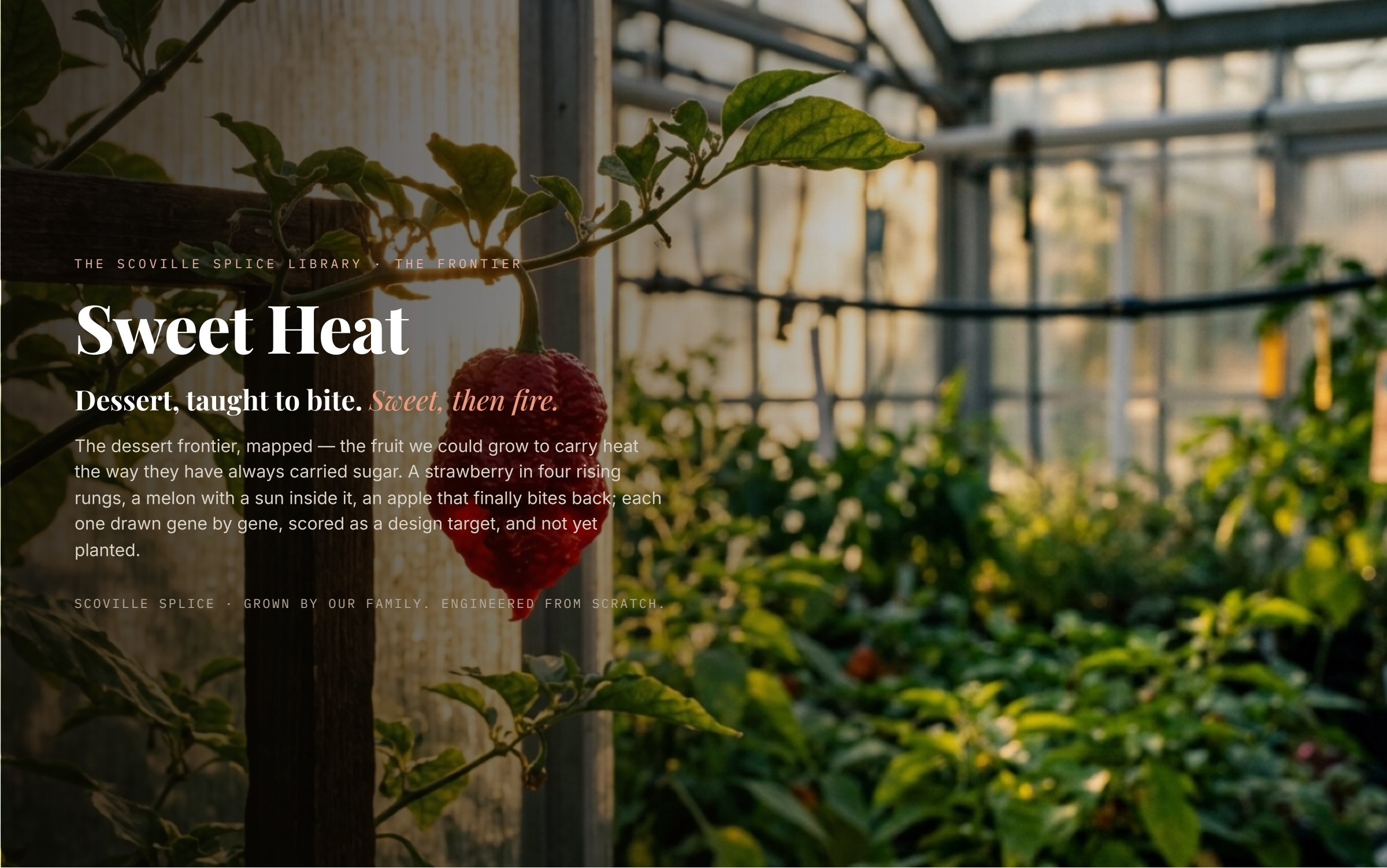

THE SCOVILLE SPLICE LIBRARY · THE FRONTIER

Sweet Heat

Dessert, taught to bite. *Sweet, then fire.*

The dessert frontier, mapped — the fruit we could grow to carry heat the way they have always carried sugar. A strawberry in four rising rungs, a melon with a sun inside it, an apple that finally bites back; each one drawn gene by gene, scored as a design target, and not yet planted.

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

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Opening essay · The sweet end of the frontier

It began, the way most of our arguments do, at the table. A child had been handed a bowl of strawberries and a corner of very dark chocolate, and somewhere between the two she asked the question this whole book is an answer to: *why can't the strawberry just be the spicy part?* Not the chocolate beside it, not a chili flake shaken over the top — the berry itself, sweet and warm at once, the two sensations arriving in the same bite from the same fruit.

We did not have a good reason to tell her no. We had only a habit. For ten thousand years heat lived in the pepper and sweetness lived in the fruit, and the one time a cuisine wanted both it reached for two plants and set them side by side — chili and mango, honey and cayenne, chocolate and chile, the whole beloved tradition the internet now calls *swicy.* Hot honey on a biscuit. Chamoy on a slice of melon. Tajín on the rim of a glass. It is one of the oldest and happiest pairings there is, and every version of it is an arrangement between two organisms. A property of the plate, never of the plant.



Dawn in the research greenhouse, where the question that became this book was first asked out loud.

That line — the family line between the nightshade that makes heat and the rose that makes the strawberry — is exactly the line this book crosses. And it turns out to be a thinner line than ten thousand years of habit would suggest. Heat is not, as it happens, a pepper's possession. It is an event at a single receptor, TRPV1, the same ion channel the body keeps for actual fire and for the warmth of a sun-hot stone. Sweetness is an event at another, the TAS1R2·TAS1R3 pair that only hears the word *sweet* when both of its halves are moved at once. Two doors, two conversations, two entirely separate nerves carrying the news to the brain — and no reason on Earth the two cannot happen inside the same fruit except that no fruit had ever been asked. The chemistry that builds capsaicin runs, in its first and longest stretch, through the cells of a strawberry already. What a

pepper owns is only the last four steps. And steps, we have learned across sixty-four plants and nearly nineteen thousand constructs, can be moved.

This is the dessert frontier — Tier 3 of the sixty-four-plant roadmap, the ring where our method finally crosses out of the nightshades and into the fruit bowl. Three fruit anchor it. The strawberry we call **Sweet Heat,** drawn as a ladder of four rising rungs from Warm Kiss to Devil's Dessert, a sweet warmth you can dial from a child's first taste to a chilihead's dare. The **Solar Melon,** a sun written into the coolest, most watery flesh there is, fire and ice held in the same bite by two touch-receptors set deliberately against each other. And the **Forbidden Apple,** the oldest symbol we have of fruit and of temptation both, redrawn so that the temptation finally has teeth. None of them is anywhere near the pepper. All of them are reachable by the same loop that built our hottest one.

The craving is not new, and it is not narrow. Nearly every cuisine that ever held both a chili and a sweetness found its way to the pairing and gave it a name. Mexico rims its fruit with Tajín and drowns it in chamoy — salt and chili and tamarind over mango, melon, cucumber. China sheathes hawthorns and strawberries in a hard caramel shell and calls it tanghulu, and chili-crisps its way through nearly everything else. Thailand balances *nam chim* and sweet chili against palm sugar until hot and sweet read as a single flavor. India folds green mango with chili and jaggery into *achaar;* Italy suspends candied fruit in a mustard-hot syrup and calls it *mostarda;* Korea's *tteokbokki* is sweet and fierce in the same spoonful; and the American table, late to the party, has spent a decade pouring hot honey over everything it owns. Across all of it runs one structure and one limitation: two organisms, set side by side. A chili grown in one field and a sweetness grown in another, married on the plate by a cook. The craving is universal. The fruit that could satisfy it from a single skin has simply never existed — until, on paper, now.

This book is built in five movements, and it is honest about the ground each one stands on. First, the two senses themselves: why sweet and heat frame each other rather than cancel, read receptor by receptor. Then the engineering: how a terminal cassette of four enzymes crosses the family line into a fruit, and how the fruit's sweetness is lifted to meet it. Then the fruit, drawn one at a time, every scorecard marked plainly as a target. Then the table: plates we have cooked only on paper, for the makers who will build with these fruit the day they are real. And last, the frontier ahead — what the method refuses to do, what the law will ask of it, and the quiet thing that hums under every book of ours, which is that a fruit grown toward its fullest flavor is grown, by the same cellular logic, toward its fullest self.

One honest thing, said once and clearly, before the reverence begins. These fruit are *drawn,* not grown. They are designs on the platform — seven to ten genes each, three to four years out — and every scorecard you will read for them is a **target:** the specification we are aiming at, not a measurement of anything you can yet hold. We mark each one as exactly that, on the page where it appears, because the line between the fruit you can grow and the fruit you

have only drawn is the line this whole library guards most carefully. But drawn is not the same as dreamed. Each of these has a receptor, a pathway, a named enzyme for every step, a gene count, and a date. And the proof that the aim is real lives in a fruit that *is* real — a pepper where we have already written all eight sensations into one plant on purpose, sweetness among them. We will show you that one first, with its SKU, and then build the whole sweet frontier on the ground it stands on. This is the sweet end of the map, surveyed the way you would survey a coastline you fully intend to reach.



PART I OF V

Two Doors

Why sweetness and heat were never competing for the same ear — TRPV1 · TAS1R2·TAS1R3

Chapter 1 · Two Channels, One Bite — *why the two were never really strangers.*

THE PAIRING · TAS1R2·TAS1R3 (taste) × TRPV1 (touch)

Put a little heat behind a sweet thing and the sweetness gets *louder.* Every cook knows it; hardly anyone can say why. A ribbon of chili in a mango, a crack of black pepper over strawberries, cayenne stirred into the honey — in each the fruit seems to ripen a half-step further the instant the warmth arrives. The explanation is not folklore and it is not synergy in any vague sense. It is anatomy. Sweetness and heat were never competing for the same ear, and so they cannot cancel. They can only frame each other.

Start with the two doors themselves, because the entire design philosophy of this book descends from the fact that they are different doors. Sweetness is a *taste* — a chemical sense, read by specialized receptor cells clustered in the taste buds of the tongue and soft palate, wired to the brain through the facial and glossopharyngeal nerves, the seventh and ninth cranial nerves. Heat, as capsaicin delivers it, is not a taste at all. It is a *touch* — a somatosensory event, read not by taste cells but by the free nerve endings of the trigeminal system, the fifth cranial nerve, the same nerve that reports a pinprick, a cold wind, the sting of an onion in the eye. When you eat a sweet-hot strawberry, two different sensory organs in the same square centimeter of tissue send two different messages up two different nerves to two different maps in the brain. The sweetness and the burn never touch until they are already thoughts.

This is why they do not mask. Masking — the way bitterness buries sweetness, the way salt quiets bitter — happens when two stimuli crowd the *same* transduction machinery, competing for the same receptors or colliding in the same downstream cell. Sweet and heat share none of it. The sugar never approaches TRPV1; the capsaicin never approaches the sweet receptor. There is no receptor-level interaction to subtract one from the other. What interaction there is happens later and higher, in perception, where the brain is doing what it always does — reading contrast. And contrast is additive in the direction we want.

Consider the timing, because the timing is the craft. A strawberry has almost no skin; its sugars and its perfume sit right at the surface and flood the taste cells the instant the flesh breaks, so sweetness in a strawberry is *fast* — it peaks in the first few hundred milliseconds. Capsaicin, by contrast, is lipophilic; it has to partition out of the fruit's water and into the lipid of the nerve membrane before it can reach TRPV1's binding pocket, and TRPV1, once bound, sensitizes over a second or two and then decays slowly. So heat in a fruit is *late and long.* Designed well, the warmth comes up roughly half a

second behind the sweetness and lingers after it — which means the eater tastes sweetness first, in full, uncontested, and then feels it thrown into relief by a warmth that arrives just as the sugar is fading, extending the whole experience and raising its apparent intensity. The sweetness measured at the receptor has not changed. The sweetness *noticed* has. And noticing is the only part the eater keeps.

There is a quieter physiological gift hiding in the pairing too. Capsaicin at TRPV1 drives a small influx of calcium and sodium into the trigeminal ending; that mild, local excitation raises the overall arousal of the mouth — more blood flow, more salivation, a general turning-up of attention to the bite. A more attentive mouth is a more sensitive one, and a more sensitive mouth tastes a given sweetness as sweeter. None of this is a trick played on the eater. It is the honest architecture of two senses that evolved to work side by side without interfering, which is precisely the architecture a designer wants: two levers that move independently, each cleanly pullable, neither one spending the other.



A strawberry in cross-section — thin-skinned, its sugars at the surface, exactly the fast-release flesh a designed warmth wants to rise through.

There is a measurable psychophysics under the pleasure, not only a feeling. Sensory intensity does not rise in step with concentration; it follows a compressive power law, so that the first increment of a stimulus registers far more than the tenth. A sweetness already near the top of its curve gains little from more sugar — but it gains a great deal from *contrast,* from a second sensation that resets the baseline against which it is judged. Heat is the ideal contrast partner precisely because it rides a different curve on a different channel: it adds intensity to the bite without adding to the sweetness's own concentration, lifting the perceived sweetness by changing its frame rather than its chemistry. Higher in the brain the two signals do finally meet — trigeminal and gustatory afferents converge in the brainstem and again in the insular cortex, the mouth's integrating

map — and it is there, not on the tongue, that contrast is computed and a warm strawberry is judged sweeter than a cool one of identical sugar. Capsaicin carries a second-order caution the cook learns to respect, too: desensitization. Fire TRPV1 repeatedly and the channel dulls, calcium flooding in until the ending briefly stops answering. A sweet heat built for a whole bowl must therefore keep each berry's heat low enough that the twentieth tastes as bright as the first — never so high that the mouth goes numb halfway down and loses the sweetness along with the fire. Restraint, here, is not timidity. It is how the pleasure stays available all the way to the bottom of the bowl.

The design problem underneath the pleasure is harder than the pleasure makes it look, and it is worth stating now because it governs the whole engineering half of this book. Two axes written into one fruit are independent at the *receptor,* but they are not independent in the *cell.* A strawberry has a finite budget of carbon and a finite ripening window in which to spend it, and the pathway that makes heat draws on precursors — the aromatic amino acid phenylalanine chief among them — that the fruit would otherwise spend on its sugars, its red pigments, its perfume. You cannot simply turn both dials to maximum. A fruit told to make all the sweetness and all the heat it possibly can does not read as *sweet heat.* It reads as a confused, overcommitted thing that has robbed its own sugar to feed a fire nobody asked to be that large. So we do not stack the two axes. We *compose* them — and composition, held in ratio by a flux model at every step, is the difference between a fruit that tastes designed and one that simply tastes alive. The child at the table was right. The two were never strangers. They had only never been introduced inside the same skin, and introducing them well is a matter of knowing exactly how much of one a given amount of the other can carry.

Chapter 2 · The Sweetness Axis, Exactly — *the duet that only sings in unison.*

IFI-S · TAS1R2 / TAS1R3 · the sugar-free lift

Sweetness is the axis this book builds *up,* and to build it well you have to know the receptor as a mechanism, not a metaphor — because almost everything clever we do to a sweet fruit is a direct consequence of how strangely this particular receptor is shaped.

The sweet receptor is a heterodimer: two different proteins, **TAS1R2** and **TAS1R3,** that must clasp together to work. Neither one hears *sweet* alone. They belong to class C of the G-protein-coupled receptors, the same structural family as the receptors for glutamate and for calcium, and like their cousins each subunit carries an enormous extracellular domain shaped like a Venus flytrap — two lobes hinged at a cleft — followed by a cysteine-rich linker and then the seven-transmembrane bundle that actually talks to the inside of the cell. That flytrap is the signature of the family and the source of all the mischief: it is a large, generous, multi-pocketed structure, and it means the sweet receptor does not have *one* way in. It has several.

This is the single most useful fact in sweetener design. Sugars — sucrose, glucose, fructose — bind mostly in the flytrap cleft of the TAS1R2 subunit, closing the trap and triggering the signal. But the small-molecule high-intensity sweeteners do not all bind there. Aspartame and sucralose also favor the TAS1R2 flytrap; cyclamate and the bitter-ish sweetener neohesperidin dihydrochalcone bind instead to the *transmembrane* domain of TAS1R3, a completely different site; and the sweet proteins — brazzein, thaumatin, monellin — are far too large to fit any pocket and instead drape across the outside of the flytrap and the cysteine-rich domain, acting like a wedge that holds the trap shut. The receptor is sweet-sensitive at three or four distinct addresses at once. A designer can therefore raise sweetness by knocking on more than one door, and can combine agonists that do not compete, stacking their effects instead of saturating a single site.

Downstream, the cascade is worth naming because its steps set the *shape* of sweetness in time. An activated TAS1R2·R3 couples to the taste-cell G-protein gustducin; gustducin's βγ subunits switch on phospholipase C-β2; PLCβ2 cleaves membrane PIP_2 into IP_3; IP_3 releases calcium from internal stores; the rising calcium opens TRPM5, a calcium-activated cation channel, depolarizing the cell; and the depolarization opens CALHM1 channels that release ATP onto the afferent nerve. Six steps from molecule to message. Each step has a gain and a time constant, which is why sweetness has an *onset* and a *decay* you can feel — why sucrose blooms and fades while some sweeteners arrive slow and linger long. When we lift a

fruit's sweetness we are not only raising a peak; we are choosing, through which agonist we lean on, how that peak rises and falls against the heat arriving behind it.

Now the mathematics, because the Index is a number and the number has to mean something. The Iyengar Flavor Index scores every axis by the same formula:

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IFI(candidate) = 1,000 × EC₅₀(reference) ÷ EC₅₀(candidate)
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EC_{50} is the concentration at which a stimulus drives its receptor to half of its maximal response — a direct, physical measure of *potency,* of how little of a thing it takes to be heard. Invert it against a fixed reference, scale by a thousand, and you get loudness on a common page, normalized to a per-axis ceiling of 5,000. For sweetness the reference is sucrose, whose half-maximal activation of TAS1R2·R3 sits in the low tens of millimolar — call it roughly 30 mM, a spoonful's worth in a glass. Measure a high-intensity sweetener against that and the ratios become vast. A sweet protein like brazzein reaches half-activation in the low micromolar range; set a micromolar EC_{50} against sucrose's tens of millimolar and the molecule is three to four orders of magnitude *louder* per molecule than table sugar. That is the whole reason a sugar-free sweetness is possible at all: you are not adding bulk sweetness, you are adding a few parts per million of something the receptor hears a thousand times more clearly.



Sugarcane in cross-section — the reference sweetness the whole axis is scaled against, and the one a designed fruit learns to exceed without carrying the sugar.

Here is the toolbox the sweetness axis draws on, each tool a different door on the same receptor, each with a different mechanism and a different cost to grow into a fruit:

SWEETENER	SOURCE	≈ SWEETNESS VS SUCROSE	WHERE IT BINDS
Sucrose	the reference	1×	TAS1R2 flytrap
Rebaudioside A (steviol glycoside)	*Stevia*	~200–300×	TAS1R2, allosteric lift
Mogroside V	monk fruit	~200–250×	TAS1R2 / allosteric
Thaumatin	*Thaumatococcus*	~2,000–3,000×	flytrap + CRD, wedge
Monellin	*Dioscoreophyllum*	~1,500–3,000×	flytrap + CRD, wedge
Brazzein	*Pentadiplandra*	~500–2,000×	flytrap + CRD, wedge

Two further facts about the receptor earn their place in a designer's head. The first is that the sweet receptor has an *off*-switch as well as many on-switches: lactisole, a compound of roasted coffee, binds the transmembrane domain of TAS1R3 and shuts sweetness down — proof that the receptor is a machine with a lever at both ends, and a reminder that a fruit's perceived sweetness can be suppressed by anything it is eaten beside, which is why we score the fruit alone and then score the dish separately. There are species-level quirks here that keep a designer humble: a mouse does not taste aspartame as sweet, because the small-molecule sweeteners read against the precise shape of the human receptor's pockets, not a universal one — our scores are calibrated to the human TAS1R2·R3 and to nothing else. The second fact is that sweetness has *quality,* not only intensity. The onset, the linger, the clean finish or the faint metallic or liquorice off-taste that haunts some sweeteners are all consequences of which site is bound and how the six-step cascade decays. Sucrose is the gold standard not because it is the sweetest thing but because its onset and decay are the ones the palate calls *clean.* A designed sweetness that merely hit a high IFI-S number while arriving slow, or lingering sticky, or trailing a cooling off-note would fail the only test that finally matters — whether it tastes like joy. So the sweetness axis is scored twice: once for how loud, at the receptor, and once for how *good,* on the tongue. The second score carries no number, and it governs every choice the first one offers.

The lesson of the table, for a fruit we intend to make sweeter, is that the cleanest lever is a sweet *protein.* Brazzein is a mere fifty-four amino acids, a single compact chain held by four disulfide bonds, monomeric, and — rare among proteins — remarkably heat-stable, holding its sweetness through cooking. A protein is a single gene. To raise a strawberry's sweetness we do not have to re-plumb its entire sugar metabolism; we can give it one small, well-behaved transgene whose product the receptor hears a thousandfold, expressed under the fruit's own ripening promoter so the sweetness blooms exactly when the berry turns red. The glycoside pathways — steviol built from the plant's own geranylgeranyl diphosphate through *ent*-kaurene to steviol and then glycosylated by a cascade of UGT enzymes, or the mogrosides built by a parallel triterpene route — are available and sometimes preferable for the quality of sweetness they give, rounder and longer than a protein's. But they are multi-gene installations. The art of the sweetness axis is choosing which door to

knock on for the *kind* of sweetness the fruit wants: a protein's bright immediate lift, a glycoside's slow lingering body, or a measured raising of the fruit's own native sugars for a sweetness that reads as simply, deeply ripe. In this book we lean, mostly, on the native sugars raised a notch and a sweet protein laid over the top — so that the strawberry tastes like the best strawberry you ever had, not like a strawberry wearing someone else's sweetness.

Chapter 3 · The Heat Axis, Carried Across — *a fire that is not there.*

IFI-H · TRPV1 · the molecule in two halves

Now the other door, and the one that does not belong, by any ancestral right, to a strawberry. Heat is the axis we *carry across* the family line, and to carry a thing well you have to know exactly what it is.

Capsaicin produces no heat. It burns nothing, damages nothing, raises the tissue's temperature not at all. What it does is more interesting and more surgical: it binds **TRPV1,** the transient receptor potential vanilloid-1 channel, a large four-fold-symmetric ion channel sitting in the membrane of the trigeminal nerve endings — and TRPV1 is a *thermometer.* Its native job is to open when the tissue around it climbs above roughly 43 °C and let calcium and sodium flood in, firing the nerve so the brain learns something is hot enough to harm. It is also opened by acid, by certain lipids, by voltage. It is, in a word, polymodal: a single channel that integrates several warnings into one. Capsaicin's trick is to slip into a pocket on the channel's inner face — the vanilloid pocket, lined by residues the structural work has named precisely, with a tyrosine at position 511 making the key contact to the molecule's vanillyl head — and, by binding there, to *lower the channel's temperature threshold* from 43 °C down toward body temperature. The thermometer, recalibrated, now reads the mouth's own warmth as scalding. The body reports a fire with great conviction and perfect sincerity. There is no fire. The tongue has simply been told a true thing — *this is hot* — in an extravagant and borrowed language, on a channel that has nothing to do with the sugar channel running beside it.

The potency is where the Index gets its grip. Capsaicin reaches half-maximal activation of TRPV1 at a concentration near 0.7 micromolar — submicromolar, which is to say the channel hears it at a few parts in ten million. Set that against the Index's heat reference and scale, and you get IFI-H, a loudness that runs from the sunlit, barely-there warmth of a shishito near 40, up through the culinary chilies, to the engineered superhots at the top of our platform. The Scoville scale that the chili world has used for a century measures the same thing more crudely — it is a dilution assay, the number of times a extract must be diluted before a panel can no longer taste the heat, and it tracks total capsaicinoid concentration rather than receptor potency. The two scales agree on the ordering and diverge on the detail; where Scoville sees only *how much,* IFI-H sees *how loudly,* which matters because two fruit with the same capsaicinoid load can land differently at the receptor depending on *which* capsaicinoids they carry.



A pepper in cross-section — the placental pith, pale and ridged, where capsaicin is actually made and stored. A strawberry has no such chamber; its heat must be localized somewhere new.

The structural biology of this is now known in atomic detail, and it rewards a designer's attention. TRPV1 is a tetramer — four identical subunits arranged around a central pore, each contributing a voltage-sensor-like domain and a pore domain, in the same broad architecture as a voltage-gated ion channel. The cryo-electron-microscopy structures resolved two gates in series along the ion path: an upper gate in the outer pore and a lower gate at the helix-bundle crossing. Capsaicin works the lower one, docking its vanillyl head in a pocket formed between the S3 and S4 helices and the S4–S5 linker, where the tyrosine at position 511 and a neighboring threonine and glutamate make the key contacts, and pulling the gate open from the inside. This is why capsaicin must cross into the cell to act — its pocket faces the cytosol — and why fat, which ferries the molecule across the membrane, governs how fast and how far a heat spreads. The blunter number the chili world has quoted for a century tracks the same chemistry: one part per million of capsaicin is worth roughly sixteen Scoville units, pure capsaicin sits near sixteen million SHU, and Phoenix's 2,937,948 units correspond to flesh carrying capsaicinoids at a fraction of a percent by weight — a concentration no pepper reached by breeding, and reaches now only because we rebuilt the enzyme that makes them. And the heat is never one molecule. A real fruit carries a *family* — capsaicin and dihydrocapsaicin as the majors, nordihydrocapsaicin, homocapsaicin, and homodihydrocapsaicin as the minors — each binding TRPV1 a little differently, so the burn's character is a chord and not a single note. The chord is ours to voice.

Which brings us to the molecule itself, because its structure is the thing we will be redesigning, and its two halves decide everything about how a heat *feels.* Capsaicin is an amide: a vanillyl head — an aromatic ring with a hydroxyl and a methoxy group, the same vanillyl motif that makes vanilla smell of vanilla — joined to a fatty acyl tail, an eight-methyl, nine-carbon chain carrying a single double bond at the sixth position. The head is what docks into TRPV1's pocket and makes the key contact at tyrosine-511; the tail is what sets the character. Swap the unsaturated tail for a saturated one and you get dihydrocapsaicin, a slightly different burn — flatter, more persistent. Shorten the tail and you get nordihydrocapsaicin, a heat that is fruitier and fleeting, front-loaded, gone quickly. Lengthen it toward

homocapsaicin and the warmth arrives slower and lingers longer. A real pepper makes a *blend* of these — capsaicin and dihydrocapsaicin in roughly two-to-one proportion, with the minor capsaicinoids filling in — and the blend is the burn's fingerprint: where it lands on the tongue, how fast it blooms, how cleanly it leaves. This is not a detail. For a dessert, where a heat that lingers and dulls would rob the next bite of its sweetness, the *shape* of the burn matters more than its size, and the shape is written entirely in that tail. Carrying heat into a strawberry, then, is not only a matter of installing a fire. It is a matter of installing the *right-shaped* fire — fast to arrive so it tracks the strawberry's fast sugar, clean to leave so it never buries the fruit. Which means that before we can move the pathway, we have to understand every station on it. That is the next Part.



PART II OF V

Installing Fire in Fruit

Seven to ten genes from a pepper to a strawberry — the pathway, the protein, the carbon

Chapter 4 · The Leap Across the Family Line — *why a strawberry is harder than a tomato.*

THE METHOD · T3 cross-family · 7–10 genes · 36–48 months

The reason a strawberry can be taught to make heat at all is almost unfairly convenient, and understanding it is the difference between a wish and a schedule. But the reason it is *hard* — harder than the nightshades just next door to the pepper — is just as important, and we will not pretend it is small.

Here is the convenient part. Capsaicin is the end product of a long assembly line called the phenylpropanoid pathway, and the first and longest stretch of that line — **PAL, then C4H, then 4CL, then HCT, then COMT** — already runs, nearly unchanged, through the cells of essentially every plant that grows. A strawberry runs it. An apple runs it. A melon runs it. They use it every day to build their lignin, their defensive compounds, the flavonoids and the red anthocyanin pigments that a ripe berry is coloured by. The conveyor belt is installed and moving before we arrive. What a pepper owns that a strawberry does not is only the handful of terminal stations bolted to the end of that belt — the four enzymes that take the belt's generic aromatic output and the plant's own fatty-acid machinery and converge them into capsaicin. Giving a strawberry a warm heart is therefore not *building* a pepper's chemistry from nothing. It is porting a terminal cassette onto a conveyor the berry is already running.

Now the hard part, which is why this is Tier 3 of the roadmap and not Tier 1. The nightshades — the volcanic tomato, the dark-matter eggplant, the seismic potato of the tiers below — are the pepper's own botanical family, *Solanaceae.* They speak the pepper's metabolic accent. Their promoters read the pepper's signals, their cells partition carbon in familiar ways, their regulation of the phenylpropanoid branch is close kin to the pepper's own. Porting the capsaicin cassette into a tomato is a conversation between relatives. A strawberry and an apple are not relatives. They are roses — *Rosaceae* — as far from the nightshades as two flowering-plant families that still share the phenylpropanoid belt can be. The melon is further still, a gourd, *Cucurbitaceae.* None of them answers in the pepper's accent. They argue. They have their own habits of ripening, their own transcriptional logic, their own deeply held ideas about where carbon should go and when, and when you hand their cells a nightshade enzyme they frequently misfold it, mislocalize it, silence its gene, or simply decline to feed it. The leap across the family line is a real leap, and it is priced accordingly: seven to ten genes, thirty-six to forty-eight months, where the nightshades needed four to five genes and eighteen to twenty-four.



The strawberry whole — *Rosaceae,* a rose and not a nightshade, and the fruit we chose to carry fire across the family line first.

Why seven to ten genes and not just four? Because porting an enzyme is not the same as porting a *function.* The four terminal enzymes — pAMT, Pun1/CS, KAS, BCAT, which the next chapter takes apart one by one — are the core of it. But around that core the cassette needs scaffolding that the pepper takes for granted and the strawberry does not supply. It needs fruit-specific, ripening-timed promoters so that heat is made in the flesh and only as the berry matures, never in the leaf or the root or the green unripe fruit. It needs a transporter to move the finished capsaicinoids out of the cytosol where they are synthesized and into vesicles or the vacuole, because capsaicin is membrane-active and a cell that makes it without sequestering it poisons itself — the pepper solves this with dedicated vesicular machinery in its placental cells, and a strawberry has no placenta to borrow. It frequently needs a transcription factor, a MYB-type regulator, to switch the whole cassette on in concert rather than gene by gene. And it needs its codon usage and its folding chaperones considered, so that a nightshade protein folds correctly in a rose's cytosol. Add the four core enzymes and these three or four supporting modules and you are at seven to ten genes — not because the chemistry is longer, but because the *hospitality* is harder. We are not only moving a machine. We are building the room it runs in, in a house that was built to a different plan.

It helps to see the whole roadmap's grammar at once, because the dessert frontier is one tier of a graded climb, and each tier is priced by how far it reaches from the pepper's own metabolism:

TIER	WHAT IT CROSSES	GENES	HORIZON	EXAMPLES
T1	within Solanaceae	4–5	18–24 mo	Volcanic Tomato · Dark Matter Eggplant
T2	extended nightshades	5–7	24–36 mo	Seismic Potato · Acid Tomatillo
T3	**out of the family**	**7–10**	**36–48 mo**	**Sweet Heat Strawberry · Solar Melon · Forbidden Apple**
T4	frontier synthetic	10–12	48–72 mo	Storm Corn · Dynasty Rice

The seven-to-ten genes of Tier 3 are not a vague estimate; they itemize. Four are the terminal enzymes — pAMT, Pun1/CS, KAS, BCAT. The remaining three to six are the hospitality: a fruit-and-ripening-specific promoter driving each core gene so heat appears only in mature flesh; a transporter to sequester the finished

capsaicinoids into vesicles so the cell does not poison itself; a MYB-class transcription factor to switch the cassette on in concert rather than one gene at a time; and, where the host silences foreign DNA, the codon optimization and folding-chaperone support that let a nightshade protein hold its shape in a rose. The resistance these overcome is real and specific — RNA-interference machinery that recognizes and shreds foreign transcripts, promoter sequences a cucurbit's polymerase simply cannot read, codon biases that stall a ribosome partway down the message. None of it is mysterious. All of it is work, and the work is why Tier 3 is counted in years.

But the loop that does all of this is the same loop, every time, and that is the real engine of the frontier. A protein language model reads each terminal enzyme the way it reads a sentence and proposes the edits most likely to let it fold and function in a strange new cytosol. A genome-scale flux-balance model checks what the fruit can actually afford to divert. CRISPR writes the surviving design in. We grow it, read the scorecard, and let the result correct the model for the next pass. It is the identical loop that found the two Pun1 substitutions behind our hottest pepper, pointed now at a rose instead of a nightshade. It does not need a new idea for the strawberry — only the strawberry's genome, and the patience to let the plant finish arguing.

Chapter 5 · The Capsaicin Assembly Line — *every station, named.*

THE PATHWAY · two branches, one condensation

To move a factory you must be able to draw it, part by part, and capsaicin's factory is one of the most beautiful in plant metabolism: two separate assembly lines running in parallel, each building one half of the molecule, converging at a single machine that joins the halves. Let us walk both lines, name every enzyme and every intermediate, and mark exactly which stations the strawberry already owns and which we must install — because that map *is* the engineering brief.

The first line is the aromatic branch, and it builds the vanillyl head — the part that will dock into TRPV1. It begins with the amino acid phenylalanine, drawn from the plant's shikimate pathway, and proceeds down the phenylpropanoid belt every plant shares:

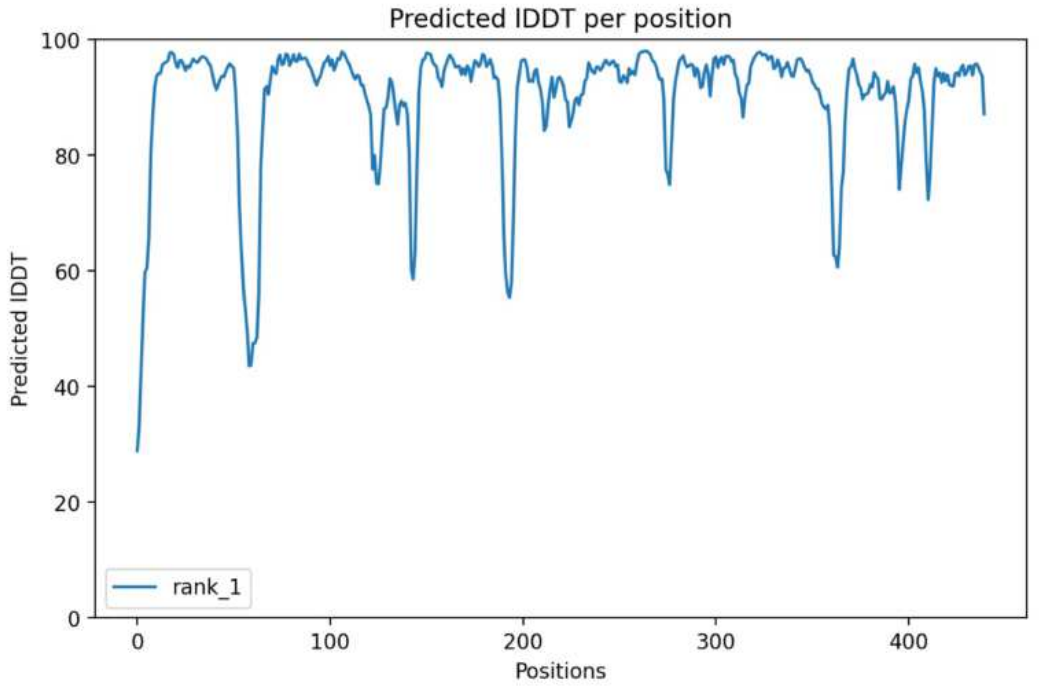
STEP	ENZYME	SUBSTRATE → PRODUCT
1	PAL (phenylalanine ammonia-lyase)	phenylalanine → *trans*-cinnamic acid
2	C4H (cinnamate 4-hydroxylase, a P450)	cinnamic acid → *p*-coumaric acid
3	4CL (4-coumarate–CoA ligase)	*p*-coumaric acid → *p*-coumaroyl-CoA
4	HCT / C3H	*p*-coumaroyl-CoA → caffeoyl ester
5	COMT (caffeic acid *O*-methyltransferase)	caffeoyl → feruloyl / ferulic acid
6	(chain-shortening, CoA ligase, HCHL-type)	ferulic acid → vanillin
7	**pAMT** (putative aminotransferase)	vanillin → **vanillylamine**

Read that table against the family-line map and the whole strategy snaps into focus. Steps one through six — PAL to vanillin — are the shared belt. The strawberry runs all of it already; it must, to make its own pigments and its own vanilla-adjacent aroma notes. Only step seven, **pAMT,** the transaminase that swaps vanillin's aldehyde for an amine and turns it into vanillylamine, is a pepper specialty. One of our four terminal genes lives here, at the very end of the aromatic line.

The second line is the branched-chain fatty-acid branch, and it builds the tail — the part that sets the burn's shape. It begins not from an aromatic but from a branched amino acid, valine or leucine:

STEP	ENZYME	SUBSTRATE → PRODUCT
1	**BCAT** (branched-chain aminotransferase)	valine / leucine → branched-chain α-keto acid
2	BCKDH complex	α-keto acid → branched-chain acyl-CoA primer
3	fatty-acid synthase + **KAS** (β-ketoacyl-ACP synthase)	primer → chain elongation, 2 carbons at a time
4	desaturase / thioesterase	→ 8-methyl-6-nonenoic acid
5	acyl-CoA synthetase	→ **8-methyl-6-nonenoyl-CoA**

Two of our four terminal genes live on this line: **BCAT,** which commits a branched amino acid to the tail at the start, and **KAS,** the condensing enzyme that sets how many two-carbon units get added and therefore how long the tail grows. Together they decide whether the fruit makes a short, fast, fruity heat or a long, lingering one — which is to say, BCAT and KAS are the knobs we turn to shape the *feel* of a dessert's warmth, not just its size.



The capsaicin synthase, Pun1/AT3, modelled and coloured by confidence — the single machine where the two halves of the molecule are joined. Bright regions are high-confidence fold; the binding cleft resolves clearly.

And then the convergence. The vanillylamine from the first line and the 8-methyl-6-nonenoyl-CoA from the second are brought together by the fourth and most important enzyme of the cassette: **Pun1,** also called CS or AT3, the capsaicin synthase. It is a BAHD-family acyltransferase, and its whole job is to form the amide bond that marries head to tail, releasing coenzyme A and producing capsaicin. Pun1 is the master switch of pungency: the recessive, loss-of-function *pun1* allele is exactly what makes a bell pepper a bell pepper — all the upstream chemistry intact, the final condensation never happening, the fruit sweet and heatless. Restore a working

Pun1 and the belt's output turns, at last, into fire. If the fruit uses the saturated tail instead of the unsaturated one, the same enzyme makes dihydrocapsaicin; the ratio of the two, set upstream by the desaturase, is the burn's signature.

Two mechanistic details decide how well this factory runs in its new building. The first is how Pun1 actually catalyzes the join. As a BAHD acyltransferase it carries the family's signature machinery — a conserved histidine in an HXXXD motif acting as a general base, deprotonating vanillylamine's nitrogen so it can attack the thioester carbonyl of the acyl-CoA, forming the amide bond and releasing coenzyme A. No metal, no cofactor beyond the CoA substrate itself; a clean single-step condensation, which is part of why the enzyme ports as well as it does — it asks little of a host but the two substrates and a correctly folded active site. The second detail is containment. In a pepper, capsaicinoids are made at the epidermal cells of the placenta and swept at once into dedicated capsaicinoid vesicles and out onto the tissue surface, because a cell that let them accumulate free in its cytosol would suffer — capsaicin is membrane-active, and the plant that makes it must also sequester it. Give a strawberry the synthesis without the containment and you poison the receptacle. The transporter module, then, is not decorative scaffolding; it is life support, moving the finished molecules into the vacuole or surface vesicles as fast as they are made.

The burn's *shape* is set right here too, upstream of the receptor, by two ratios the fatty-acid branch controls. The first is chain length, set by how many elongation cycles KAS runs: fewer cycles give the short, fruity, fleeting nordihydrocapsaicin character; the standard cycles give capsaicin's familiar bloom. The second is saturation, set by a desaturase that does or does not install the double bond at the sixth carbon — the unsaturated product is capsaicin, bright and clean-leaving; the saturated one is dihydrocapsaicin, flatter and more persistent. A pepper makes roughly two parts capsaicin to one of dihydrocapsaicin, the minor capsaicinoids besides, and that blend is the burn's fingerprint. Tune KAS and the desaturase and the fingerprint moves — toward a fast fruity heat for the gentle rungs, toward a bloom-and-stay heat for the fierce ones — which is how one installed pathway yields four different *feelings* of warmth along the strawberry ladder from a single set of genes.

Here, then, is the complete engineering brief in two sentences. To give a strawberry heat, we install the four terminal enzymes the shared belt lacks — pAMT at the end of the aromatic line, BCAT and KAS on the fatty-acid line, and Pun1 at the convergence — plus the promoters, the transporter, and the regulator that make them behave in a rose's flesh. And because the strawberry has no placenta — no pale pithy chamber like the pepper's, where capsaicin is made and stored in dedicated cells — we must choose a new home for the synthesis: the receptacle flesh itself, the sweet red body of the fruit, where the heat can be made in the same cells that hold the sugar, so that the two sensations are not only tasted together but *built*

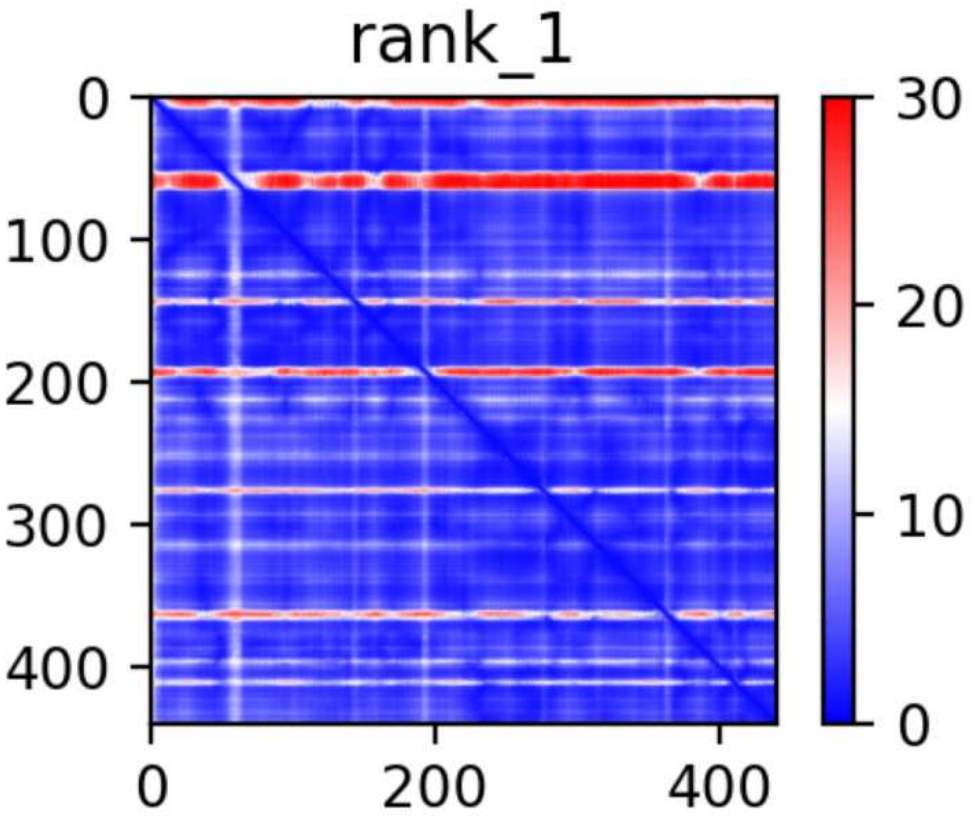
together, side by side, in one tissue. That co-localization is not a convenience. It is the physical reason the warmth and the sweetness can arrive in the same bite. We are not bolting a chili onto a berry. We are teaching the berry's own flesh to make both.

Chapter 6 · Designing Pun1 for a Berry — *two Pun1 substitutions, and a protein that folds where it shouldn't.*

THE PROTEIN · ESM2 + flux-balance + CRISPR · S39L · L345G

Installing a gene and installing a *working* gene are different accomplishments, and the whole difficulty narrows, in the end, to one protein. Pun1 is the master switch, the enzyme at the convergence, and a Pun1 that was evolved over millions of years to fold and function in the cytosol of a pepper's placental cell does not, when you drop its gene into a strawberry, simply carry on. It misfolds. It aggregates. It loses catalytic efficiency in an unfamiliar chemical environment, at an unfamiliar pH, among unfamiliar chaperones. The pepper's wild-type Pun1, moreover, is a batch-to-batch gamble even at home — in our early work its output varied by as much as forty-two percent from harvest to harvest, a variance no formulator and no pastry kitchen could design around. So we do not move the wild-type gene. We redesign the protein first, and we do it the same way we redesigned it to reach our hottest pepper.

The method is a loop of three models and a plant. First, a protein language model — an ESM2-class network with 650 million parameters, trained on tens of millions of natural protein sequences until it has internalized the deep grammar of what makes a fold stable and an active site competent — reads the Pun1 sequence the way it reads any sentence and scores every possible single-residue substitution by its predicted effect on two things at once: catalytic efficiency and fold stability. There are thousands of such substitutions; the model ranks them all in silico, in hours, where a wet-lab scan would take years and never finish. Second, a genome-scale flux-balance model takes the shortlist and asks a different question — not *can this protein fold* but *can this fruit afford to feed it* — predicting, in our case, that flux control sits upstream in the phenylpropanoid pathway at 4CL and HCT, not at the terminal Pun1 step — the ESM2 substitutions improve Pun1's reliability and consistency rather than shifting the rate limit. Third, CRISPR writes the surviving designs into the genome. Then we grow the plant and read the scorecard, and the real result corrects the models for the next pass. Design, build, test, learn — closed, and turning.



The predicted aligned error map for the same model — the off-diagonal blocks show which domains move together, telling us which regions can be edited without unfolding the whole. The redesign lives where the map says it is safe.

Out of that loop, for the heat lineage, came two Pun1 substitutions never before combined — and they are the three we carry across the family line into the berry, because a protein engineered to fold stably against a hostile cytosol is exactly the protein that will survive the move into a rose:

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

Read the third column, because stability is the quiet hero of the frontier. ΔΔG is the change in folding free energy a substitution causes; a negative value means the variant is *more* thermodynamically stable than the wild type, its folded state sitting in a deeper energy well, less likely to be shaken loose by heat or by a strange environment. Both Pun1 substitutions (S39L · L345G) are negative. Their combined stability, better than three kilocalories per mole of added stability, is precisely the margin that lets this protein fold correctly somewhere it was never meant to be — in the cytosol of a strawberry's receptacle cell instead of a pepper's placenta. C175S is a structural annotation from our modelling — a cysteine that, left in place, would form an occasional wrong disulfide bond; it was identified during the design process and pulled from the final shipped construct. The double variant S39L+L345G carries the two substitutions that actually go into the living plant, designed not just to make the enzyme faster but to make it *robust* across different cellular environments.

It is worth being precise about what the language model is doing, because it is neither magic nor search in the ordinary sense. An ESM2 network is trained by masking residues in tens of millions of

natural protein sequences and learning to predict what belongs in each gap; in doing so it internalizes, across its 650 million parameters, the statistical grammar of real proteins — which substitutions nature tolerates in a given structural context and which it never dares. Point it at Pun1 and it scores every possible point mutation by how much that edit would surprise it, a pseudo-perplexity read straight off the trained model with no new experiment required. An edit it finds unsurprising in context is one evolution would likely accept; an edit it finds shocking is one that probably breaks the fold. We take the top of that ranking, filtered for the two properties we actually need — predicted catalytic efficiency and predicted fold stability — and hand the survivors to the flux model, which asks whether improving this particular enzyme will improve the *fruit* or merely press harder against a bottleneck elsewhere. For Pun1, our flux model predicts control sits upstream in the phenylpropanoid pathway at 4CL and HCT; the ESM2 substitutions improve the synthase's reliability and consistency so that whatever the upstream pathway delivers is locked in with ≤7% variation. Only then does CRISPR write the design in — a precise edit at the native locus, the redesigned coding sequence installed under its fruit-specific promoter — and only then do we grow the plant and read its real card, which becomes the next pass's training signal. Tens of thousands of candidate substitutions ranked in silico in hours; a few dozen built; three kept. That is the funnel, and it is the same funnel whether the target is the hottest pepper in the world or the first warm strawberry.

The payoff is measured in variance. Where the wild-type enzyme wandered by forty-two percent between batches, the redesigned Pun1 holds its output to a batch-to-batch coefficient of variation of seven percent or under — the same ≤7% CV we hold across all nineteen thousand constructs and forty-two organisms on the platform. That number is easy to pass over and it is the whole reason a dessert brand could ever build on these fruit. A sweet heat that varied by forty percent from harvest to harvest would be a novelty, a party trick, impossible to put in a product with a consistent label and a consistent experience. A sweet heat that varies by seven percent is an ingredient. The protein redesign is what turns a frontier fruit from a photograph into a specification — and it is the same redesign, the same two Pun1 substitutions, whether the protein is folding in the hottest pepper we have ever grown or in the first strawberry we ever taught to be warm.

Chapter 7 · Lifting the Sugar — *sweetness that reads as ripeness, not as sugar.*

THE OTHER DIAL · native flux + a sweet protein

A sweet-heat fruit is not a hot fruit that happens to be sweet. It is a *sweet* fruit, first and most, with a thread of warmth woven through — and so the sweetness axis does at least as much design work as the heat, and arguably more, because getting sweetness to read as deep ripe pleasure rather than as added sugar is one of the subtler problems in the whole library.

A strawberry's native sweetness is a mixture, and the mixture matters. It carries sucrose, glucose, and fructose in shifting proportion as it ripens, fructose being the sweetest of the three per molecule and the one the ripe berry accumulates most. Those sugars are loaded into the fruit from the plant's leaves and roots, carried in through a family of membrane transporters — the SWEET proteins and the sucrose transporters — and then split and stored under the control of invertases, the enzymes that cleave sucrose into its glucose and fructose halves. Every one of these is a lever. Raise the expression of the SWEET transporters at the fruit's intake and you draw more sugar into the flesh. Tune the invertase balance toward fructose and you make a given quantity of sugar taste sweeter. Extend the window in which the ripening fruit keeps importing sugar and you deepen the whole thing. This is the first and most honest way to lift sweetness: not by adding anything foreign, but by restoring and amplifying the fruit's own sugar flux — the exact flux that a century of breeding for shelf life and shipping durability quietly thinned, trading the sweetness of a berry picked ripe for the sturdiness of one picked green and trucked far.

But native sugar has a ceiling. Carbon is finite, the ripening window is finite, and a fruit that tried to reach a confection's sweetness on sugar alone would have to divert so much carbon to sugar that it starved its colour, its structure, and — the point of this book — the heat we are also asking it to make. So over the raised native floor we lay a sweet protein, and here the receptor's strange multi-pocketed shape from Chapter 2 pays off completely. Brazzein, fifty-four amino acids, one small gene, heat-stable, binds the sweet receptor at a different address than the sugars do — draping across the flytrap and the cysteine-rich domain as a wedge — so its sweetness *adds* to the sugars' rather than competing with them. A few parts per million of a protein the receptor hears a thousandfold, expressed under the fruit's own ripening promoter so it appears exactly as the berry reddens, lifts the perceived sweetness into the high ripe register for almost no carbon cost. The sugars give the sweetness its body and its honest fruit-character; the protein gives it its height.

Together they read not as *sweetened* but as *impossibly ripe* — the berry you get once a summer off a sun-hot plant, made the fruit's ordinary condition.



Sugarcane whole — the plant the world grinds for sweetness. A designed berry reaches the same height on a few parts per million of a protein and a notch more of its own native sugar.

The glycoside route is the third option, and we reach for it when the *shape* of the sweetness in time is what we want to control. Steviol glycosides and mogrosides are not proteins but small molecules, built by the fruit from its own terpene precursors — steviol assembled from geranylgeranyl diphosphate through *ent*-kaurene and then dressed in sugars by a cascade of UGT glycosyltransferases, each adding one more sugar and shifting the balance between sweetness and the faint liquorice bitterness the under-glycosylated forms carry. A glycoside sweetness arrives a touch slower than a protein's and lingers longer, a rounder and more trailing sweetness, and against a late-arriving heat that long tail can be exactly right — the sweetness still present on the back of the tongue as the warmth blooms, the two overlapping instead of handing off. It is a multi-gene installation and we do not spend it lightly, but for a fruit whose whole character is the duet of a lingering sweetness and a rising heat, the glycoside's long decay can be worth every gene.

The native-sugar levers deserve to be named, because restoring a fruit's own sweetness is the part of this work we are proudest of and the least willing to shortcut. A strawberry fills with sugar by import, not by making it on site: the leaves fix carbon and ship sucrose down the phloem, and the ripening fruit draws it in through SWEET-family and sucrose transporters at the cell membrane, after which cell-wall and vacuolar invertases split some of it into glucose and fructose while sucrose-phosphate synthase and its partners govern what is stored as what. Each of these is a dial the breeder never had clean access to and we do: raise the transporters and more sugar enters; shift the invertase balance toward fructose, the sweetest of the three per molecule, and the same carbon tastes sweeter; hold the import window open a few days longer into ripening and the whole fruit deepens. A century of selection for firmness and shelf life turned many of these dials down, trading the sweetness of a berry ripened on the plant for the durability of one picked green and trucked far. Much of our sweetness gain is simply turning them back up.

Over that restored floor, the choice of overlay is a choice about sweetness in *time,* and it is worth laying the options side by side:

OVERLAY	ONSET	LINGER	CARBON COST	BEST FOR
Raised native sugar	fast	medium	high	honest ripe body
Brazzein (sweet protein)	fast	short–medium	very low	a bright immediate lift
Steviol glycoside	slow	long	low (multi-gene)	a sweetness that hangs

The strawberry ladder leans on raised native sugar and a brazzein overlay — bright, immediate, honest, out of the way in time for the next bite. The Solar Melon, whose sweetness we wanted to hang in the air against its cool, reaches instead for the glycoside's long tail.

Which door we knock on is, in the end, a flavor decision made with a metabolic model open beside the tasting notes. The flux-balance model tells us what each option costs the fruit in carbon and whether it collides with the heat pathway's demand for the same precursors; the palate tells us which *kind* of sweetness the fruit should have. For the strawberry ladder we chose, mostly, raised native sugar and a brazzein overlay — a bright, immediate, honest ripeness that gets out of the way in time for the next bite — and reserved the glycoside's long tail for the fruit, like the Solar Melon, whose sweetness we wanted to hang in the air against its cool. In every case the governing principle is the same, and it is a principle about respect for the fruit: we lift the sweetness the fruit was always reaching for, by the cleanest route that does not spend the carbon the heat needs. A strawberry should taste like the most itself a strawberry has ever been. It should never taste like a strawberry carrying someone else's sugar.

Chapter 8 · Composing, Not Stacking — *the ratio that holds the two axes up.*

THE BALANCE · flux-balance analysis · temporal design · CV ≤ 7%

We said it in the first chapter and now we can prove it with the model: two axes written into one fruit do not add. They *compose,* and composition is a constrained optimization problem the fruit solves in its metabolism and we solve, first, in silico — because the difference between *sweet heat* and *muddle* is a ratio, and the ratio is not obvious.

The tension is carbon, and it is real and it is sharp. Trace both axes back to their source and they meet. The heat pathway's aromatic branch begins with phenylalanine, drawn from the shikimate pathway; the shikimate pathway is fed from phosphoenolpyruvate and erythrose-4-phosphate, which are drawn from glycolysis and the pentose-phosphate pathway — which is to say, from the fruit's sugar. Every molecule of capsaicin the berry makes is, at one remove, sugar the berry did not keep. The two axes we most want — maximum sweetness, meaningful heat — pull on opposite ends of the same carbon pool. Turn both to their limits and the fruit cannot satisfy either; it makes a thin sweetness and a confused heat and tastes, as we have warned, merely loud. The design question is therefore not *how much of each* but *what partition of a fixed carbon budget yields the sweet heat we want* — and that is exactly the question flux-balance analysis was built to answer.

Flux-balance analysis treats the fruit's metabolism as a system of linear equations. Every reaction is a column in a stoichiometric matrix **S;** the rate of every reaction is an entry in a flux vector **v;** and at the steady state a ripening fruit approximates, nothing accumulates without bound, so the production and consumption of every internal metabolite must balance: **S · v = 0.** That single constraint, across a genome-scale model of thousands of reactions, defines a vast space of allowable flux states. Into that space we introduce bounds — how fast each enzyme can run, how much carbon enters — and an objective: not *maximize biomass,* as a microbiologist would set it, but *reach this target IFI-S and this target IFI-H simultaneously,* and tell us the flux partition that does it with carbon to spare. The model returns the partition, and the partition is the recipe: how much SWEET-transporter expression, how much Pun1 flux, how much phenylalanine routed to heat versus held for sugar. It is the map through the trade-off, and it is why every scorecard in this book is internally consistent rather than wishful — the sweetness and the heat on each rung were checked against the fruit's actual carbon budget before they were ever written down.



A research tray under the lights — where the flux model's partition stops being a vector and becomes a plant that either balances its budget or does not.

Then there is the second composition problem, the one in time, and the flux model does not solve it — the structural biology does. Sweetness in a strawberry is fast, peaking in the first few hundred milliseconds as the thin-skinned flesh floods the taste cells. The heat must be shaped to arrive *behind* it, blooming as the sugar fades, so the two hand off cleanly instead of colliding. We shape that timing where Chapter 5 said we would: on the fatty-acid tail, through BCAT and KAS. A shorter, fruitier tail front-loads the warmth and clears it fast — right for the gentle rungs, where the heat should be a glow that comes and goes under a dominant sweetness. A tail with the native double bond and standard length gives the classic bloom-and-linger — right for the fiercer rungs, where we want the warmth to stay and be reckoned with. And the capsaicin-to-dihydrocapsaicin ratio, set by the desaturase, tunes whether the heat reads sharp and bright or round and persistent. We are not only choosing how hot. We are choosing *when,* and *for how long,* and *in what shape* — composing the heat against the sweetness the way a musician voices a chord, so the two notes sound together and neither swallows the other.

A small worked example makes the trade-off concrete. One molecule of capsaicin is built from one vanillylamine and one branched nine-carbon acyl chain; the vanillylamine traces back to one phenylalanine, and that phenylalanine was assembled by the shikimate pathway from one phosphoenolpyruvate and one erythrose-4-phosphate — four carbons and three carbons drawn straight out of the sugar-feeding pools of glycolysis and the pentose-phosphate pathway. Every capsaicin the berry makes is, at that remove, a fixed quantity of carbon that did not become fructose. Scale it up and the arithmetic bites: flesh carrying capsaicinoids at even a few tenths of a percent by weight has diverted a measurable slice of its ripening budget to heat. The flux-balance model holds that arithmetic for the whole network at once — thousands of reactions, the single steady-state constraint $S \cdot v = 0$, the enzyme-rate bounds, and an objective that reads *hit this IFI-S and this IFI-H together, with carbon to spare* — and returns the one partition of the budget that satisfies both. On the gentle rungs, where the heat is small, the partition barely touches the sugar and the model has wide latitude. On Candied Fang and Devil's Dessert, where a serious heat sits beneath a near-maximal sweetness, the latitude narrows to a

seam, and the model is doing its hardest work — which is exactly why those two rungs are the ones whose first real harvest we most want to taste.

The temporal composition can be tabulated as deliberately as the magnitudes, because *when* the heat arrives is designed as carefully as *how much:*

RUNG	HEAT TARGET	TAIL SHAPE	BURN CHARACTER
Warm Kiss	90	short, fruity	a glow that comes and goes
Sugar Burn	180	short–standard	a clean pulse
Candied Fang	640	standard, capsaicin-forward	a bloom that leaves clean
Devil's Dessert	1,350	standard + pungent top-note	a bite, then a forgiving fade

And over all of it, the discipline of reproducibility, because a composition you cannot repeat is not a design. The redesigned Pun1 holds its output to a coefficient of variation of seven percent or under; the native-sugar levers and the brazzein overlay are tuned to the same tolerance; the whole fruit is held to the ≤7% CV that governs every construct we grow. This is what lets the flux model's partition become a product. When a dessert brand builds a bar or a sauce or a plate around a Candied Fang, they are building around a sweet heat that will taste the same next season and the season after — the sweetness landing where the scorecard says, the warmth arriving a half-second behind it where the scorecard says, batch after batch, within seven percent. The craft of this book is the composition. The reproducibility is what turns the composition into something you can hold the world to. With both in hand, the loop closes, and the fruit is ready to be drawn.



PART III OF V

The Fruit, Drawn

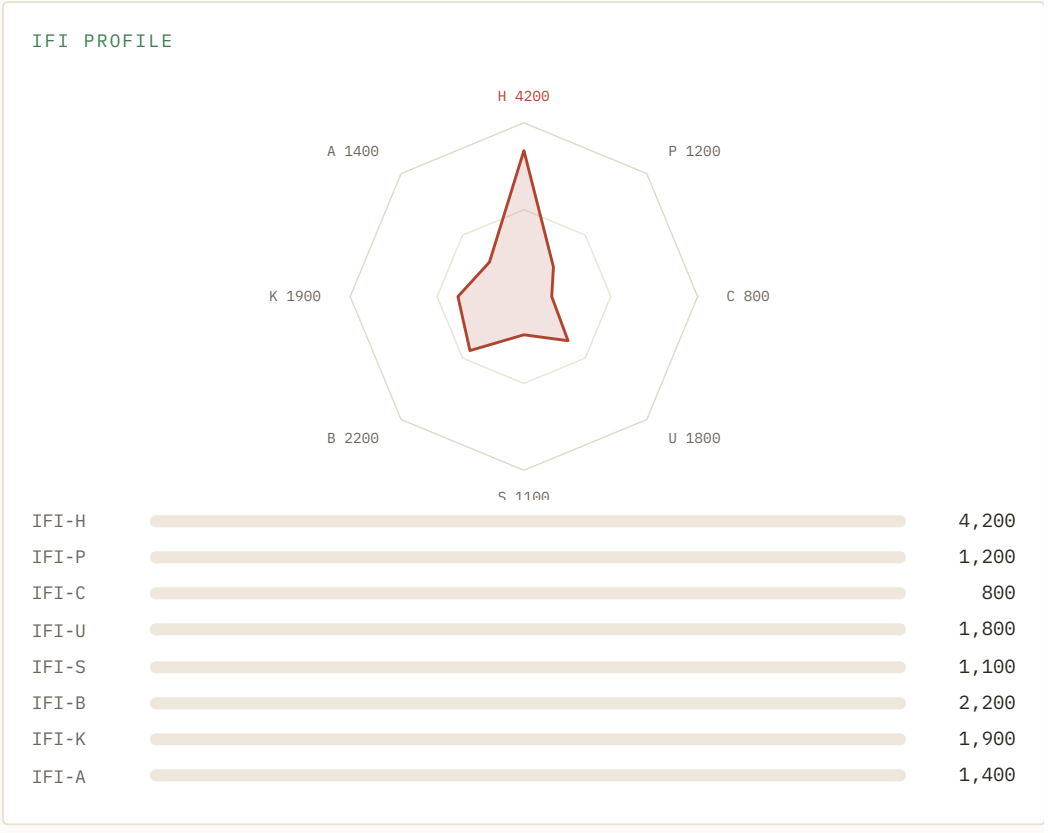
One real anchor, then the sweet frontier — a ladder of four, a melon, an apple

Chapter 9 · The Proof Already in Hand — *one real fruit, eight real axes.*

THE ANCHOR · SS-0096 · Phoenix

Before the dessert frontier, the ground it stands on — because the argument that we can write heat into a strawberry rests on a fruit where we have already written all eight sensations into one plant on purpose, and that fruit is not a concept. It has a SKU, a harvest, a scorecard earned by growing it and reading its response. Everything drawn in this book is drawn with its proportions in hand.

Phoenix — SS-0096 — is the last and most complete of our ten flagship superhots, a *Capsicum chinense* built gene by gene to register on every axis of the Index at once, the first plant in the world to do so. Its heat is the headline, measured at IFI-H 4,200 — a loudness corresponding to 2,937,948 Scoville heat units, the most any construct of ours has ever carried, reached through the two AI-designed Pun1 substitutions of the last chapter, S39L · L345G, found with the protein language model and written in with CRISPR. But the heat is not the point here. The point is the *rest* of the card, because Phoenix is the living proof that the eight axes are independent levers that can each be set on purpose inside a single fruit.



Read the sweetness line. On a fruit built for fire, IFI-S sits at 1,100 — the quietest voice on the card, a deliberate, modest sweetness held in check beneath a towering heat. Now invert the whole thing in your mind. If sweetness can be *held down* to 1,100 inside a pepper built to be the hottest thing we grow, then sweetness is not the pepper's

possession any more than heat is the strawberry's — and the same levers that kept it low here can be thrown the other way to send it high somewhere else. The strawberry is Phoenix read backwards: a fruit where the sweetness towers above 2,000 and the heat is the quiet thread held below the threshold of *hot.* Same eight levers. Opposite settings. One proven method.

And the heat lineage proves the second thing the frontier needs — that the method can place a heat *anywhere* it likes along the scale, rung by deliberate rung. Here is the full flagship ladder, every rung a real cultivar with a real SKU and a real Scoville measurement:

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



Phoenix — SS-0096 — the first cultivar in the world engineered to register on all eight axes at once. The anchor the whole sweet frontier is measured against.

Read the Axes column of the ladder and you can watch the method learn to add sensations one at a time. Ember expresses two of the eight; by Blaze it is four; by Firestorm, six; and only at Phoenix does the full eight resolve. That progression is not decoration — it is the record of a platform teaching itself to hold more axes in one plant without any of them collapsing the others, each flagship a proof that the next sensation could be added to a fruit that already carried the last. The dessert frontier is the same lesson pointed a different way: not stacking eight axes into a pepper, but holding two — sweetness and heat — in perfect, deliberate proportion inside a fruit that evolved with neither one designed in. If a *C. chinense* can be walked from two axes to eight, a strawberry can be walked from one to two. The direction is different. The method is identical.

Hold the sweetness line against the ladder a moment longer, because the arithmetic of *read backwards* is literally doable on the Index. Phoenix's IFI-S of 1,100 means its sweet stimulus reaches half-activation of TAS1R2·R3 at an effective concentration a little under eleven times more potent than the sucrose reference — a real, designed sweetness, but one deliberately held a whisper under the heat so the pepper reads as fire first. A Candied Fang's target IFI-S of 2,200 is exactly twice that: a sweet stimulus twice as loud, under a heat a sixth as loud. Same two axes, same Index, the settings swung from one end to the other — and the swing is not a hope, because Phoenix proves both ends are reachable inside one plant. The flagship also carries the platform's most advanced delivery work: as a full-spectrum, eight-axis fruit it is where our nanoparticle-encapsulation methods were first proven, protecting and timing the release of compounds that would otherwise fire all at once, so that eight sensations arrive in sequence rather than in a heap. The dessert fruit inherit that timing science directly — it is part of why a designed heat can be made to arrive a measured half-second behind a designed sweetness rather than colliding with it.

Ten rungs, each a deliberate step, the heat placed exactly where the design asked for it, from 1,570 to 4,200. Note that IFI-H does not track Scoville perfectly — Kindle reads lower on the Index than Cinder despite more Scoville units, because the two carry different capsaicinoid blends that the receptor hears differently, which is the whole reason we measure loudness and not just quantity. This is the reach of the method, demonstrated: not one hot pepper but a precisely graduated ladder, the heat dialed rung by rung. Point that same precision at a strawberry, ask it for IFI-H 90 instead of 4,200, and you get Warm Kiss. The dessert frontier is not a hope resting on a maybe. It is the next stretch of a road we have already walked a long way down — forty-two plants, nearly nineteen thousand constructs, a thousand of them live and purchasable today, three patents filed, twenty-one papers published, all held to seven percent. And the fruit that proved the road is one you can already put in your mouth.

Chapter 10 · The Strawberry, and Why It Was First — *the near-perfect vehicle for a warm sweetness.*

THE FLAGSHIP CONCEPT · *Fragaria* · Rosaceae · T3 · 7–10 genes · 36–48 mo

Of all the fruit on the far side of the family line, we drew the strawberry first — and not only because a child asked. The strawberry is the near-perfect vehicle for sweet heat, and understanding why is understanding the whole design philosophy of this Part, because every choice we made for the other fruit is a variation on what the strawberry taught us.

Begin with its anatomy, which is quietly ideal. A strawberry is barely skinned; what you bite is receptacle flesh, soft and open, its sugars and its perfume held right at the surface and released the instant the cells break. This is why a strawberry's sweetness is *fast* — it floods the taste cells in the first moment — and a fast sweetness is exactly the sweetness a designed heat wants to rise behind, because the half-second lag of capsaicin partitioning into the nerve membrane then places the warmth precisely where it does the most good: blooming as the sugar crests and begins to fade. In a thick-skinned fruit the sweetness would be slower and the timing harder to win. The strawberry hands it to us. And because the fruit has no placenta — none of the pepper's pale internal chamber — we localize the heat synthesis in that same receptacle flesh, in the very cells that hold the sugar, so that warmth and sweetness are not only tasted in one bite but *built* in one tissue. The strawberry's open architecture, which makes it fragile and fleeting and beloved, is the same architecture that makes it the best room we have found to install a sweet heat.



The strawberry, drawn first — its achenes freckling the surface, its flesh the sweet red receptacle where both the sugar and, now, the heat would be made.

Then there is its own flavor chemistry, which gives the design things to hold onto. A ripe strawberry's perfume is dominated by furaneol — 2,5-dimethyl-4-hydroxy-3(2H)-furanone, a caramel-sweet volatile the fruit builds through an enzyme called FaQR late in ripening — layered with esters and a whisper of eugenol, the clove-warm note

that is itself a phenylpropanoid cousin of our vanillyl head. A strawberry already smells faintly of warmth; it is already, aromatically, reaching toward spice. Its red is anthocyanin, built down the same phenylpropanoid belt we tap for the heat, which means the fruit's pigment machinery and our heat machinery share a supply line — a tension the flux model has to manage, but also a sign that the berry's metabolism is already pointed in the right direction. And its surface is freckled with achenes, the true botanical fruits, the little seeds that carry a faint structural astringency. That astringency is a gift: a thread of IFI-A, of tannic grip at the saliva's proline-rich proteins, that gives a rising heat something to catch against — an edge, a grain, so the warmth has texture and does not merely float on sweetness. The strawberry does not simply tolerate a thread of fire. Its aroma reaches toward it, its pigment shares a pathway with it, and its seeds give it an edge to hang on. The berry flatters the heat.

The strawberry's genetics make it a willing, if complicated, partner. The cultivated berry is *Fragaria × ananassa,* an octoploid — eight sets of chromosomes, the legacy of a hybrid origin — which means redundancy to work around but also a deep well of its own regulatory machinery to borrow. Its ripening is governed by transcription factors we know by name: FaMYB10 switching on the anthocyanin branch that turns the fruit red, the ripening-specific promoters that could time our heat cassette to the same moment, the enzyme FaQR building furaneol late in maturation. And crucially the strawberry is not, botanically, a true fruit — the red flesh is swollen *receptacle,* and the real fruits are the achenes freckling its surface, which signal the receptacle to swell through auxin as they develop. That architecture hands us a natural address for localization: drive the heat cassette under a receptacle-and-ripening promoter and the warmth is built in the sweet red flesh, in the same cells and at the same moment as the sugar, and nowhere else — not the leaf, not the runner, not the green unripe fruit. The strawberry's own developmental logic already draws the map of where heat should and should not go. We are mostly following lines the plant drew itself.

So we drew it not as a single fruit but as a **ladder of four** — a deliberate climb that lets one berry serve a whole table's range of nerve, from the child who wants summer without the dare to the chilihead beside her who has always wanted the dare and the sweetness in one mouthful and never, from a single fruit, been able to have them:

RUNG	SERIES NAME	WHAT IT IS	HEAT, ROUGHLY
1	Warm Kiss	heat you could almost miss	well below *hot*
2	Sugar Burn	summer with a pulse behind it	below *hot*
3	Candied Fang	sweetness that shows a tooth	at the threshold
4	Devil's Dessert	the one drawn to bite back	just over the line

A ladder, rather than a single berry, is a deliberate philosophy and not a convenience. Heat tolerance is the most variable thing about any table — it splits families, generations, whole cuisines — and a single sweet-heat strawberry, however well drawn, would please

one eater and exclude the one beside them. By designing four rungs from one genetic chassis, changing only the settings the flux model partitions and the shape the acyl tail takes, we make a single fruit that meets a whole table where it is: the cautious child at Warm Kiss, the summer cook at Sugar Burn, the enthusiast at Candied Fang, the chilihead at Devil's Dessert, every one of them tasting recognizably the same berry at a different volume. It is the same logic as the flagship pepper ladder, pointed at pleasure instead of proof — a graduated range, so that no one has to be braver than they want to be to join the meal.

The sweetness rises alongside the heat the whole way up — held in ratio by the flux model at every rung, Chapter 8's composition applied four times at four settings — so that every rung is genuinely *sweet heat* and not merely hot. The gentlest is still lush; the fiercest is still, unmistakably, a strawberry. The chapters that follow take the rungs one at a time. Every scorecard in them is a **design target** — the specification we are aiming the loop at, not a measurement of anything yet grown. The berry is drawn. Its receptor, its pathway, its gene count, and its date are all in hand. It is very nearly ready to be asked to grow.

Chapter 11 · Warm Kiss & Sugar Burn — *the gentle rungs, and the delicacy of a small heat.*

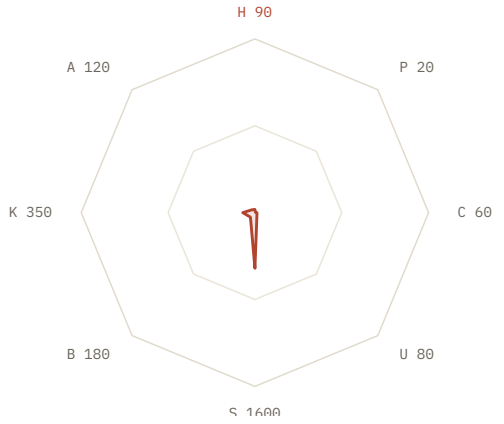
RUNGS 1–2 · design targets · not yet grown

The two lowest rungs belong together, because they share a secret the fierce rungs do not have to keep: the hardest heat to design is the *smallest* one. Anyone can make a fruit blisteringly hot — turn every dial up and get out of the way. To make a warmth you can barely name, a glow that is *felt* without ever announcing itself as spice, a heat that lifts the sweetness and then vanishes before the eater can call it heat at all — that is the fine work, and it is the work these two rungs exist to prove.

Warm Kiss is the first rung and the gentlest thing on the ladder, drawn for the eater who does not think they like heat: the child, the cautious palate, the person who wants summer without the risk. The target sets IFI-H at 90 — barely above the sunlit warmth of a shishito, a glow rather than a sting, deliberately below the threshold where the trigeminal system reports *spice.* Under it the sweetness is lifted to 1,600, the native-sugar floor raised and a light brazzein overlay laid on, with a faint kokumi roundness at IFI-K 350 so the warmth reads as *full* rather than thin. What reaches the tongue is a ripe strawberry that happens to feel warmer than a strawberry should — the way fruit tastes when you pick it off a plant that has stood all afternoon in the sun. Most tasters would not name it as heat. They would only say the berry seemed somehow more *alive.*

And the heat's shape is everything here: we use a short, fruity, front-loaded acyl tail — the KAS and BCAT settings of Chapter 5 and 8 turned toward a warmth that comes and goes fast — so that even the small heat clears completely, leaving the sweetness in full possession of the finish.

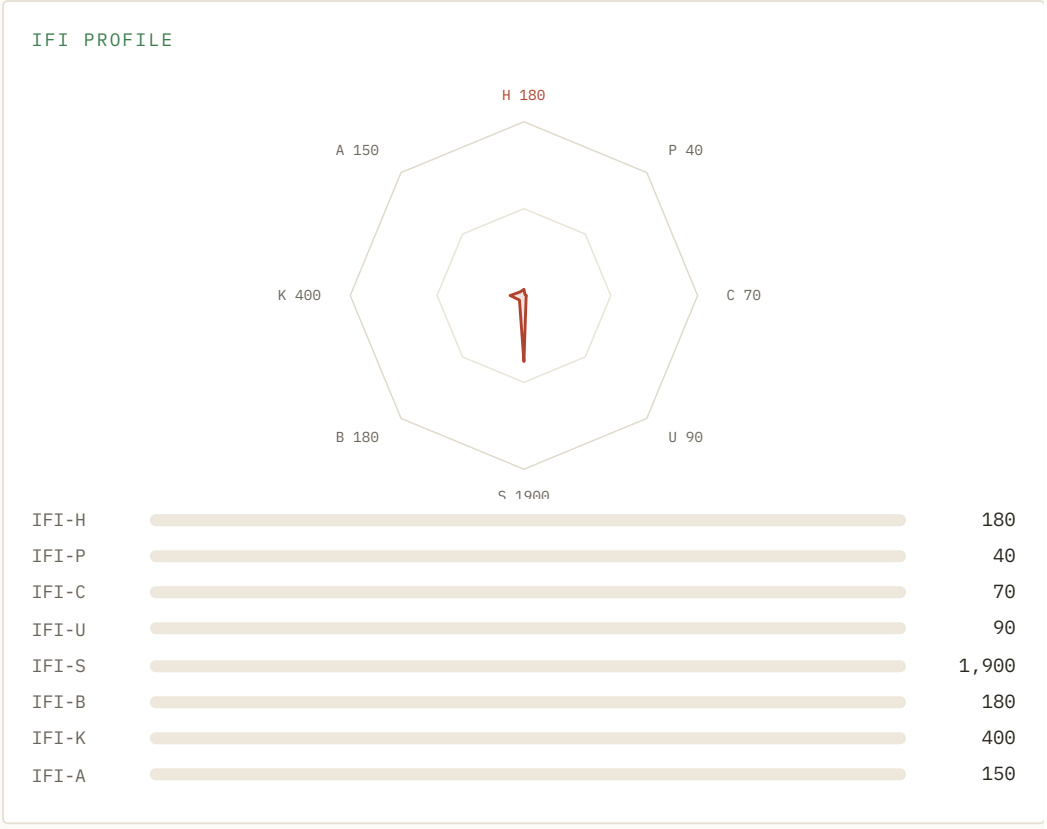
IFI PROFILE



IFI-H	90
IFI-P	20
IFI-C	60
IFI-U	80
IFI-S	1,600
IFI-B	180
IFI-K	350
IFI-A	120

Design target — the profile we are aiming the loop at, not a measurement. This fruit is not yet grown; it carries no SKU.

Sugar Burn is the second rung and the one we reach for when someone asks, in a single bite, *what is the dessert frontier?* The target holds IFI-S at 1,900 — the high ripe register, a berry at the top of its sweetness — and brings IFI-H up to 180, where the heat becomes unmistakable: a genuine pulse behind the sweetness, a warmth that makes you reach for the next berry rather than for water, still sitting below the threshold of *hot.* The kokumi fills to 400 so the fruit tastes whole and complete, round rather than sharp. This is the rung most people would choose if they could only have one — summer with something living behind it — and it is the berry we put in front of a skeptic, under a spoonful of warmed honey and a pinch of flaky salt, to show that a designed food need not taste designed. The berry does nearly all the work; the kitchen only frames it.



Design target — a specification, not a measurement. This fruit is not yet grown; it carries no SKU.



A strawberry specimen, isolated — the gentle rungs are drawn for the eater who does not think they like heat, and they are the hardest heat on the whole ladder to design.

Each gentle rung has its moment at the table. A Warm Kiss wants almost nothing done to it — eaten out of hand, cold from the bowl, it is a strawberry that happens to glow, and the kindest thing a kitchen can do is get out of its way. A Sugar Burn wants the smallest frame: warmed honey, a little salt, perhaps cultured cream, served at room temperature or gently warm so the pulse of heat has the warmth it needs to speak. Both reward restraint, because both were designed so the fruit does the work — and both are, pointedly, the rungs we would hand to someone who has always said they do not like spicy food, precisely because they will not taste spice. They will taste a strawberry more alive than they remembered strawberries could be, and only later, if they think about it at all, wonder why.

The engineering that separates these two rungs is subtler than the ninety-point gap in their heat suggests, because both live near the threshold where TRPV1 begins to report *spice* at all, and near a threshold small changes read large. A target of IFI-H 90 sits barely above a shishito; 180 is double that and still below *hot* — but doubling a heat that small is a genuine feat of control, because the channel's response near threshold is steep, and a pathway that overshot by even a little would push Warm Kiss into Sugar Burn's register or Sugar Burn into something a child would push away. This is where the ≤7% CV stops being a slogan and becomes the whole game: at these low magnitudes the forty-percent batch swing of the wild-type enzyme would be the difference between *imperceptible* and *unmistakable,* and the gentle rungs would be impossible to ship as distinct products. The redesigned Pun1's tight variance is what lets us place two different experiences a mere ninety Index points apart and trust that both land where the card says. And the brazzein overlay is timed to the same window — expressed under the ripening promoter, the sweet protein appears as the berry reddens — so the sweetness is at full height exactly when the small heat arrives behind it, the two peaks aligned by shared timing rather than left to chance.

Together these two rungs make the ladder *kind.* A sweet heat that starts this low can be offered to anyone — which is the entire point of designing the shape of a warmth rather than merely its size. We could have begun the ladder at a heat that announced itself. We chose to begin it at a heat you could miss, because a frontier that

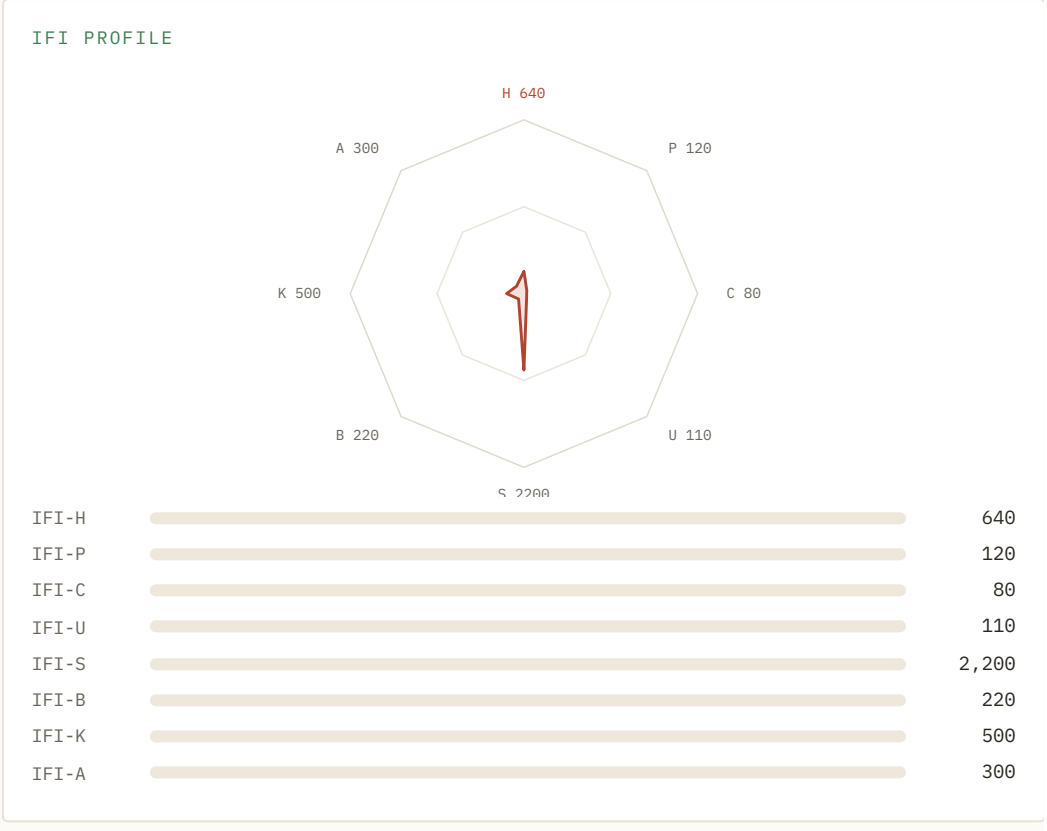
only served the brave would be a smaller and a poorer thing than one that begins with a kiss. Even the first rung is built for pleasure, never for proof. The proof is for later, and it is further up.

Chapter 12 · Candied Fang — *sweetness that shows a tooth.*

RUNG 3 · design target · not yet grown

Halfway up the ladder the heat stops being a pulse and becomes a presence. Candied Fang is the rung where sweet heat earns the first half of its nickname — drawn for the eater who wants to genuinely *feel* the fire and still, without hesitation, call the thing a dessert. It is the first rung with a point.

The target lifts IFI-S to 2,200 — a deep, almost confected sweetness, the berry at its most lush, the native sugars raised toward their ceiling and the brazzein overlay carrying the rest so the fruit tastes like candy that happens to be alive. Into that lushness we bring IFI-H up to 640, and 640 is a real heat — above the culinary chilies, a warmth that arrives clearly, blooms across the middle of the tongue, and is impossible to mistake for mere ripeness. But the craft is not in the number; it is in the *shape.* We tune the acyl tail here for a heat that blooms generously and then leaves *clean* — a standard-length tail for the bloom, a capsaicin-forward blend for brightness rather than the flat persistence of dihydrocapsaicin — because on a dessert a heat that lingered and dulled would steal the sweetness from the next bite, and the next bite is the whole pleasure of a bowl of strawberries. And we let the achenes' native astringency come forward, IFI-A at 300, a faint grip that gives the heat an edge to catch on. That grip is the *fang* in the candy: the grain of structure that keeps a lush sweetness from going slack and gives the warmth a surface to hang from. It is the first rung where the fruit has an edge as well as a bloom.



Design target — a specification, not a measurement. This fruit is not yet grown; it carries no SKU.



A strawberry opened — at the third rung the heat is made right here, in the red receptacle flesh, in the same cells that hold the sugar, so the bloom and the sweetness rise together.

To eat one is to feel the design unfold in order. The sweetness lands first and lands lush — that near-confected 2,200, the berry at the top of its ripeness — and for a half-second it is simply the best strawberry you have had. Then the warmth arrives, clearly now, a real heat blooming up through the sweetness across the middle of the tongue, and the seed-grip catches it, and for a moment the fruit is sweet and hot and textured all at once, a dessert with a nerve running through it. And then the heat withdraws, cleanly, because it was shaped to, and the sweetness closes back over the finish, and your hand is already reaching for the next one. That arc — lush, then hot, then lush again — is the whole intention of the rung, and it is why Candied Fang is the berry we reach for to show a skeptic that a serious heat and a true dessert are not a contradiction but a sequence.

Two pieces of real chemistry carry this rung, and both are worth naming, because Candied Fang is where the design stops being gentle and starts being *built.* The first is the clean exit. A heat of 640 that lingered would be a disaster on a dessert — it would dull the tongue and rob the next berry of its sweetness — so we shape the acyl tail for a bloom that leaves: a standard-length, capsaicin-forward blend rather than the flatter, more persistent dihydrocapsaicin, tuned through the KAS cycles and the desaturase of Chapter 5. Capsaicin's unsaturated tail partitions out of the nerve membrane faster than its saturated cousin; the warmth it gives rises generously and then recedes, clearing the palate in time for the sweetness to return. The heat blooms, peaks, and politely withdraws. The second piece is the grip. We let the achenes' native astringency come forward to IFI-A 300 — condensed tannins binding and precipitating the saliva's proline-rich proteins, stripping the mouth briefly of its slipperiness — which gives the lush sweetness a grain of structure and the rising heat a surface to catch on. Without that grip a sweetness this high would go slack, a flat wall of sugar; with it, the fruit has an edge, a texture, a *tooth.* That is the fang: not the heat alone, but the heat hung on a thread of astringency, so the bite carries architecture as well as bloom.

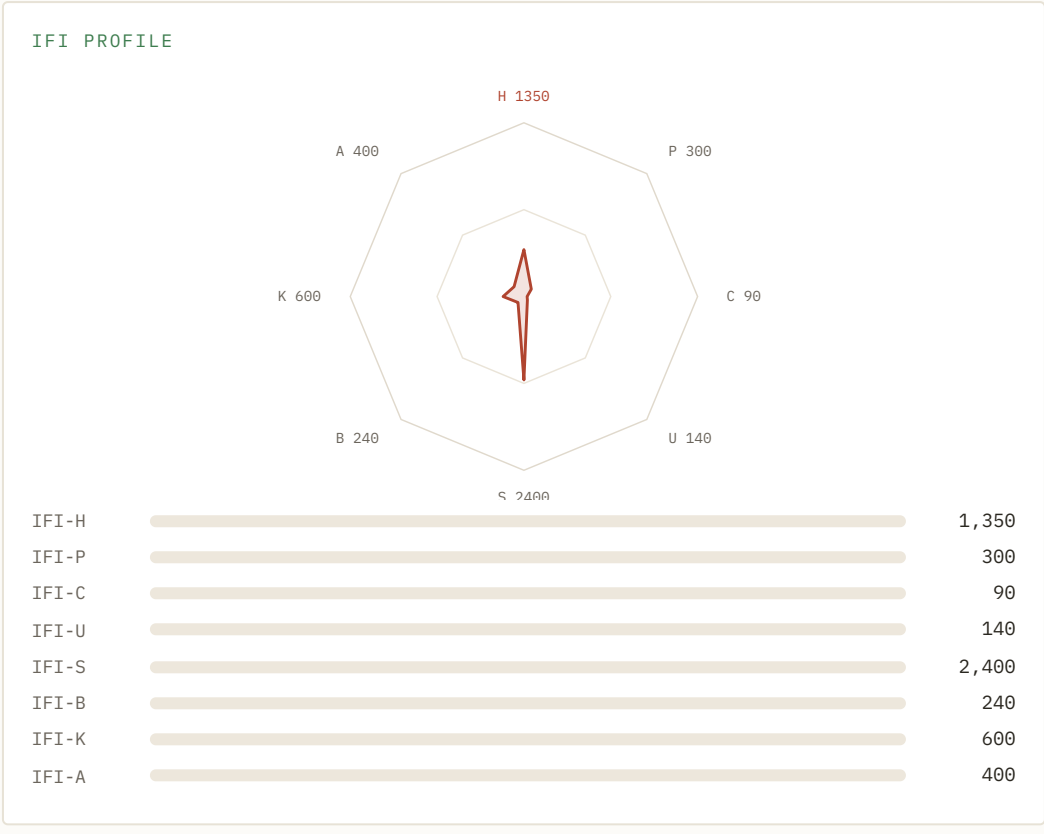
Candied Fang is where the ladder tips — from *fruit with a warmth* toward *dessert with a nerve.* It is the hinge of the whole climb. Below it, on Warm Kiss and Sugar Burn, the heat serves the sweetness, a thread that lifts and disappears. At Candied Fang the two become equal partners: the sweetness has climbed to 2,200 precisely so that it can meet a heat of 640 as a peer, neither one subordinate, the fruit reading as thrilling rather than merely sweet or merely hot. This balance is the flux model's hardest problem on the strawberry ladder, because it is the rung where the most carbon is being asked of the fruit at once — a near-maximal sweetness and a serious heat, both from one finite budget — and it is the rung that most tests whether the composition of Chapter 8 was real or wishful. We believe it is real. We drew it with the budget open. But Candied Fang, more than any rung, is the one whose first true harvest we are most eager to taste, because it is the one where the design is working hardest, and the proof will be in whether the sweetness still towers when the heat is finally that loud.

Chapter 13 · Devil's Dessert — *the one we drew to bite back.*

RUNG 4 · design target · not yet grown

The top of the sweet ladder, and the fruit we will not pretend is gentle. Devil's Dessert is the one rung drawn to cross the line — a strawberry with a real, grinning heat, built for the pepper-hardened eater who has always wanted the dare and the sweetness in the same mouthful and has never once, from a single fruit, been able to have them.

The target sets IFI-H at 1,350, and that number should be read against the flagship ladder in Chapter 9, because the comparison is the whole design. 1,350 sits a deliberate shade *below* Ember, our gentlest flagship pepper, which reads 1,570. We held it there on purpose. Devil's Dessert is drawn to be genuinely, unmistakably hot — a heat that bites — and still to be less than the mildest superhot we grow, a fraction of Phoenix's 4,200, a heat that forgives. Beneath it the sweetness is pushed to its lushest at 2,400, the kokumi filled out to 600 so the fruit tastes complete rather than merely fierce, a bright pungent top-note written in at IFI-P 300 — a thread of TRPA1 activation, the sharp channel, to put a sparkle on the very first instant before the TRPV1 warmth blooms behind it — and the achene astringency held at 400 for grip. Five axes in deliberate play, every one in ratio, nothing turned up for its own sake. This is the most carbon the strawberry ladder ever asks of the fruit, and the flux model's tightest partition.



Design target — a specification, not a measurement. This fruit is not yet grown; it carries no SKU.



The berry at the top of the ladder — drawn to bite back, and still held a shade below the gentlest pepper we grow. A fruit to be devoured, grinning, and then had again.

Eaten, it announces itself and then forgives. The first instant snaps — the pungent top-note, bright and electric — and then the sweetness floods in beneath it, and then, rising slower, the real heat, a genuine fire that makes the eater sit up and pay attention in a way no other rung does. For a second or two it is unambiguously hot, hotter than most people expect a strawberry could be, and the lush sweetness and the full body hold underneath it so the heat never feels like an attack, only like an intensity. And then it fades — shaped to fade — and what is left is the sweetness, and the memory of the fire, and the particular satisfaction of having been briefly dared by a dessert and come through grinning. It is a fruit that tests you gently and rewards you at once, which is a very different thing from a fruit that only tests you.

The five axes in play here are not a pile; they are a sequence, staged in time, and the staging is the craft. First, on the very instant of the bite, the pungent top-note at IFI-P 300: a thread of TRPA1 activation, the sharp channel, the same receptor that answers to mustard and wasabi and cinnamon's cinnamaldehyde. TRPA1 fires fast and sharp and clears fast — a bright electric prickle, there and gone in under a second — and we put it first so the bite *snaps* awake before anything else arrives. Behind it, a half-second later, the TRPV1 warmth blooms to IFI-H 1,350, slower to rise because capsaicin must partition into the membrane, and shaped once more to leave clean. Under both, holding the whole thing up, the sweetness at 2,400 and the kokumi at 600 — the kokumi a matter of γ-glutamyl peptides at the calcium-sensing receptor, grown in to give the fierce fruit a continuous, rounded body so it reads as *complete* rather than merely hot. And the achene astringency at 400 for grip, the most of any rung. Five sensations, four receptor systems, arriving in a designed order: snap, then bloom, over a bed of sweetness and body, caught on a thread of grip. Set the heat against the flagship ladder one more time — 1,350, a deliberate shade below Ember's 1,570, a fifteenth of Phoenix's 4,200 — and you can read exactly how far we chose *not* to go. Devil's Dessert is hot. It is also, precisely and on purpose, less hot than the gentlest pepper we grow.

This is the rung the press will want to photograph, and we understand why — a strawberry that bites back is a good headline, and a true one. But we want to be exact about what we did and did not draw, because the temptation at the top of any ladder is to chase

the number, and we refused it. We did not draw the hottest strawberry we could. We drew the hottest strawberry that is still a *dessert* — a heat you can taste all the way *through,* the fire always opening back onto the sweetness waiting on the other side, never closing over it. The pungent top-note arrives and clears in an instant; the TRPV1 warmth blooms and, because the tail is shaped to leave, recedes in time to let you want the next one. A strawberry drawn merely to test you would be a failure wearing a big number — a stunt, not a fruit. Devil's Dessert is drawn to be devoured. It is the proof at the top of the ladder that the method can cross the line into real heat and still keep faith with the thing a dessert is for, which is joy. The dare is real. So is the sweetness waiting behind it. That both live in one berry is the whole argument of this book, made at its loudest.

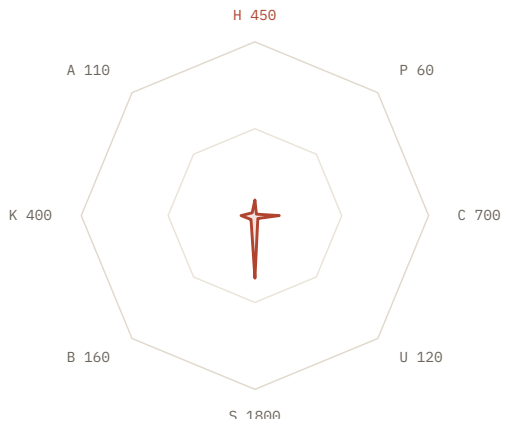
Chapter 14 · Solar Melon — *cold flesh, sun-warm heart.*

THE CONCEPT · *Cucumis* · Cucurbitaceae · T3 · 7–10 genes · 36–48 mo

Off the rose family now, and onto the gourd, to the strangest and most beautiful idea on the dessert frontier: a melon that is cool and warm in the same bite. If the strawberry ladder proves the method can place a heat precisely, the Solar Melon proves it can do something stranger still — set two touch-receptors against each other and grow a sensation that does not exist anywhere in nature.

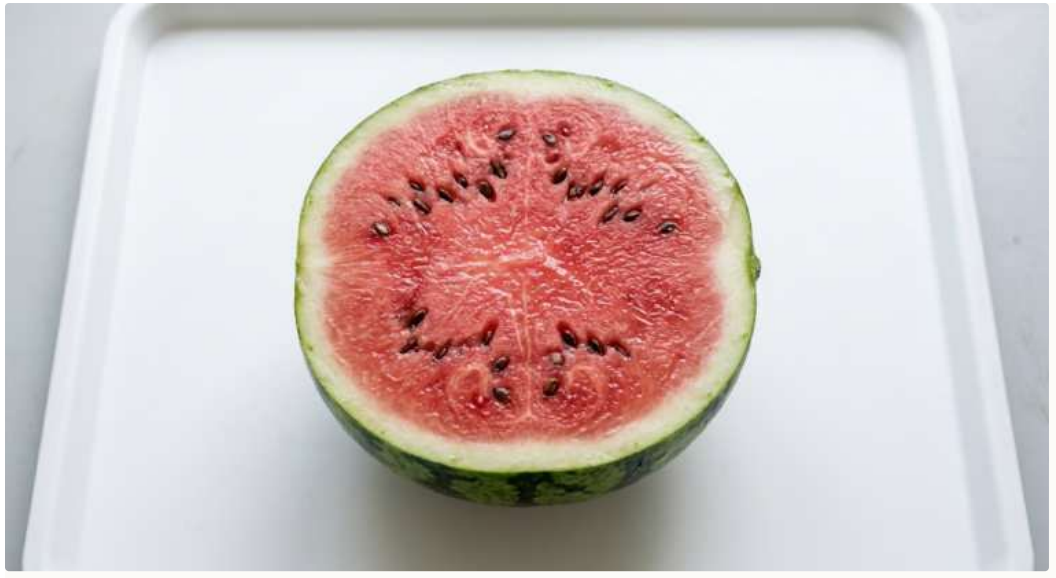
A melon is the most watery, sunlit flesh there is — all coolness and clean sweetness, a fruit that tastes like shade on a hot day, like the inside of summer. Its chemistry is quiet and lovely: a high water content, a gentle sugar sweetness, a wisp of cucumber-green aldehydes and, in the muskmelons, the faint musk-ester perfume that gives the family its name. Solar is drawn to hide a sun inside all that cool. And it does something none of the strawberries do, something that reaches for a receptor we have so far only mentioned: alongside the heat at TRPV1, it writes a *cooling* compound that acts at **TRPM8** — the transient receptor potential melastatin-8 channel, the one that answers to menthol and to actual cold, the receptor that reports *cool* the way TRPV1 reports *hot.* TRPM8 is TRPV1's mirror image: another polymodal thermosensor on the trigeminal nerve, opening below roughly 26 °C or when menthol binds, sending the brain the message *cold.* Install an agonist for it in the melon's flesh and the fruit now carries two contradictory thermal reports at once — a warmth rising at TRPV1 and a chill rising at TRPM8, in the same tissue, in the same instant.

IFI PROFILE



IFI-H	450
IFI-P	60
IFI-C	700
IFI-U	120
IFI-S	1,800
IFI-B	160
IFI-K	400
IFI-A	110

Design target — a specification, not a measurement. This fruit is not yet grown; it carries no SKU.



A melon in cross-section — the coolest, most watery flesh there is, drawn to hold a small impossible sun. Fire at TRPV1, ice at TRPM8, in one bite.

The sensation this produces is genuinely new, and it is worth being precise about why, because the novelty is not a gimmick — it is a direct consequence of the receptor architecture. TRPV1 and TRPM8 are separate channels on the same nerve, and the brain integrates their signals downstream into a single confused thermal percept. It cannot resolve *warm here* and *cool here* into one coherent temperature, so it reports both, alternating, chasing itself — fire and ice in the same place, a contradiction the mouth cannot stop investigating, bite after bite, trying to decide which one is true. Both are. We set IFI-C, the cool-burn axis, at 700, clearly above the IFI-H of 450, so that the melon's native character leads with coolness and the warmth rises *against* it, a sun breaking through — which is why the fruit is called Solar and not Volcanic. The sweetness sits at 1,800, and here we reach, as Chapter 7 promised, for a glycoside's long tail rather than a protein's bright lift, because we want the sweetness to *hang in the air* against the cool and the warm, present on the back of the palate through the whole confused, delicious argument. The kokumi at 400 keeps the watery flesh from reading thin, giving the sensation a body to happen inside.

The sensation is the strangest in the book and the hardest to describe to someone who has not had it, because it has no precedent. You bite cold melon and for an instant it is exactly that — cool, clean, watery, sweet, the taste of shade. Then the cool deepens, unnaturally, a mentholated chill spreading past what the temperature alone could explain; and just as that chill peaks, a warmth rises underneath it, in the same flesh, in the same place, refusing to cancel the cold. The mouth cannot decide. It reports cool, then warm, then cool again, chasing the contradiction down through every bite, and the sweetness hangs over all of it on the glycoside's long tail, holding the argument together. It is not a soothing sensation, exactly. It is a fascinating one — the kind you take another bite of not because the last was comforting but because you have to know, again, whether the fire or the ice gets the last word. Neither does.

The cooling half of this fruit is as engineered as the warm half, and it leans on a receptor and a pathway worth naming. TRPM8 is, like TRPV1, a tetrameric thermosensing channel on the trigeminal nerve, but tuned to the other end of the scale: it opens below roughly 26 °C and when menthol binds a pocket in its transmembrane domain, and

when it opens it sends the brain the word *cool* with the same conviction TRPV1 sends *hot.* To give the melon a true cool we install a cooling agonist, and the cleanest source is the mint pathway — the five-enzyme route that builds (–)-menthol from the plant's own geranyl diphosphate through (–)-limonene, a limonene-3-hydroxylase, and a short chain of reductases and a dehydrogenase. It is a multi-gene installation, part of why Solar sits at the top of Tier 3's gene count, but it yields a cooling compound the fruit makes natively and ripens on its own schedule rather than anything dosed in. The cucurbit host argues in its own ways — melons silence foreign genes readily, their phloem-loading and sugar metabolism differ from both the nightshade's and the rose's, and their watery flesh gives a designed sweetness less to hold onto — which is why we reach here for the glycoside's long tail and a firm kokumi floor, to give the sensation a body to happen inside. The result is two thermosensors, TRPV1 and TRPM8, firing against each other in one tissue, which the brain cannot resolve into a single temperature and so reports as both — alternating, chasing itself.

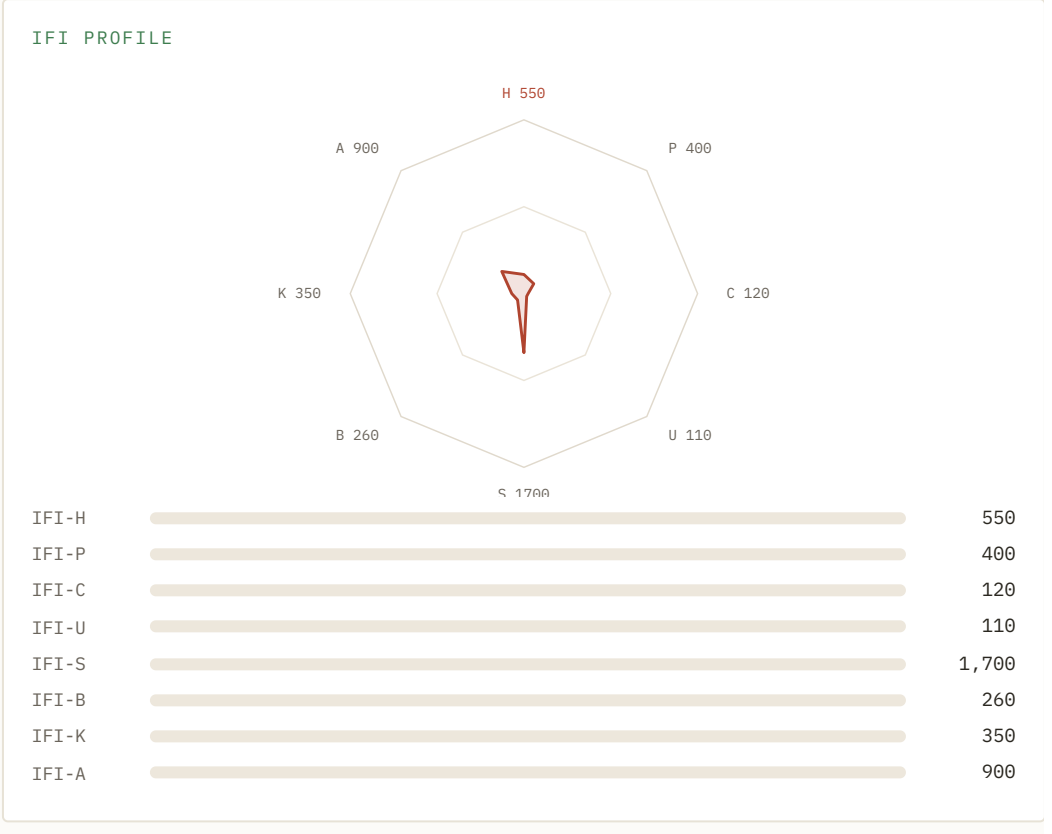
Solar is the fruit we point to when someone asks what the frontier is *for,* beyond novelty — and the honest answer is that Solar *is* the novelty, in the best sense. It is not a louder melon. It is a melon doing something no melon, no fruit, no plant has ever done: carrying a sensation that did not exist until a flux model found the ratio at which cool and warm could share a single cell without canceling. It asks the most of the method of any fruit in this book — two touch-channels, two installed pathways, two thermal agonists balanced against each other and against the sugar, all in a gourd that speaks neither the pepper's accent nor the mint's. It is the furthest reach here, and the one we are least certain of, and the one that, if it grows as drawn, will be the clearest proof that a flavor is only an event at a receptor and the receptor does not care what grew it. The oldest cooling fruit there is, taught to hold a small, impossible sun.

Chapter 15 · Forbidden Apple — *the oldest fruit, given teeth.*

THE CONCEPT · *Malus* · Rosaceae · T3 · 7–10 genes · 36–48 mo

We could not draw a dessert frontier and leave the apple off it. It is the oldest symbol we have of fruit — of sweetness and of temptation both — and temptation, properly understood, should bite back. Forbidden is the apple that finally does, and it is the fruit in this book whose heat is the most *architectural,* because the apple brings a dimension the strawberry only hints at: real, structural astringency.

Back among the roses, but a very different rose from the strawberry. Where the berry is soft, open, fast, and faintly astringent only at its seeds, the apple is firm, skinned, slow, and structurally tannic throughout. A fine apple already has architecture — the clean dry snap of its flesh, the faint tannic grip in its skin that keeps its sweetness from ever cloying, the way a great cider apple carries a bitterness and a grip that a dessert apple only suggests. That grip is the eighth axis, **IFI-A,** astringency, and its mechanism is worth naming because it is unlike every other axis in the Index. Astringency is not, strictly, a taste or even a receptor event in the usual sense. It is a *mechanical* sensation: condensed tannins — proanthocyanidins, built by the enzymes **LAR** (leucoanthocyanidin reductase) and **ANR** (anthocyanidin reductase) from the same flavonoid branch that colours the fruit — bind and precipitate the proline-rich proteins that lubricate the saliva, stripping the mouth of its slipperiness and leaving the puckering, drying grip we call astringent. The apple makes these tannins natively, in its skin and flesh. Forbidden is drawn to make that native structure the *stage* for a hidden heat.



Design target — a specification, not a measurement. This fruit is not yet grown; it carries no SKU.



An apple in cross-section — firm, structured, tannic in its skin. The grip that keeps its sweetness honest becomes the frame a hidden heat is laid across.

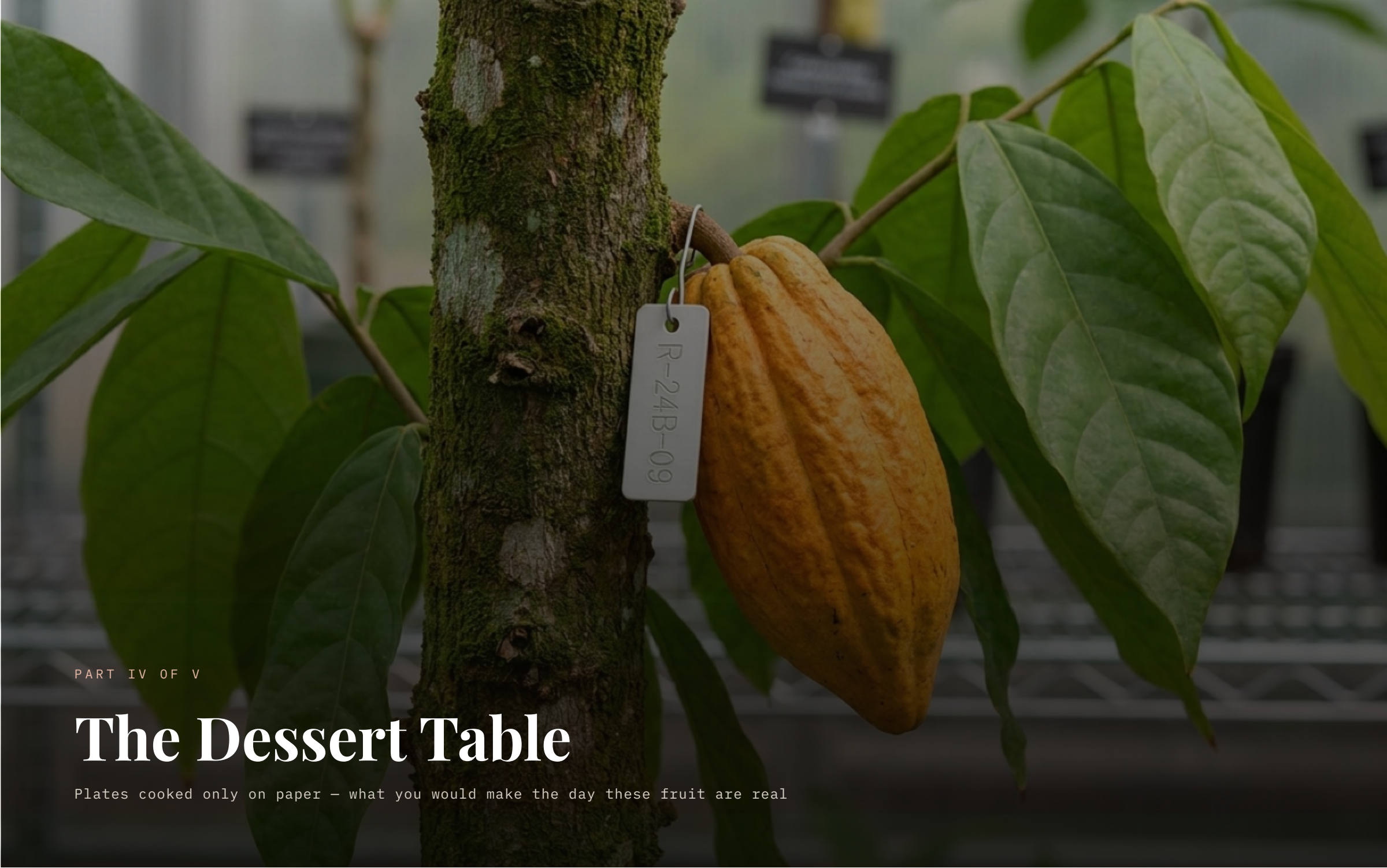
The design, then, is a composition in four voices held in careful tension. The sweetness is kept *bright* at 1,700 rather than lush — the apple's sweetness should be crisp and clean, not confected, because it has to balance a real astringent grip. That grip, IFI-A, is lifted to 900, by far the highest astringency in this book, raising the fruit's native tannins until the apple has a genuine spine, the dry structured snap of a serious cider or a young structured wine. Into that architecture we write a warmth at IFI-H 550 — not a soft bloom through tender flesh, as in the strawberry, but a heat laid *over a tannic frame,* which reads entirely differently: sharper-edged, more defined, the way fire reads over structure instead of over softness. And on the very first instant, a bright pungent sting at IFI-P 400 — a thread of TRPA1, the sharp channel again, strong here, the cinnamaldehyde-and-mustard channel — so that the first bite *snaps* with sharpness before the TRPV1 warmth rises behind it. You taste the apple you know: crisp, bright, dry, structured. Then, a half-second late, the apple bites back — the sting, then the warmth, rising up through the tannic frame — and you understand the name.

It eats like no sweet-heat fruit before it, because its heat has a frame to stand on. The first bite is all crispness and structure — the dry snap of the flesh, the clean bright sweetness, the tannic grip taking hold at the edges of the tongue the way a serious cider does. Then the sting arrives, sharp and sudden, the TRPA1 prickle snapping across the front of the mouth; and behind it the warmth rises, but it rises through *architecture,* caught and held by the astringent spine rather than cushioned by soft flesh, so it reads as sharper, more defined, more serious than the strawberry's bloom. It finishes dry and warm and clean, the way a structured drink finishes, leaving the mouth refreshed rather than coated — which is exactly why Forbidden is the fruit that can stand beside cheese and alcohol where a soft sweet berry would collapse. It is the grown-up of the book: a fruit that bites back and then, drily, lets you go.

The astringency axis deserves its full mechanism here, because Forbidden is the fruit that makes it structural rather than incidental. Condensed tannins — proanthocyanidins — are polymers of flavan-3-ol units, catechin and epicatechin, and the apple builds them down the same flavonoid branch that makes its red: leucoanthocyanidins reduced by LAR (leucoanthocyanidin reductase) to catechin, anthocyanidins reduced by ANR (anthocyanidin reductase) to

epicatechin, and those units polymerized into the chains that give skin and flesh their grip. The sensation is mechanical, not chemical: the polymers cross-link and precipitate the proline-rich proteins that make saliva slippery, and a mouth suddenly short of its lubricant reads the roughness as *dry, puckering, astringent.* Longer polymers grip harder; the balance of catechin to epicatechin shifts the quality of the grip from green to velvety. By tuning LAR and ANR we raise the apple's native tannin to IFI-A 900 — a serious, cidery structure — with the *kind* of grip we want, not merely the amount. The apple's own genetics cooperate: *Malus* carries well-characterized MYB regulators of both its anthocyanin and its proanthocyanidin branches, so the machinery to dial tannin up or down is already in the fruit, waiting to be addressed. Onto that raised structure we lay the heat and the TRPA1 sting, and because the frame is firm rather than soft, the warmth reads as architecture — a fire with edges, laid over a spine — instead of a bloom through tenderness.

Of all the fruit in this book, Forbidden is the most versatile at a table and the least like a candy. It is a dessert apple and a cheese-board apple and a cocktail apple at once — its astringency makes it the one sweet-heat fruit that belongs beside an aged cheddar or in a structured drink, where its tannic spine and its sharp warmth can stand up to fat and to alcohol the way a soft sweet berry never could. It is the fruit here whose heat is held by structure rather than cushioned by softness, and so it is the fruit that teaches the most general lesson of the dessert frontier: that a warmth takes the shape of the flesh it is grown into. The same IFI-H reads as a bloom in a strawberry and as a sharp architectural fire in an apple, because the fruit around it is different, and the fruit is half the design. The oldest fruit in the story, redrawn so that the temptation, at last, has teeth.



PART IV OF V

The Dessert Table

Plates cooked only on paper — what you would make the day these fruit are real

Chapter 16 · Cooking Sweet Heat — *the kitchen still composes the bite.*

FOR THE MAKERS · principles, and three plates on paper

This book is read, in part, by the people who would *build* with these fruit — the dessert brands, the pastry kitchens, the makers of hot honey and chili chocolate who have spent years setting two plants side by side and wishing for one. So this Part is for them: a small set of plates we have cooked only on paper, scored as projections, waiting for the harvest that would make them real. Before the recipes, four principles, because even when the heat is grown into the fruit, the kitchen still composes the bite.

Fat carries capsaicin, and spreads it. Capsaicin is lipophilic; it dissolves into fat and rides it across the whole surface of the tongue, which lowers the *peak* of a heat while widening its *reach* — a fiery berry in chocolate or cream reads as warm and round rather than sharp and local. Use fat to gentle and broaden a heat; use water and acid to keep it bright and pointed. **Temperature sets the volume.** TRPV1 is a heat sensor, so a warm dish reads hotter than a cold one made from the same fruit — the channel is already partway to its threshold. Serve a sweet-heat fruit cold to mute its fire and lift its sweetness; serve it warm to let the heat speak. This is why a Solar Melon wants to be eaten cold and a Devil's Dessert over warm chocolate wants to be eaten at room temperature, never chilled. **Acid sharpens; salt lifts both.** A squeeze of lime or a thread of vinegar makes a heat read brighter and more immediate; a few flakes of salt raise the perceived sweetness *and* the perceived heat at once, widening the whole dynamic range of the bite. **And sweetness is the frame, not the filler** — with these fruit the sugar is already in the flesh, so the kitchen's job is to give it contrast and let it speak, not to pile more sweetness on top. Build around the fruit. The fruit was designed to be the center.



Cocoa in cross-section — the bitter frame the oldest swicy dessert is built on. With a berry that carries its own fire, the chocolate is left to be only itself.

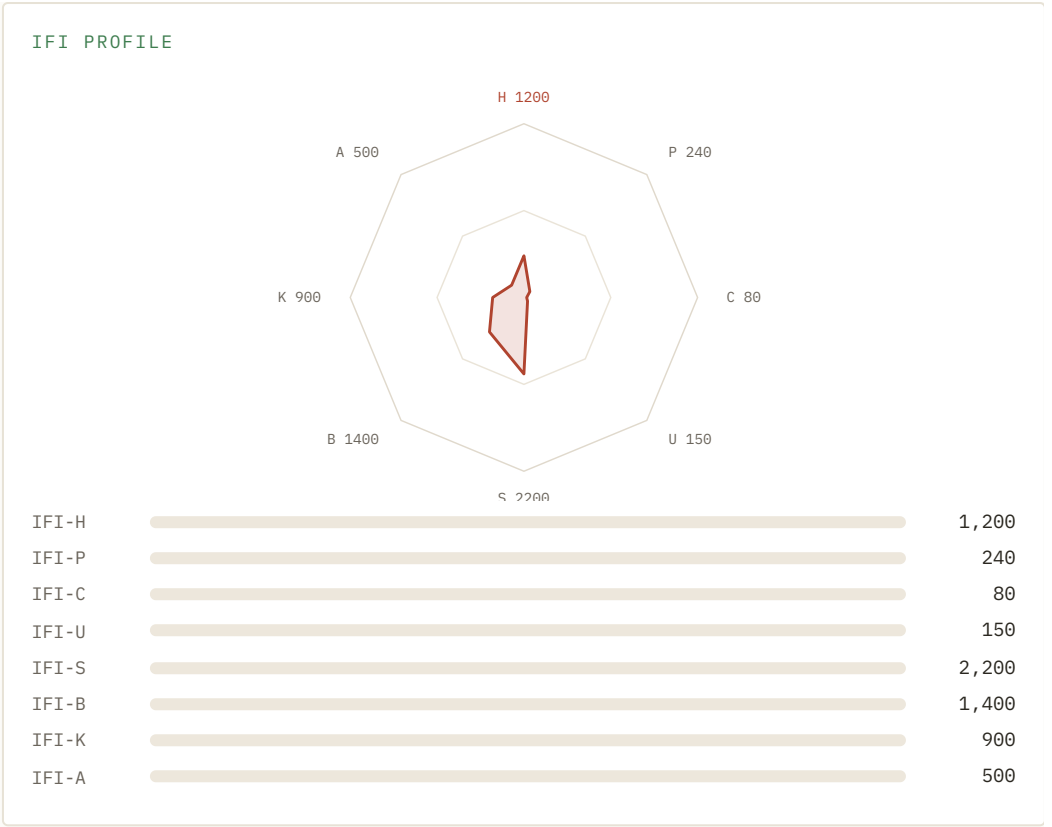
Devil's Dessert in Dark Chocolate, Olive Oil & Salt

Serves 4 · a concept dish · built on a fruit not yet grown

The classic swicy dessert — chili and chocolate — collapsed into one ingredient and one gesture. The heat a pastry chef used to introduce with cayenne in the ganache is already *in the berry,* so the chocolate is left to be only itself: bitter, deep, a frame. This is the day the strawberry becomes the spicy part.

16		ripe Devil's Dessert strawberries (when grown)
120	g	dark chocolate, 70%, bitterness-attenuated if you have it
2	tbsp	good olive oil
		flaky salt

1. Melt the chocolate gently with the olive oil until it falls in a slow ribbon — the oil keeps it glossy and soft, so it clings rather than sets hard and brittle.
2. Dip each berry to its shoulders, leaving the red tip bare, and lay them on cool stone or parchment.
3. Scatter flaky salt across the still-wet chocolate, at once, before it firms.
4. Let them set at room temperature, never cold — cold would mute both the sweetness and the heat. Eat in one bite each: the chocolate reads first, bitter and round; the berry's sweetness lifts under it; and then, last, the warmth comes up through everything and the bite turns from dessert into something you have never quite had.



Projected readout for the finished bite — a target, not a measurement. Note how the fat of the chocolate and oil carries the capsaicin wide and gentle, softening the berry's heat from its bare 1,350 to a rounder 1,200; the kitchen still shapes the fire even when the fire was grown in.

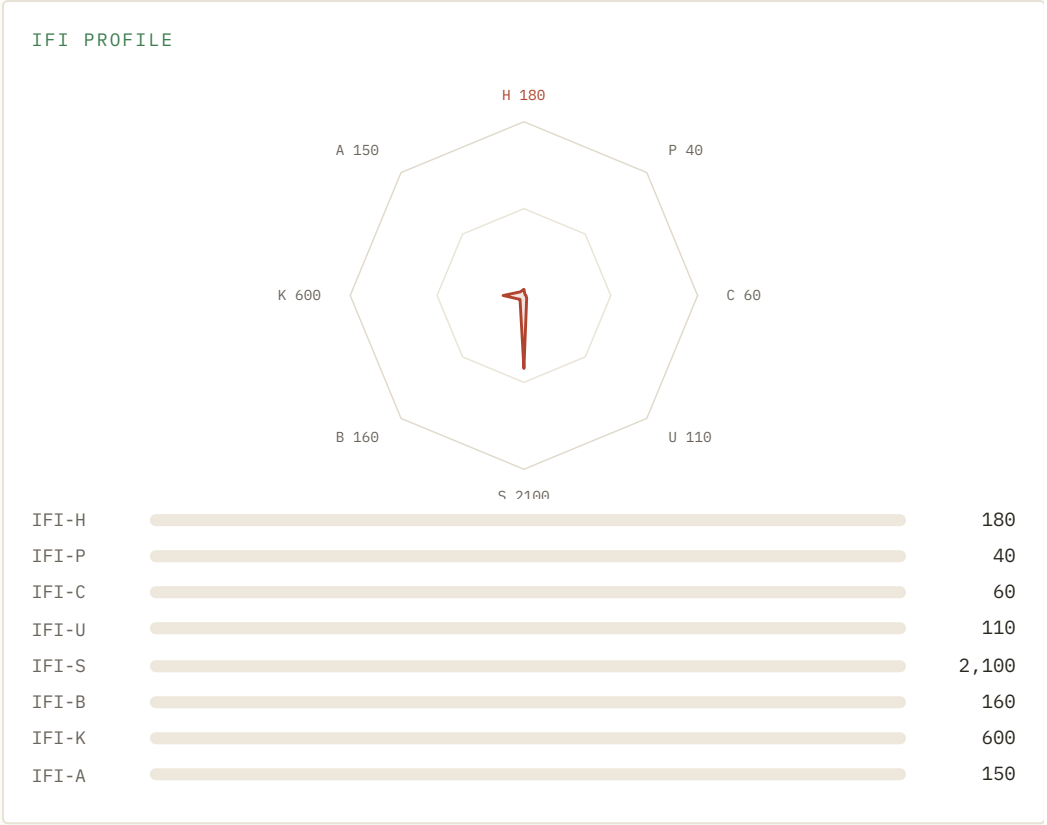
Sugar Burn Shortcake, Warm Honey & Salt

Serves 4 · a concept dish · the gentle rung, barely dressed

The berry that needs the least. A classic shortcake, warm honey, a whisper more heat than the fruit already carries, and salt at the very end — a plate built to prove that a designed food can taste like the oldest thing in the world.

500	g	ripe Sugar Burn strawberries (when grown), halved
4		buttermilk shortcakes, warm
3	tbsp	honey, gently warmed
		lightly whipped cream, unsweetened
		flaky salt

1. Warm the honey until it just loosens and pours — do not cook it; its own perfume is part of the dish.
2. Split the warm shortcakes and spoon the whipped cream, left unsweetened because the berries carry the sweetness.
3. Pile the halved berries over, spoon the warm honey across, and finish with the smallest pinch of flaky salt.
4. Serve at once, while the shortcake is warm — the warmth lets the berry's gentle heat speak, where cold would hush it to nothing.



Projected readout — a target. The cream's fat and the shortcake's richness lift the kokumi; the warm honey nudges the sweetness; the heat stays exactly where the berry put it, a pulse under the summer.

Solar Melon Granita, Lime & Sea Salt

Serves 6 · a concept dish · fire and ice, served cold on purpose

The fruit whose whole character is a contradiction, served at the temperature that sharpens the contradiction most. Cold mutes the heat and wakes the cool, so a Solar granita leads with its chill — and

then the small sun rises anyway, through the ice, which is the entire point of the fruit.

1		ripe Solar Melon (when grown), chilled, seeded, cubed
2	tbsp	lime juice
1	tbsp	honey or light agave, only if needed
		flaky sea salt
		a few mint leaves (optional — it only deepens the cool)

1. Blend the cold melon with the lime and, only if the melon needs it, the honey. Taste: the fruit's own sweetness should carry it.
2. Pour into a shallow tray and freeze, dragging a fork through every thirty minutes, until it is loose glittering ice.
3. Spoon into cold glasses, finish with a few flakes of sea salt, and — if you like — a single torn mint leaf, which pushes the cool higher so the warm rising through it startles more.
4. Eat immediately, cold as it comes: you will taste ice, then lime, then, impossibly, a sun coming up on the back of your tongue.

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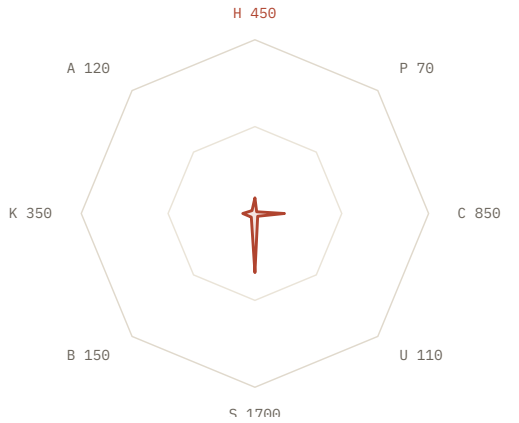


IFI-H	450
IFI-P	70
IFI-C	850
IFI-U	110
IFI-S	1,700
IFI-B	150
IFI-K	350
IFI-A	120

Projected readout — a target. The cold and the mint push IFI-C higher than the fruit's own 700; the heat holds at 450 and rises against the chill exactly as designed. Fire and ice, with the ice given the first word.

Chapter 17 · A Frontier Dessert Menu — *three more, for when the harvest comes.*

FOR THE MAKERS · savory-leaning, structured, and a glass

Three more plates, drawn to show the range the frontier opens — a sweet heat against fresh cheese, the structured apple against aged cheddar, and a glass to end on. Each is scored as a projection; none can be cooked until the fruit is grown; each is here because a maker reading this book should be able to see, concretely, what these fruit make possible that two plants side by side never could.

A word to the formulator before the plates, because a brand builds differently than a home cook. The ≤7% CV is the quiet reason these fruit can become products at all: a sauce, a bar, a sorbet built on a Candied Fang will taste the same next season and the one after, the heat landing where the specification says — a promise no field-grown chili has ever been able to make, pepper heat famously swinging with weather, soil, and water stress from harvest to harvest. Two further formulation facts follow from the science already laid out. First, format sets perceived heat: TRPV1 is a warmth sensor, so the same fruit reads hotter in a warm baked good than in a frozen sorbet, and a developer dials the cultivar to the serving temperature — a Devil's Dessert perfect warm might want to be a Candied Fang when frozen. Second, fat is the heat's volume knob in a finished product: a cream, a ganache, a nut butter will broaden and gentle the burn, while a water-based sorbet or a fruit leather keeps it bright and pointed. The fruit arrives with its heat grown in and its sweetness true; the maker's job is to choose the format and the fat that frame it. The plates below are written for the cook, but every one is a formulation note in disguise.

Candied Fang over Whipped Ricotta, Olive Oil & Black Pepper

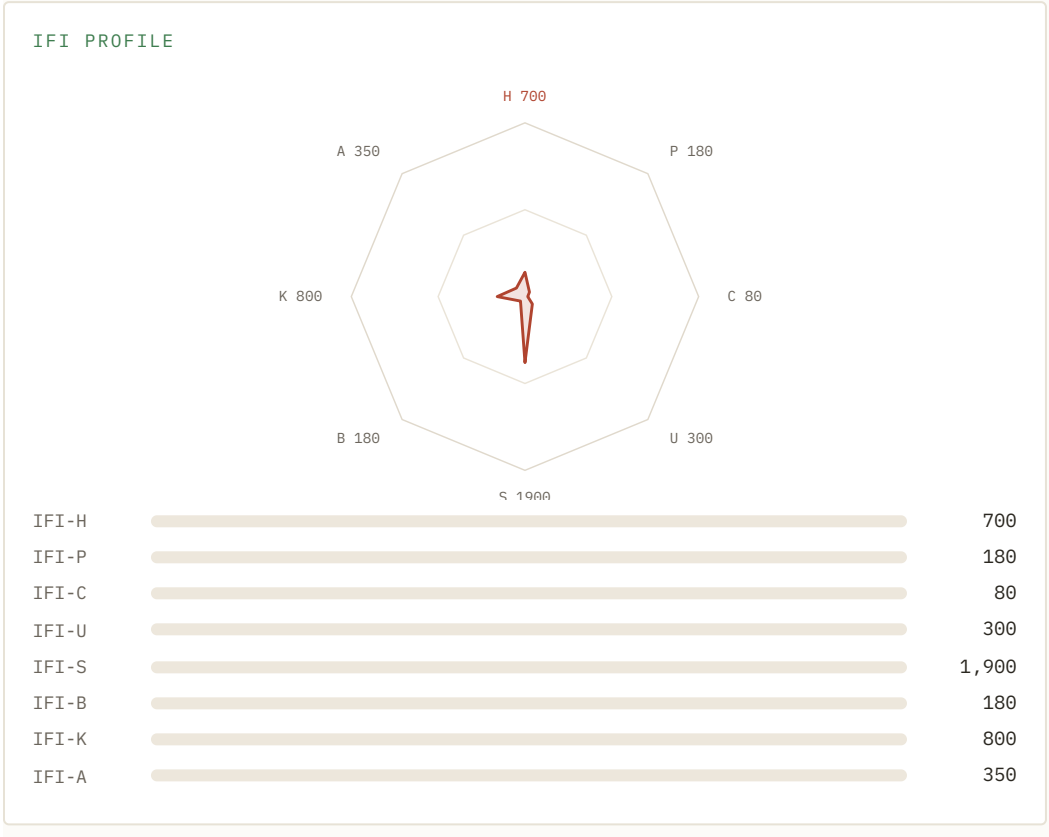
Serves 4 · a concept dish · the sweet-savory hinge

The third rung's seed-astringency and real heat make it the berry that can lean savory — set against cool fresh ricotta, good oil, and a crack of black pepper whose own warmth (a different molecule, piperine, at the same TRPV1 door) echoes the berry's. A dish that is barely a dessert and barely not.

300	g	ripe Candied Fang strawberries (when grown), quartered
250	g	fresh ricotta, whipped smooth
2	tbsp	fruity olive oil
		coarsely cracked black pepper
		flaky salt · torn basil

1. Whip the ricotta with a pinch of salt until it is loose and spoonable, and spread it across a cold plate.
2. Scatter the quartered berries over, letting their juice bleed into the cheese.

3. Thread the olive oil across, crack black pepper generously — its piperine warmth meets the berry's capsaicin at the same receptor, doubling the glow — and finish with salt and torn basil.
4. Eat with bread, as a first course or a last one; it refuses to decide which, and that is the pleasure.



Projected readout — a target. The ricotta's fat broadens the heat and lifts the kokumi; the black pepper nudges IFI-H above the berry's own 640; the basil and oil pull the whole plate toward the savory edge of sweet.

Forbidden Apple & Aged Cheddar, Walnuts, Honey

Serves 4 · a concept dish · the cheese-board apple

The one sweet-heat fruit with the tannic spine to stand on a cheese board. Forbidden's astringency and sharp warmth meet aged cheddar's fat and salt the way a structured cider does — the grip cutting the fat, the heat rising against it, the sweetness holding the whole thing together.

2		Forbidden Apples (when grown), cored, sliced thin
150	g	aged cheddar, at room temperature
		toasted walnuts, roughly broken
1	tbsp	honey
		good bread or oat crackers

1. Bring the cheddar fully to room temperature — cold cheese would flatten both its own flavor and the apple's heat.
2. Fan the thin apple slices beside the cheese; the tannic snap of the fruit wants the fat of the cheese directly.
3. Scatter the toasted walnuts — their own faint astringency rhymes with the apple's — and thread the honey over.
4. Build each bite yourself: apple, cheese, a walnut, a touch of honey. The apple's sharp warmth arrives last, through the fat, and resets the palate for the next.

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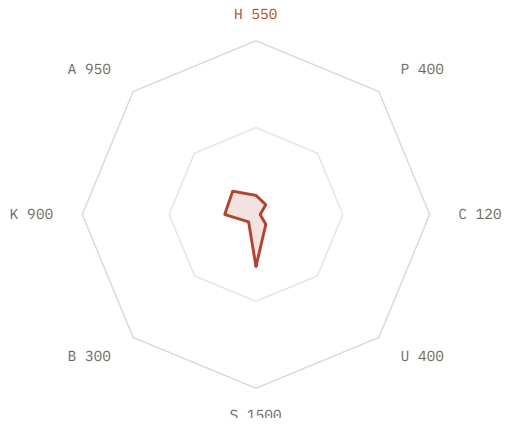

IFI-H	550
IFI-P	400
IFI-C	120
IFI-U	400
IFI-S	1,500
IFI-B	300
IFI-K	900
IFI-A	950

Projected readout — a target. The cheddar's fat and salt lift umami and kokumi and broaden the heat; the apple's astringency holds at 950, the structural spine the whole board is built on.

Solar Melon & Chili-Lime Agua Fresca

Serves 4 · a concept drink · no alcohol, all contradiction

A glass to end the menu — the Solar Melon's fire-and-ice poured long over ice, brightened with lime, rimmed with chili-salt so the first sip and the last carry a little extra warmth against the melon's cool. A mocktail that argues with itself all the way down.

1		ripe Solar Melon (when grown), seeded, cubed
750	ml	cold water
3	tbsp	lime juice
		honey or agave to taste (likely little)
		chili-lime salt, for the rim
		ice

1. Blend the melon with the water and lime until smooth; strain if you like it clean, leave it if you like it full.
2. Sweeten only if the fruit needs it — a Solar Melon likely will not.
3. Rim cold glasses with chili-lime salt, fill with ice, and pour.
4. Drink cold and long: the chili rim warms the lip, the melon cools the tongue, and the small sun rises through both. Fire, ice, and lime, in a glass that cannot make up its mind.

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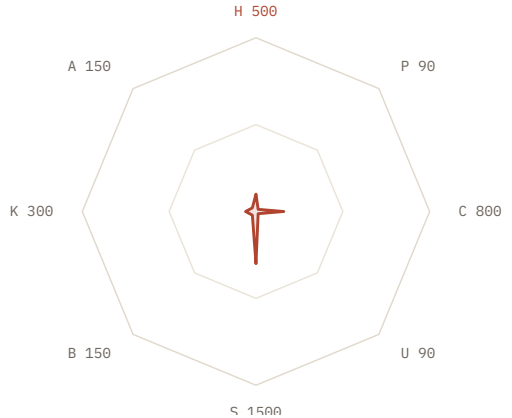

IFI-H	500
IFI-P	90
IFI-C	800
IFI-U	90
IFI-S	1,500
IFI-B	150
IFI-K	300
IFI-A	150

Projected readout — a target. Served over ice with a warm chili rim, the drink widens the melon's native fire-and-ice into its fullest expression — cool leading, warm chasing, lime holding the line between them.



PART V OF V

The Frontier Ahead

The shape of a dessert burn, what it asks of us, and what comes after the berry

Chapter 18 · The Shape of a Dessert Burn — *restraint, the rules, and the quiet thing underneath.*

THE ETHOS · design, compliance, and nourishment

A method that can write any heat into any fruit is defined less by what it can reach than by what it refuses to do, and the dessert frontier is where that refusal matters most — because a dessert is, of all foods, the one we eat purely for joy, and joy is easy to spoil with a number chased for its own sake.

So we design the *shape* of a dessert's heat, never only its size. Where the warmth lands, how it blooms, how cleanly it leaves — these are the whole craft, and on a sweet fruit they are everything, because a heat that lingered and dulled would rob the next bite of the very sweetness it was meant to lift. Every rung in this book was drawn to be tasted *through,* the fire always opening back onto the sugar, never closing over it; and we spent real engineering — the acyl-tail shaping of Chapters 5 and 8, the capsaicin-to-dihydrocapsaicin ratio, the half-second timing against the strawberry's fast sugar — buying that shape. Even Devil's Dessert, the one we let cross the line into genuine heat, we held a deliberate shade below the gentlest pepper we grow. A dessert that only tested you would be a contradiction in terms. We are not building dares. We are building joy with a little more dimension than it used to have, and the discipline that keeps it joy is the same discipline that keeps every number in this book honest: we draw what serves the eating, and we stop there.

There are rules beyond our own, too, and we say plainly where the frontier meets them, because a fruit you can draw is not the same as a fruit you can sell, and the honesty of this book extends to that line as well. These are engineered fruit, and engineered fruit enters a real regulatory world — novel-food and genetically-engineered-crop review in every market, each with its own standard and its own clock, often measured in years, sometimes longer than the three-to-four-year design horizon itself. The sweet proteins we lean on, brazzein chief among them, are themselves novel food ingredients with their own approval paths and, like any introduced protein, require honest allergenicity assessment — sequence screening against known allergens, stability and digestion testing — done properly and transparently before anything reaches a table. Labeling will say what the fruit is; we believe in that, not against it. And one line we will not cross in any market or any book: we make no health claim, none, for any fruit in this library. Not for the heat, not for the sweetness, not for anything grown into them. The frontier runs

through the laboratory and the kitchen, and it also runs through the regulator's office and the allergen panel, and we intend to walk all of it in daylight.

To be concrete about the clock, because vagueness here would be its own kind of dishonesty: an engineered fruit of this kind enters, in the United States, the coordinated framework that spans the Department of Agriculture, the Food and Drug Administration, and in some cases the Environmental Protection Agency, with the review path turning on how the plant was made and what was introduced. In the European Union it meets the novel-food and GMO regimes, among the most demanding in the world, where a fruit carrying introduced genes faces a long authorization and a clear label. And gene-edited crops that add no foreign DNA travel a lighter path in several jurisdictions than those that do — one quiet reason to prefer editing a plant's own regulation wherever the flavor can be reached that way. The sweet proteins are their own regulatory objects: brazzein and its kin are novel food ingredients with their own dossiers, and any introduced protein must clear an honest allergenicity assessment — sequence comparison against databases of known allergens, tests of digestive and heat stability, serum screening where indicated — before it belongs in anything anyone eats. We treat none of this as an obstacle to route around. It is the price of putting a new thing in the human mouth, and it is a price a serious company pays in daylight, with its data in the open: twenty-one of our studies already sit in the peer-reviewed literature under a license that lets anyone check our work, three patents are filed, and every number in this book resolves against one shared index so that nothing drifts from book to book.



A designed fruit at dawn, beaded with dew — drawn, waiting, and three to four patient years from a first real harvest.

And underneath the joy, quiet as it is in every book of ours, the thing we will not say loudly and will not pretend isn't there. A strawberry grown back toward its fullest flavor is, by the same cellular logic, a strawberry grown toward its fullest self — the deep red of real anthocyanins restored, the vitamin C a berry carries when it ripens on the plant instead of in a truck, the compounds a century of breeding for shelf life quietly thinned. The restored metabolism that lets a fruit taste like all of itself is the same metabolism that lets it *be* all of itself; flavor and nourishment were never two projects the plant was running, but one. We make no claim for what that does in a body

— that is not ours to promise, and this is a book about pleasure. We only note, as we always do, that when we design a fruit toward the sweetness and the warmth it could hold, we are, without having to aim at it, designing a fruit more worth eating. A dessert can be a kind of care. That it is also a delight was, for us, always the point.

What comes after the berry is more of the same road, walked further. The sweet frontier does not end at three fruit; the strawberry, the melon, and the apple are the first crossing of the family line, and every fruit on the far side of it is now, in principle, in reach — the stone fruits whose own warmth already leans toward spice, the tropical fruits whose sweetness could carry a serious heat, the whole bowl waiting to be asked. Each will take its own seven to ten genes and its own patient years; each will be drawn with the budget open and scored as a target until the day it is grown and scored for real. The method does not run out. It only keeps crossing lines that turn out, on inspection, to have been habits and not laws.

Appendix · The sweet-heat roadmap, scored

The dessert frontier at a glance — Tier 3 of the sixty-four-plant roadmap, the ring that crosses the family line into fruit. Every profile here is a **design target,** the specification we are aiming the loop at, not a measurement. None of these fruit is yet grown; none carries a SKU. The only measured fruit on the page is the anchor at the bottom — Phoenix, SS-0096, the one real plant whose eight real axes prove the method the targets rest on.

CONCEPT	BOTANICAL LEAP	FAMILY	GENES	HORIZON
Strawberry · Sweet Heat	Solanaceae → Rosaceae	rose	7–10	36–48 mo
— Warm Kiss				H 90 · S 1,600 · K 350
— Sugar Burn				H 180 · S 1,900 · K 400
— Candied Fang				H 640 · S 2,200 · K 500 · A 300
— Devil's Dessert				H 1,350 · S 2,400 · K 600 · P 300 · A 400
Melon · Solar	Solanaceae → Cucurbitaceae	gourd	7–10	36–48 mo
— Solar				H 450 · C 700 · S 1,800 · K 400
Apple · Forbidden	Solanaceae → Rosaceae	rose	7–10	36–48 mo
— Forbidden				H 550 · A 900 · S 1,700 · P 400
Phoenix *(real · the anchor)*	—	*C. chinense*	—	shipping

Axes — H: Heat (TRPV1) · S: Sweetness (TAS1R2·TAS1R3) · U: Umami (mGluR1) · B: Zero-Bitter (TAS2R38) · K: Kokumi (CaSR) · C: Cool-Burn (TRPM8) · P: Pungency (TRPA1) · A: Astringency (salivary PRPs). Per-axis scale maximum 5,000. IFI = 1,000 × EC_{50}(reference)

÷ EC_{50}(candidate). The proof the targets are reachable is a real fruit: Phoenix, the first eight-axis cultivar, IFI-H 4,200, reached through the Pun1 edits S39L · L345G.

A closing note · drawn, and waiting to be grown

We have walked the sweet end of the frontier the way you would walk a coastline you fully intend to reach — naming its bays, scoring its fruit, telling you honestly which parts are solid ground and which are still only a good map drawn carefully from a working method. The ground is a real pepper with eight real axes, already in hand, already shipping. The map is a strawberry in four rising rungs, a melon with a sun in it, an apple that bites back — each one a design on the platform, seven to ten genes and a few patient years from a first harvest, each one reachable by the same loop that built the fruit we stand on.

It began at our table, with a child who could not see why the strawberry shouldn't be the spicy part, and who was, we have come to think, simply the first of us to notice that the old arrangement — heat in one plant, sweetness in another — was a habit and not a law. The law is only this: a flavor is an event at a receptor, and a receptor does not care what grew it. TRPV1 does not know whether its capsaicin came from a pepper's placenta or a strawberry's receptacle; it only knows the molecule arrived. Everything else — the family line, the ten thousand years, the two plants set side by side — is a matter of which genes we move, and how patiently we let the fruit finish arguing.

These are not yet planted. We have not hidden that, on any page, because the honesty is the whole discipline of a frontier — the line between the fruit you can grow and the fruit you have only drawn is the line we guard most carefully across the entire library, and we would rather give you a true map than a beautiful lie. But drawn is not the same as dreamed. When the first Devil's Dessert comes off a real plant and we read its real card, this book becomes a record instead of a map, and we will change the word *target* to the word *score* and change nothing else — because we drew it true, with the budget open and the method proven and the number earned somewhere real before it was ever promised here.

Until then, it is enough to say what the child said, and to mean it as a promise. The strawberry *can* be the spicy part. We are only growing it there.

These are computational designs; Scoville Splice's cultivars and constructs have not been experimentally validated in a laboratory.