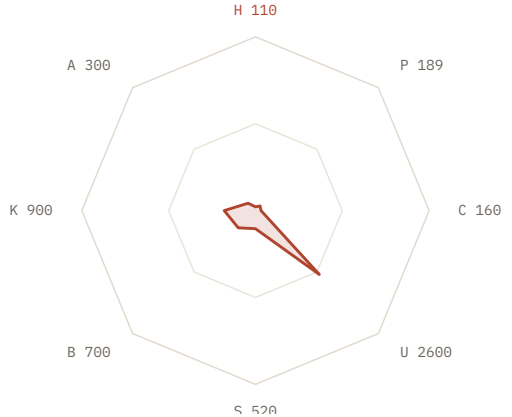


IFI-H		110
IFI-P		189
IFI-C		160
IFI-U		2,600
IFI-S		520
IFI-B		700
IFI-K		900
IFI-A		300

Vegetable tempura with tentsuyu — the scorecard is mostly the dipping sauce, because that is the design: a near-flavorless crisp crust, a bright barely-cooked vegetable, and all the umami (U 2,600) concentrated in the dashi-based tentsuyu you dip into, lifted at the table by the fresh pungency (P 189) of grated daikon and ginger. The vegetable is texture and freshness; the sauce is flavor; the crust is only architecture. Lightness as a whole philosophy of frying.

Chapter 15 · Noodles & broth — *ramen, udon, soba, and umami at full volume.*

If the clear soup of Chapter 11 was umami at its most restrained, the noodle bowl is umami at full volume — and nowhere more than in ramen, which is, viewed through this book's lens, the most aggressive stacking of umami synergy in the entire cuisine, a deliberate maximization of everything Part I described. Where a formal dashi whispers, a bowl of ramen *shouts*, and it shouts in the exact language of glutamate and inosinate and guanylate layered on top of one another until the savoriness is almost overwhelming. To understand ramen is to understand the synergy equation pushed to its ceiling on purpose.



Garlic, whole — the aromatic engine of a ramen bowl's *tare* and oils, and a validated host at 560 constructs on kokumi and pungency. Burnt-garlic oil (*mayu*), raw grated garlic, confited cloves: the allium's γ-glutamyl kokumi and alliin pungency are layered into ramen as deliberately as the broth's umami. A bowl of ramen is an exercise in stacking receptors.

A serious ramen is built in layers, and each layer is a separate umami source chosen to synergize with the others. The *broth* might be a pork or chicken stock (glutamate and, from the long-simmered bones and meat, inosinate) often fortified in the modern style with a *dashi* element — kombu for glutamate, dried sardine (*niboshi*) or katsuobushi for more inosinate, dried shiitake for guanylate. This is the famous *double soup* (*W-soup*) technique: an animal broth and a seafood-mushroom dashi combined precisely so that the glutamate

of one meets the inosinate and guanylate of the others, multiplying. The *tare* — the concentrated seasoning base in the bottom of the bowl, soy-based (*shoyu*) or miso or salt (*shio*) — adds another massive dose of fermented glutamate and kokumi. The *aroma oil* carries garlic, scallion, or the burnt-garlic *mayu*. And the toppings pile on more: a soy-marinated egg, pork, more scallion, nori (glutamate), menma. Count the umami sources in a single bowl — animal inosinate, kombu glutamate, niboshi inosinate, shiitake guanylate, shoyu glutamate, nori glutamate — and you are looking at a receptor-level composition of real complexity, every component chosen to multiply the others. Ramen is Yamaguchi's equation weaponized.

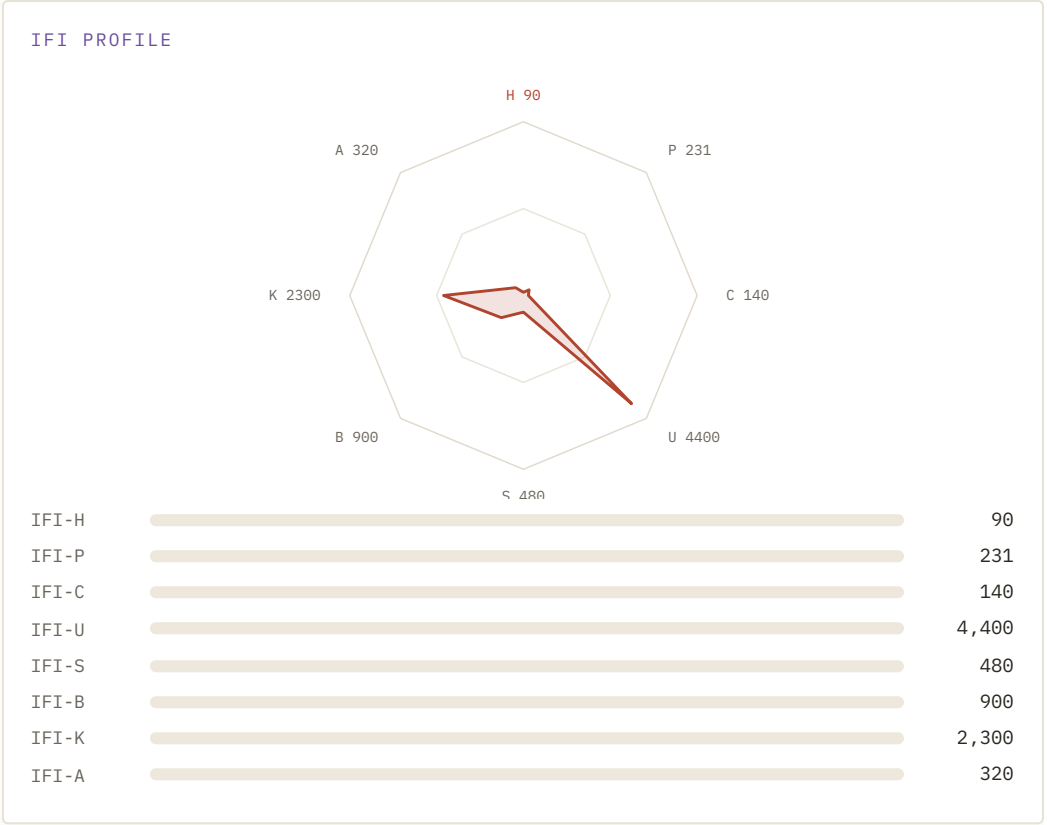
The quieter noodle traditions deserve their due. *Udon* — thick, soft wheat noodles in a lighter dashi broth, often the kombu-and-katsuo dashi seasoned simply — is the gentle counterpart, a bowl where the noodle's chew and a clean dashi are the whole pleasure. *Soba* — buckwheat noodles, nuttier and more structured, served hot in dashi broth or cold with a concentrated dipping *tsuyu* — carries its own faint grain bitterness and, in the cold preparation, is one of the purest expressions of a good dashi-soy-mirin balance there is. And the water the soba cooked in, *sobayu*, is traditionally drunk mixed with the leftover dipping sauce at the end — nothing wasted, the starchy cooking water turned into a final warm broth. The thrift of this cuisine runs all the way to the bottom of the bowl.

Where does heat enter? Gently, and from our shelves when a cook wants it. Japanese noodle bowls are not, traditionally, spicy — but the modern bowl welcomes a chili oil (*rayu*), a spoon of *la-yu* with its sesame and chili, or a hit of *shichimi togarashi*, the seven-spice blend. Here, and only here in this restrained cuisine, our pepper platform's range comes forward — not the superhot flagships, which would obliterate a delicate bowl, but a measured heat. A *rayu* built on a milder engineered pepper, or the barest trace of a cultivar like Ember (SS-0087) bloomed into sesame oil for a disciplined 2-of-8-axis warmth, lets a cook lay a thread of capsaicin heat across the glutamate flood without drowning it. The art is proportion: in a bowl this savory, heat is a seasoning, not the subject.

Shoyu ramen broth — the double soup

```
— seafood-mushroom dashi (the vegetarian half) —
kombu                        20 g
dried shiitake               4 caps
niboshi (dried sardine)      20 g  [omit for vegetarian]
water                        1,200 ml
— animal broth (or second mushroom-kombu draw for vegetarian) —
chicken backs/wings          500 g  [or 300 g more mushroom + kombu]
scallion, ginger, garlic     aromatics for the pot
water                        1,200 ml
— shoyu tare (per bowl) —
soy sauce                    2 tbsp
mirin                        1 tsp
sake                         1 tsp
— aromatic oil —
garlic + scallion in 2 tbsp sesame oil, warmed
— to serve —
ramen noodles; soy egg; greens; nori; scallion
```

1. Make the dashi: soak kombu, shiitake, and niboshi in the cold water several hours, then warm to a bare simmer, pull the kombu, and strain. This is your glutamate-and-nucleotide half.
2. Make the broth: simmer the chicken (or the extra mushroom and kombu, for a fully vegetarian double soup) with aromatics 2–3 hours, skimming, then strain. This is your inosinate-rich half.
3. Combine the two broths roughly 1:1 and taste — this is the double soup, the glutamate of the dashi now multiplying the inosinate of the broth. Adjust strength with water.
4. In each warmed bowl, put the shoyu tare — soy, mirin, sake — then ladle in the hot combined broth and stir. The tare is the final glutamate-and-salt layer; the broth is the synergy; together they are the bowl.
5. Cook and drain the noodles, lift them into the broth, and top: a halved soy-marinated egg, greens, a sheet of nori, scallion, a thread of warmed garlic oil. Eat immediately, noodles first, while they are taut.



Shoyu ramen — U 4,400, the loudest umami in this book, past even the awase dashi, because ramen is the one dish engineered to stack every synergy partner at once: kombu and shoyu glutamate, niboshi and chicken inosinate, shiitake guanylate, all multiplying in one bowl. K 2,300 from the garlic and the long-cooked broth. The fully vegetarian double soup — mushroom-and-kombu on both sides — lands near U 4,000, a hair quieter and still a roar. This is umami with the volume knob turned all the way up, and it is glorious.

Chapter 16 · Pickles & ferments — *tsukemono, the fourth plate.*

The Japanese meal ends, almost always, with something pickled — a few slices of bright, crunchy, sour-salty *tsukemono* that reset the palate, aid the digestion of the rice, and provide the final counterpoint of acid and crunch against everything soft and savory that came before. *Tsukemono* are not an afterthought; they are a structural element, the near-silent fourth voice of a meal, and they span a range from a quick salt-pickle made in an hour to a deep fermented pickle aged for months in a living bed of rice bran. In the frame of this book they are a tour of several axes at once — the sourness of lactic fermentation, the pungency of mustard and ginger, the bitterness-attenuation of a quick-cured brassica — and they are, quietly, among the most nourishing things on the tray.



Cucumber — one of the great quick-pickle vegetables, salt-pressed into *asazuke* in under an hour or fermented longer into something deeper. Crisp, cooling, faintly bitter; the fourth plate's fresh green note. In a cuisine of warm savory depth, the pickle is the bright, sharp punctuation at the end of the sentence.

The deepest tsukemono tradition is *nukazuke*, the rice-bran pickle, and it is a genuine living ferment worth understanding. A *nukadoko* is a bed of roasted rice bran, salt, and water, inoculated and tended until it teems with lactic acid bacteria and yeasts — a stable microbial community, fed daily, that can live for years or generations (famous nukadoko are handed down like sourdough starters). Vegetables buried in the bed for a day or two emerge transformed: the bacteria have fermented them to a tangy sourness, the bran has lent B vitamins and a nutty depth, and the enzymes have deepened

their flavor. The gardener's secret is that the bed must be *turned by hand* every day — mixing oxygen through it keeps the right microbes dominant and the wrong ones down — so a nukadoko is a pet, a daily tending, a relationship. It is also a nutrition story: lacto-fermented vegetables carry live cultures and the bran enriches them, which is a fact we state as a fact and attach no promise to. The tradition built these pickles to make vegetables keep and to make a plain bowl of rice into a meal; that they are also living and nutritious is the kind of quiet gift this cuisine is full of.

The quick pickles are a cook's everyday tool. *Asazuke* — "shallow pickle" — is vegetables salted and pressed for under an hour, drawing out water and concentrating flavor into something crisp and lightly sour. *Sunomono* is a vinegar dressing. *Karashizuke* uses mustard. And here our pungency platform returns: the engineered mustards of Chapter 4, the daikon of Chapter 12, the ginger that pickles into the bright pink *gari* beside sushi — all carry the isothiocyanate and gingerol pungency that gives so many tsukemono their lift. A pickle is where the sharp finish and the sour counterpoint meet.

Quick cucumber asazuke with ginger

Japanese or Persian cucumber	3 (about 300 g)
sea salt	1 tsp
kombu	a 3 cm square, cut in fine threads
fresh ginger	1 tbsp, fine julienne
rice vinegar	1 tsp
chili thread or shichimi	a pinch (optional)

1. Rub the cucumbers with salt and roll them on the board (*itazuri*) — this sets the color, softens the skin, and starts drawing water. Cut into thin bias slices or smash and tear into craggy pieces (smashing opens more surface for the cure).
2. Toss the cucumber with the salt, kombu threads, and ginger in a bowl. Press under a weight (a plate with a can on top, or a Japanese pickle press) for 30–60 minutes. Water will weep out; this is the cure concentrating the vegetable.
3. Squeeze out the excess liquid with your hands. Dress with the rice vinegar and, if you like, a pinch of chili thread or shichimi for a thread of heat.
4. Serve cold, in small quantity, as the fourth plate — a few bright, crunchy, salty-sour, gently pungent slices to end the meal and reset the mouth.

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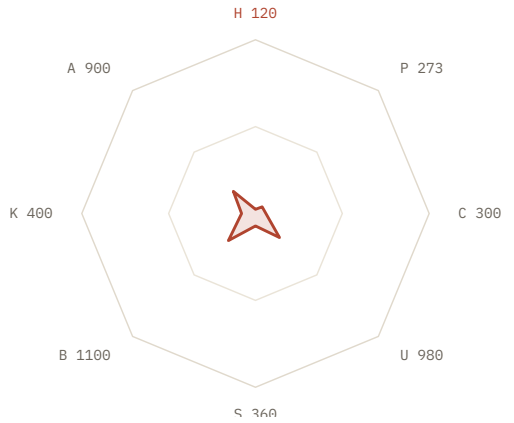

IFI-H		120
IFI-P		273
IFI-C		300
IFI-U		980
IFI-S		360
IFI-B		1,100
IFI-K		400
IFI-A		900

Cucumber asazuke — P 1,300 from the ginger and optional chili, A 900 and the acetic brightness for the vinegar, U lifted toward 980 by the kombu thread. This is the smallest-scored dish in the book and one of the most necessary: in a meal built on warm savory depth, the pickle is the cold, sharp, sour exclamation point that makes you ready to eat the whole thing again. Nothing on the tray is wasted; even the punctuation is engineered.



PART IV OF IV

The Frontier & the Table

the engineered kaiseki · washoku and the body you are feeding

Chapter 17 · The engineered kaiseki — *a seasonal menu scored on eight axes.*

Kaiseki is the summit of Japanese cooking — a multi-course seasonal tasting menu, descended from the meal served before the tea ceremony, in which each small course is chosen for its season, its technique, its vessel, and its exact place in a progression that is composed the way music is composed. A kaiseki is not a pile of good dishes; it is a *sequence*, built on contrast and balance and the arc of a meal, where a clear soup follows a raw course follows a grilled course in a deliberate rhythm of light and rich, cool and warm, sharp and round. It is, in other words, a composition on exactly the axes this book has spent its length describing — and so it is the perfect place to show what it would mean to compose a Japanese meal not by intuition alone but with the Iyengar Flavor Index open on the counter beside the knives.



The controlled environment where a frontier cultivar is proven before it is ever cooked. A kaiseki composed on the Index treats the whole menu as a single eight-axis object: each course a chord, the sequence a progression, no two courses loud on the same axis in a row. The platform's forward concepts — Volcanic tomato, Dark Matter eggplant, Dynasty rice — are imagined here for a Japanese table that does not yet exist.

Composing on the Index means treating the menu as a single eight-axis object and the courses as its movements. The principle is *contrast across the sequence*: no two consecutive courses should be loud on the same axis, because the palate tires of a repeated note and thrills to a new one. A high-umami clear soup should not follow a high-umami custard; a sharp-pungent course wants a round-kokumi course on either side of it to frame its sting; a sweet-

glazed grilled course needs an astringent or sour palate-reset before the next savory wave. Read down the IFI column of a well-built kaiseki and you should see each axis rise and fall like a voice in a fugue, no voice shouting twice in a row, the whole thing resolving. Here is a spring menu composed that way, each course scored, the progression designed:

#	COURSE	DISH	LOUD AXES	IFI READING (H/P/C/U/S/B/K/A)
1	Sakizuke (opener)	Chilled tofu, engineered-mustard accent	P, K	60 / 441 / 240 / 1800 / 300 / 900 / 1600 / 280
2	Suimono (clear soup)	Osuimono, best ichiban dashi, yuzu	U, C	50 / 27 / 200 / 4000 / 280 / 1000 / 1800 / 300
3	Mukozuke (sashimi)	Sashimi, real wasabi, soy	P, U	90 / 504 / 180 / 3200 / 300 / 700 / 1400 / 420
4	Takiawase (simmered)	Shiitake & spring vegetables in niban dashi	U, K	60 / 34 / 110 / 3000 / 520 / 1000 / 1900 / 340
5	Yakimono (grilled)	Nasu dengaku, miso-glazed	U, S, K	70 / 42 / 110 / 3000 / 1900 / 1100 / 2100 / 360
6	Agemono (fried)	Vegetable tempura, tentsuyu	U, P	110 / 189 / 160 / 2600 / 520 / 700 / 900 / 300
7	Gohan & kō no mono	Rice, miso soup, tsukemono	U, A	90 / 273 / 220 / 2800 / 640 / 1100 / 1700 / 900
8	Mizumono (dessert)	Matcha, engineered-tea; a sweet-bean sweet	A, S, U	40 / 25 / 180 / 1900 / 1400 / 2200 / 640 / 2600

Read the menu as a single composition and the design reveals itself. The pungency axis (P) spikes at course 1 (mustard-accented tofu), falls to near silence through the soup, spikes again at course 3 (wasabi with the sashimi), recedes, and returns softened at courses 6 and 7 — a pungent voice that enters, rests, re-enters, never twice in a row. Umami (U) runs high throughout, as it must in this cuisine, but it *peaks* at the clear soup (course 2, U 4,000) where it is the whole point, then deliberately steps down and varies so the diner never adapts to one level. Sweetness (S) is held back entirely until the glazed course 5 and the dessert, so its two appearances land. Astringency (A) is saved almost entirely for the final matcha (course 8, A 2,600), the tea's catechins arriving as the meal's clean closing note, resetting a palate that has been warm and savory for an hour. No axis shouts twice consecutively; every axis gets its moment; the sequence resolves on the cool astringent clarity of a whisked bowl of green tea. That is kaiseki composed as a chord progression, and the Index is the score.

The frontier enters this menu as possibility. The dishes above are cookable today from the pantry of Parts II and III. But our roadmap holds sixty-four concept organisms imagined for tables that do not yet exist, and several were conceived with a cuisine like this one in mind. The *Volcanic* tomato line — Ember, Magma, Pyroclast, Caldera, Krakatoa — imagines a Solanaceae-core fruit with real engineered heat folded into its restored umami, a tomato that could bring both glutamate and a measured capsaicin warmth to a simmered course. The *Dark Matter* eggplant — Smolder, Nightshade,

Eclipse, Obsidian, Event Horizon — imagines the dengaku canvas with its own heat, a nasu that smolders. The *Dynasty* rice is the long-horizon ambition of a staple grain engineered on its own umami and nourishment. None of these is validated; all are concept, measured in years and tiers, honest frontier. But a kaiseki is a form that has always welcomed the new seasonal ingredient as its organizing delight, and when these cultivars move from concept to host, they will have a table already composed and waiting for them — an eight-axis menu with an empty chair at exactly the course each was designed to fill.

Chapter 18 · Washoku — *one soup, three sides, and the body you are feeding.*

We end where the Japanese meal has always ended its thinking: with the whole, and with the body it is for. *Washoku* — Japanese cuisine, recognized by UNESCO as an intangible cultural heritage — is not finally a collection of dishes but a *structure*, and the structure carries a wisdom about nourishment that this book has been circling from its first page. The traditional meal is *ichiju-sansai*: one soup, three sides, and rice. A bowl of rice at the center. A soup — the miso or the clear dashi. And three okazu, three accompaniments, conventionally built around three techniques and a spread of ingredients: something grilled, something simmered, something raw or pickled. It is a template, and like all the best templates it is secretly an argument about how to eat.



Where the day's questions get asked and the long work gets done — the greenhouse before the light. The computing that built this platform was one pair of hands; the table it is all for belongs to the whole family. Washoku is a structure for feeding people well, and that is the only thing we have ever been trying to engineer.

Look at what *ichiju-sansai* quietly enforces. A plate built around rice and vegetables, with protein as one component rather than the center, and with umami — not fat, not sugar, not quantity — carrying the satisfaction. The soup makes the meal feel complete on little. The pickle aids digestion and adds the live cultures of ferment. The variety of three small sides delivers a spread of nutrients that no single large dish would. The portions are modest, served in small vessels, composed to be looked at — and there is an Okinawan

phrase, *hara hachi bu*, eat until you are eight parts of ten full, that names the restraint the whole structure encourages. None of this is health advice and we offer it as none. It is simply the observation, which anyone can make, that a cuisine organized around umami is a cuisine that does not *need* the heavy levers — the salt, the fat, the sugar, the sheer volume — that other traditions lean on to satisfy, because it reaches for a different lever, the fifth taste, which satisfies without them. That is the deepest reason this book has been, from the start, a book about the body as much as the tongue.

This is where our family's work and this cuisine's wisdom turn out to be the same work. We build organisms that carry more of their best flavor and more of their best nourishment at once, because on the axes that matter most here they are not separable — the glutathione that is kokumi is also the cell's own antioxidant; the theanine that is a tea's umami is also its calm; the free glutamate that makes a vegetable satisfying is the amino acid your body runs on. When we tune a soybean to arrive at fermentation richer in glutamate, or a shiitake to yield more guanylate on drying, or a tea to hold its theanine high and its bitterness attenuated, we are doing, with a protein language model and a flux-balance solver and CRISPR, the thing the Japanese kitchen has done with kombu and koji and patience for four hundred years: making the plant speak its most nourishing self more loudly. Forty-two organisms validated, each held to a batch-to-batch consistency at or under seven percent, every one scored on the same eight axes so a cook can read them like a score. Twenty-one peer-reviewed papers behind the method, open under a Creative Commons license, because a standard for measuring flavor is only worth anything if everyone can check our arithmetic. These are computational designs; Scoville Splice's cultivars and constructs have not been experimentally validated in a laboratory. The computing that built all of it was, truthfully, one pair of hands at a keyboard. The table it was always for belongs to all of us.

Make the dashi. That is where we started and it is where we will leave you, because it is the whole book in a pot: kombu's glutamate and a nucleotide's synergy, extracted into clear water in fifteen minutes, a savoriness complete enough to build a meal on and clean enough to let everything else speak. Steep the kelp below a simmer. Pull it before the boil. Add the katsuobushi or the dried shiitake off the heat. Strain without pressing. Taste it warm and unsalted and notice how full your mouth feels from so little — glutamate finding a receptor, a nucleotide holding the trap shut, a taste named in Tokyo in 1908 and felt in every kitchen for a thousand years before that. Then build your meal around it: one soup, three sides, a bowl of rice, a few bright pickles, and whatever the season set in front of you, cooked with reverence and seasoned with a light hand because the dashi did the heavy work.

That is *washoku*, and that is us: a family of scientists who revere what they grow, writing about the mathematics of a bowl of broth the way you would write about something you love and want to nourish you. Ikeda was right for ninety-two years before the biology agreed.

The cuisine was right for four hundred. We are only the latest to arrive at the kelp with a question, and the first to bring a number. Set the number down, keep the reverence, and eat well.