PROCESS NMR ASSOCIATES

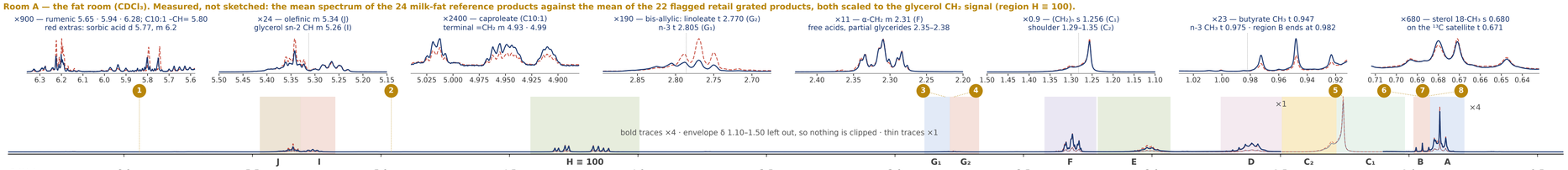
The Cheese Spectral Lineup · second interrogation, paired tubes

Sixteen suspects and the same two interrogation rooms — a 5 mm tube of CDCl₃ for the fat and a 5 mm tube of D₂O for everything the fat left behind — with 84 cheese products booked under one code in both. Forty of them are retail grated Parmesan and Romano of unknown composition; forty-two are reference products of nine classes, there to show what an honest spectrum looks like; two are held on a paperwork problem. Every cheese confesses somewhere in the ¹H spectrum. The lineup walks downfield to upfield, room by room, sorted by the δ of each suspect's most incriminating signal, and every confession is graded on how much of it would survive cross-examination. The headline charge, as it stands after external review: twenty-two of the forty were flagged for a fat that is roughly half not milk fat, and twenty-one of those twenty-two have a water extract that reads as processed cheese, not ripened cheese. The oil has not been named, the recipe has not been found, and nobody's age has been established. This is a screening, not a verdict.

¹H NMR field guide · cheese edition · second interrogation
84 products with paired CDCl₃ and D₂O extracts · 43 further lipid spectra · 14 reference fats and oils · 55 Cs-EDTA spectra
300 MHz (Varian Mercury-300 MVX), 27 °C, single pulse, no presaturation, recycle time 8.27 s · nominal 200 mg per product, one extraction each
Process NMR Associates, LLC · 84 Patrick Lane, Ste 115, Poughkeepsie, NY 12603 · www.process-nmr.com
compiled November 2026 from the white paper "Paired ¹H NMR Screening of Retail Grated Cheese", version 2.2 (November 15, 2026)
Shifts: CDCl₃ vs. TMS; D₂O vs. TSP-d₄ at native extract pH · products identified by type and sample code only

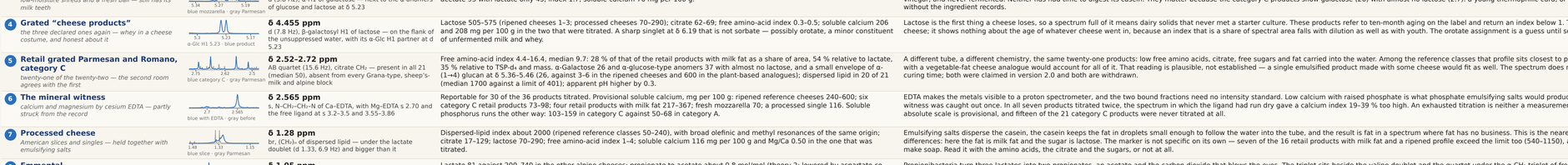
Where the bodies are buried

Room A — the fat room (CDCl₃). Measured, not sketched: the mean spectrum of the 24 milk-fat reference products against the mean of the 22 flagged retail grated products, both scaled to the glycerol CH₂ signal (region H ≡ 100).



CDCl₃ against TMS, downfield on the left · integration regions A–J shaded, with the splits C₁ | C₂ at δ 1.282 and G₂ | G₁ at δ 2.786 · **navy** the milk-fat reference population · **red dashes** the 22 flagged retail products — butyrate and caproleate at about half, linoleate more than doubled and without its n-3 partner, more olefinic signal, a heavier C₂ shoulder · every expansion is drawn on its own full scale, with its gain over the ×1 trace · gold pins are the Room A suspects, numbered as in the lineup below; three of them share δ 0.947, which is the point of the room.

Room B — the water room (D₂O). Two measured extracts on one scale of total spectral area: a domestic extra-aged Parmesan block of 18 months (B-042) and a retail grated Parmesan of category C (B-013).



D₂O against TSP-d₄ at the native pH of each extract (apparent pH 5.3–5.9), acquired without presaturation · every aqueous index on this poster is a share of total spectral area, not a concentration · **navy** the Parmesan block — free amino acids everywhere, no citrate, no sugars · **red dashes** the category C product — quiet amino-acid windows, the four lines of citrate, anomeric doublets, sorbate, and a lactate doublet riding on dispersed fat · blue pins are the Room B suspects; the hollow pin marks Ca–EDTA, a signal that exists only after cesium EDTA has been added.

Reading the lineup

- **Established** Textbook chemistry, or a control whose label and spectrum say the same thing.
- **Supported** Several chemically distinct markers agree within the two spectra. One laboratory, one extraction per product, no reference method yet.
- **Plausible** Inferred from composition. It fits; so would something else.
- **Speculative** One product, an uncalibrated scale, or a mechanism nobody measured.
- **Exhibit** One to five declared products — identities, does not generalize.
- **Confounder** Real chemistry that mimics a fraud; convicts nobody, acquits somebody.
- **Withdrawn** Claimed in an earlier version and struck out after review; see the bottom row.

Mugshots are measured spectra of the suspect in its headline window, drawn with a reference on one vertical scale unless the caption says otherwise. **Multiplicity:** s singlet · d doublet · t triplet · q quartet · dd doublet of doublets · m multiplet · br broad · AB two-spin system. **Sort key** is the δ of the headline signal. **Regions:** A terminal CH₃ · B butyrate and n-3 CH₃ · C₁ | C₂ methylene envelope · D β-CH₂ · E allylic · F α-CH₂ · G₂ | G₁ bis-allylic · H glycerol CH₂ · I glycerol CH · J olefinic. **The cast:** Grana-type 6 · sheep's-milk 4 · Gouda- and Cheddar-type 7 · alpine 4 · young and fresh 5 · blue-veined and brined 3 · processed 4 · plant-based 3 · declared vegetable-fat 6 · retail grated 40 · records that disagree 2.

The arithmetic

Milk fat is the only fat here with butyrate and caproleate. If a marker x has been diluted from the reference mean x̄ (9.08 and 0.497 mol %), the share of acyl chains that is not milk fat is

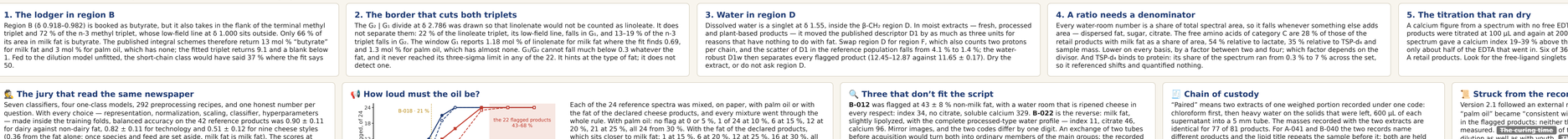
$$f = 100\,(1 - \bar{x}/\bar{x}) \qquad s(f) = (100/\bar{x}) \cdot \sqrt{[\,s(\bar{x})^2 \cdot (1 + 1/n) + \sigma_x^2\,]}$$

where σ_x is the spread of the marker in milk fat (0.47 and 0.076 mol %, n = 24) and σ_x the scatter between retail lots (0.33 and 0.019). For a product with no foreign fat at all, one standard error is 6.4 points from butyrate and 16 from caproleate, so nothing below about 19 % can be called. A marker at or below the blank floor (1.27 and 0.13 mol %, from 17 fats without milk fat; marked *) gives only a bound, f ≥ 86 %.

mol % of acyl chains	milk-fat reference (24)	the 22 flagged, median	replacing fat, back-calculated	declared cheese products (3)	palm oil (1 reference)
butyrate, C4:0	9.08 ± 0.47	4.53	0, by construction	0.8–0.9 *	0.07 *
caproleate, C10:1	0.50 ± 0.08	0.23	0, by construction	0 *	0 *
linoleate, C18:2	1.77 ± 0.60	4.60	7.3	7.5	9.6
n-3 acids, as C18:3	0.69 ± 0.16	0.36	not measurable	0.26	0.40
monounsaturated	27.6 ± 2.4	33.1	39	40	48
saturated	69.9 ± 2.4	61.9	53	52	42
carbons per chain, NC	14.22 ± 0.18	15.37	16.4	16.7	17.5
C₂/C₁	0.471 ± 0.018	0.528	0.58	0.57	0.69
non-milk fat, % of chains	0	**51 (43–68)**	100	**≥ 86**	100

The replacing fat is found by x(ext) = x̄ + (x − x̄) / f. It resembles the fat of the declared cheese products more than the one whole palm oil at hand. By mass the fraction is about three points higher at 50 %, because the foreign chains are longer.

The lineup itself — forty retail grated products against the height chart



Bar: non-milk fat as % of the acyl chains of the extracted fat, ± two standard errors (†: from butyrate only, for sheep's-milk products). **Dotted outline with a diamond:** lipolyzed, not quantified — the outline is what butyrate alone would say if it were missed as dilution, the diamond what caproleate says. **Tile:** the free amino-acid index of the same product in the water room, green where the aqueous call is ripened, red where it is unripened or processed-type. A-041 and B-040 are held out because their lipid and aqueous records name different products. B-012 (D) and B-022 (E) are mirror images whose codes differ by one digit; neither counts for anything until both have been extracted again.

The rule book

Set on the same 84 products it then judged. Conditions are tested in this order and the first match decides; z is the standard score against the 24 reference products.

1. Butyrate < 1.5 and caproleate < 0.10 mol % → **non-dairy fat, milk-fat markers at the blank level**
2. z(butyrate) < −3 (< 7.66 mol %) and two of four shifts — linoleate > 3.58 mol %, NC > 14.77, C_2/C_1 > 0.526, G_1/G_2 < 0.38 → **non-dairy fat**
3. z(butyrate) < −2.5 (< 7.90), one shift, no lipolysis, caproleate < 0.38 → **low-level non-dairy fat indicated**
4. z(butyrate) < −2 (< 8.13) and more than 3.5 chains per glycerol → **milk fat, strongly lipolyzed**
5. z(butyrate) < −2 and lipolysis (free acids and partial glycerides > 3 % of chains, or > 3.14 chains per glycerol) → **milk fat, lipolyzed**
6. One shift → **milk fat, composition outlier**
7. None of the above → **milk fat**

Water room: free amino-acid index < 21.4 with citrate > 10 or free sugars > 10 → unripened or processed-type. Dispersed lipid > 401 is recorded and does not vote. **Categories:** A milk fat, ripened · B lipolyzed milk fat, ripened · C non-dairy fat, processed-type · D non-dairy fat, ripened · E milk fat, processed-type · F rule 3. **Known hole:** a butyrate deficit with neither a shift nor lipolysis is not flagged. H-001, 3.4 s.d. low in butyrate with everything else normal, walked.

A — Room A — the fat room · CDCl₃ · sorted downfield → upfield

what the triacylglycerols will admit to

#	SUSPECT	MUGSHOT (MEASURED)	HEADLINE SIGNAL	FULL SIGNATURE	HOW IT GIVES ITSELF AWAY · CROSS-EXAMINATION	EVIDENCE	CASE FILE (v2.2)
1	**Sheep's-milk and alpine cheeses** *Pecorino Romano, Gruyère, Emmental — the pasture accent*		**δ 5.94 ppm** t (11 Hz), H10 of rumenic acid, with dt 5.65 and dd 6.28 — the conjugated diene	Conjugated diene 0.95–1.17 mol % of acyl chains and n-3 acids 1.1–1.2 mol % in the two Pecorino Romano blocks and the two imported grated Pecorino Romano products; 0.8–1.2 and 0.9–1.1 in Gruyère and Emmental; 0.2–0.4 and 0.5–0.7 in the lowland cow's-milk cheeses. G_1/G_2 1.4–1.9 against 1.19 ± 0.27 for the reference population. Butyrate ordinary, 8.2–9.6 mol %.	Grass and altitude write themselves into the fat of a ruminant: more rumenic acid, more n-3. It is an accent, not a fingerprint — the conjugated diene has a relative standard deviation of 56 % in the reference population — so it suggests a style and convicts nobody. Its one forensic use in this case was negative. The retail product labeled grated Pecorino Romano, B-014, carried 0.08 mol % of conjugated diene and 0.33 mol % of n-3 acids in a fat estimated at 62 ± 7 % non-milk fat: neither the fat of a sheep's-milk cheese nor that of any cheese alone.	**Plausible** four sheep's-milk and two alpine products; the direction agrees with the dairy literature on pasture and altitude	§5.4 · Fig. 14c · Table 12
2	**Lipolyzed grated cheeses** *five retail products of category B and a sixth in category E — the suspects with an alibi*		**δ 4.93 / 4.99 ppm** m, terminal =CH₂ of caproleate (9-decenoate, C10:1) — the witness who stayed in the room	Butyrate down to 4.9–8.0 mol % in six retail products whose linoleate (1.8–2.2 mol %), chain length (14.0–14.4 carbons) and C_2/C_1 (0.46–0.49) are those of milk fat. Free acids and partial glycerides 6–26 % of chains against a reference mean of 0.5 %; the grated Romano B-003 reaches 4.3 chains per glycerol. Caproleate in the three most lipolyzed: 0.45–0.48 mol %, normal.	A lipase takes butyrate off the glycerol first; the free acid is water-soluble and volatile, and it leaves the chloroform tube. Read as dilution, the butyrate of the three most lipolyzed products says 43–46 % non-milk fat. Caproleate says 4–9 %, because a ten-carbon acid stays in the lipid extract and keeps its vinyl signal. Both down in step is dilution; butyrate down alone is lipolysis. The missing butyrate turns up in the water room, where the β-CH₂ sextet of free butyrate at δ 1.56 is up to three times its usual size. A screen on region ratios alone, without this witness, would have booked four lipolyzed cheeses with the twenty-two.	**Confounder** mechanism established (pregastric lipase, enzyme-modified cheese); six retail products and three reference cheeses here	§5.5 · §6.5 · Figs 14a, 14d, 15a
3	**Prepared cheese loaf** *A-034, pasteurized prepared cheese product — vegetable oil on the label, linoleate in the tube*		**δ 2.805 ppm** t (6.0 Hz), bis-allylic CH_2 of linolenate and other n-3 chains — the G_1 side of region G	Linoleate 12.2 mol % and n-3 acids 4.6 mol % (reference 1.8 and 0.7); G_1/G_2 1.0; 16.5 carbons per chain; C_2/C_1 0.98; butyrate 3.0 mol %. Non-milk fat 65 ± 7 % of acyl chains. The region ratio B/A reads 0.12, flattered by the n-3 methyl triplet that lodges in region B.	This much linoleate with a strong n-3 triplet beside it is a canola- or soybean-type oil, and the label declares a vegetable oil, so nobody is surprised. The loaf earns its place twice: as the control that proves the unsaturation markers work, and as the cautionary tale for region B, where its n-3 methyl triplet refills part of the window that the missing butyrate emptied. The regression model trained on palm-type blends placed it outside its calibration domain — correctly, and only because somebody had built the check.	**Exhibit** n = 1, label-declared; chemistry unambiguous	§4.2 · §5.4 · §5.6 · Table 13 · Fig. 5
4	**The replacing fat** *back-calculated, product by product — the accomplice nobody can name*		**δ 2.770 ppm** t (6.5 Hz), bis-allylic CH_2 of linoleate (G_2) — more than twice its milk-fat size, and without its n-3 partner	Linoleate 7.3 mol % (interquartile range 7.0–7.7), no measurable n-3 acids, monounsaturated 39 and saturated 53 mol %, 16.4 carbons per chain, C_2/C_1 0.58. The one palm oil of the reference panel: 9.6, 48 and 42 mol %, 17.5 carbons, 0.69. The three declared grated cheese products: 7.5, 40 and 52 mol %, 16.7 carbons, 0.57.	Subtract the milk fat from each flagged product and the same stranger is left every time. It is poor in n-3 acids, which argues against canola and soybean; it is more saturated and shorter than whole palm oil; and it is a near match for the fat of the products that call themselves cheese products. "Consistent with a palm-type fat" is as far as the evidence goes. No palm-specific marker was seen, one reference oil cannot stand for every palm fraction in commerce, and a blend of fractions would fit as well. Resemblance is not a shared supplier, a shared recipe or a shared factory.	**Plausible** gross composition only; the identity of the oil is no longer asserted; a ¹³C spectrum of the lipid extract would test it	§5.6 · Fig. 13a · Table 7
5	**Plant-based analogues** *a snack round and two kinds of Cheddar-style slices — convicted by silence*		**δ 1.256 ppm** br s, $(CH_2)_n$ of saturated chain segments (C_1) — with almost no C_2 shoulder, and nothing at all at δ 0.947	Fitted butyrate 0.1–0.7 mol %, below the blank floor of 1.27; caproleate not distinguishable from zero. In the two lauric products: 12.5–12.6 carbons per chain, C_2/C_1 0.41 (milk fat 0.471 ± 0.018; palm oil 0.69), linoleate 1.3 mol %. Sterol signal 0.14–0.24 per 100 glycerol against 0.73 for milk fat.	A lauric fat is short and saturated, so it pulls C_2/C_1 down where a palm-type fat pushes it up; the one marker that tells the two butyrate-free fats apart, read from the tallest line in the spectrum. With the milk-fat markers at the blank level only a lower bound can be stated — at least 86 % non-milk fat. Whether the truth is 86 or 100 is not decidable here, and these products make no dairy claim that would care. With the fourteen reference fats and oils they define the floor on which every other estimate stands.	**Established** n = 3, dairy-free by declaration; the blank of the method	§4.2–4.3 · §5.4 · §5.6 · Fig. 6
6	**Retail grated Parmesan and Romano, flagged** *twenty-two of forty — butyrate at half-mast*		**δ 0.947 ppm** t (7.4 Hz), CH_3 of butyryl chains — 2.7–5.5 mol % of chains (median 4.5) against 9.08 ± 0.47 in 24 reference products	Butyrate 7.6–13.6 s.d. below the reference mean; caproleate 0.17–0.29 mol % (reference 0.50 ± 0.08), down in step; linoleate 4.2–5.1 mol %, 4.0–5.6 s.d. above; 15.2–15.7 carbons per chain, 5.3–8.0 s.d. above. Non-milk fat 43–68 % of acyl chains, median 51 %, each ± 7 to 8 points at two standard errors; about 54 % of the fat by mass. A regression on binned spectra says 53 %.	Milk fat is the only fat in the room with butyrate on the glycerol, and it has caproleate too. In these twenty-two both are cut by about half while linoleate and chain length climb — four chemically different markers telling one story, with lipolysis ruled out by the caproleate. That is the charge. What it is not: a fraction of the product (the fat content was not measured), a validated figure (no gas chromatography, no gravimetric blends, one extraction each), or the name of an oil. The highest value, 68 % for A-007, belongs to a product that is also lipolyzed; its caproleate estimate, 56 ± 16 %, is the one to trust.	**Supported** rule and limits were set on these same 84 products; 19 further spectra agree, but they are five products of four brands	§5.2–5.7 · Tables 13, 20 · Figs 11–16
7	**Declared products** *three grated "cheese products", an imitation topping and a declared blend — the labels that told the truth*		**δ 0.947 ppm** t, butyrate CH_3 — 0.8–0.9 mol % in the three cheese products, which is what an empty window returns	Grated cheese products A-002, B-019 and B-020: butyrate below the floor and caproleate at zero, so non-milk fat is at least 86 %. Reduced-fat topping labeled imitation cheese (A-001): 57 ± 7 %. Grated Parmigiano Reggiano blend that declares palm oil (A-005): 26 ± 10 %. In the water room the cheese products show lactose, citrate and a free amino-acid index below 1.	Every one of these says on its label what the spectrum says in the tube, which makes them the positive controls of the method and costs nobody anything. They also keep the method humble. Version 2.0 reported one of the cheese products at 100 ± 0 %; a marker near zero cannot carry an error bar of zero, and a lower bound has been reported since version 2.1. And the declared blend, at 26 %, stayed in the dairy branch of the unsupervised clustering — a preview of how quiet a quarter of palm-type fat can be.	**Exhibit** n = 5, label-declared; spectrum and label agree	§5.6 · §7.3 · §8.1 · Table 13
8	**The milk-fat reference population** *24 cow's-milk products from Parmigiano Reggiano to American singles — the control group*		**δ 0.947 ppm** t, butyrate CH_3 — the same height in every one of them, to within about 5 %	Butyrate 9.08 ± 0.47 mol % of chains (RSD 5.2 %); caproleate 0.50 ± 0.08; 14.22 ± 0.18 carbons per chain; B/A 0.153 ± 0.006; C_2/C_1 0.471 ± 0.018. The feed-dependent descriptors wander: linoleate 1.77 ± 0.60, n-3 acids 0.69 ± 0.16, conjugated diene 0.40 ± 0.23 mol %, G_1/G_2 1.19 ± 0.27. Eleven retail grated products are indistinguishable from it in every descriptor.	Grana, Gouda, Gruyère, mozzarella and processed slices from six countries land on one butyrate value because the mammary gland, not the cheesemaker, puts it there. Being boring is the signature, and it is the ruler every other row is measured with. It is also the soft spot. Twenty-four retail products of presumed, not certified, authenticity, all from cow's milk, cannot span the seasonal, regional and breed variation of milk fat — and the decision limits and every error bar on this poster depend directly on that ± 0.47.	**Supported** n = 24; agrees with the established composition of bovine milk fat; authenticity presumed from the labels	§3.6 · §5.1 · Table 10

B — Room B — the water room · D₂O · sorted downfield → upfield

what the amino acids, the sodas, the sugars and the additives will admit to — in shares of spectral area, never in concentrations

#	SUSPECT	MUGSHOT (MEASURED)	HEADLINE SIGNAL	FULL SIGNATURE	HOW IT GIVES ITSELF AWAY · CROSS-EXAMINATION	EVIDENCE	CASE FILE (v2.2)
1	**Ripened hard cheese** *Grana-type, Pecorino, alpine and Dutch-type blocks, and sixteen retail products of categories A and B — the elder who talks too much*		**δ 7.33–7.43 ppm** m, phenylalanine ring, with Tyr d 6.90 / 7.19 — the aromatic end of a spectrum full of free amino acids	Free amino-acid index (Leu, Ile and Val methyls, δ 0.925–1.070, per 10^4 of spectral area): medians 45 for Grana-type, 46 for alpine and 36 for Dutch-type and sheep's-milk blocks; 28–45 (median 35) for the 16 retail products with milk fat. Citrate absent or in traces; free sugars 2–7. Glutamate, lysine, alanine, phenylalanine and histidine 20–100 times the level in processed cheese.	Months of proteolysis fill the methyl and aromatic windows with free amino acids and empty the sugar window. A young cheese, a processed cheese and a diluted cheese cannot fake the profile, and sixteen of the forty retail products have it. What it will not do is tell the time. The index climbs from 2 in fresh mozzarella through 29 in a six-month Manchego to 40–48 at ten to twelve months, and there it stops: two 18-month Parmesans give 46 and 50, a 26-month Gouda 31. Past about ten months the witness repeats itself.	**Established** 21 ripened reference cheeses; consistent with four independent literature groups on Grana-type ripening	§6.1 · §6.7 · Figs 7, 17a, 23
2	**Anything from a shaker can** *33 of the 40 retail grated products, with milk fat or without — the tattoo that proves nothing*		**δ 5.83 ppm** d (15 Hz), H2 of sorbate, with m 6.12–6.33 (H4, H5), dd 7.0–7.1 and CH_3 d 1.83	Present in 33 of the 40 retail grated products, in all six declared vegetable-fat products and in two each of the processed cheeses and plant-based analogues; in none of the ripened block cheeses. The largest signal in the set belongs to a category A product with nothing wrong with its fat. Sorbic acid follows the fat into the chloroform tube as well (d 5.77, m 6.2, CH_3 d 1.87), clear of every integration region.	Potassium sorbate is a permitted antimycotic and weighs nothing as evidence of adulteration. It is, however, a nearly perfect marker of a retail grated product, which is exactly why its windows were cut out of the multivariate data. A classifier left alone with it would learn to recognize the can instead of the cheese, and would report the result as chemistry.	**Established** named-additive chemistry; irrelevant to the fat charge	§3.9 · §6.4
3	**Mozzarella** *low-moisture shreds and a fresh ball — still has its milk teeth*		**δ 5.27 ppm** d (3.8 Hz), α-H1 of galactose — next to the α-anomers of glucose and lactose at δ 5.23	Low-moisture mozzarella: α-galactose index 109–119, citrate 43–57, free amino-acid index 1.3–1.7. Fresh mozzarella: lactose 470, acetate 93 with lactate only 45, index 1.7, soluble calcium 70 mg per 100 g.	A thermophilic starter that cannot ferment galactose leaves it behind, so galactose is the signature of a young pasta filata curd. The fresh ball tells a different story — plenty of acetate, almost no lactate, the lactose untouched: acidified directly, as with vinegar, and never fermented. Neither has had time to digest its casein. They matter because the category C products show galactose (26) with almost no lactose (2.7): a young thermophilic curd, or lactose-hydrolyzed dairy solids, and no way to tell which without the ingredient records.	**Established** n = 3; textbook starter chemistry	§6.2 · §6.5 · Fig. 10
4	**Grated "cheese products"** *the three declared ones again — whey in a cheese costume, and honest about it*		**δ 4.455 ppm** d (7.8 Hz), β-galactosyl H1 of lactose — on the flank of the unsuppressed water, with its α-Glc H1 partner at d 5.23	Lactose 505–575 (ripened cheeses 1–3; processed cheeses 70–290); citrate 62–69; free amino-acid index 0.3–0.5; soluble calcium 206 and 208 mg per 100 g in the two that were titrated. A sharp singlet at δ 6.19 that is not sorbate — possibly orotate, a minor constituent of unfermented milk and whey.	Lactose is the first thing a cheese loses, so a spectrum full of it means dairy solids that never met a starter culture. These products refer to ten-month aging on the label and return an index below 1. That shows the extract as a whole is not that of a ripened cheese; it shows nothing about the age of whatever cheese went in, because an index that is a share of spectral area falls with dilution as well as with youth. The orotate assignment is a guess until somebody spikes it.	**Exhibit** n = 3, label-declared; orotate tentative	§6.2 · §6.4 · §6.7 · §8.1
5	**Retail grated Parmesan and Romano, category C** *twenty-one of the twenty-two — the second room agrees with the first*		**δ 2.52–2.72 ppm** AB quartet (15.6 Hz), citrate CH_2 — present in all 21 (median 50), absent from every Grana-type, sheep's-milk and alpine block	Free amino-acid index 4.4–16.4, median 9.7: 28 % of that of the retail products with milk fat as a share of area, 54 % relative to lactate, 35 % relative to TSP-d₄ and mass. α-Galactose 26 and α-glucose-type anomers 37 with almost no lactose, and a small envelope of α-(1→4) glucan at δ 5.36–5.46 (26, against 3–6 in the ripened cheeses and 600 in the plant-based analogues); dispersed lipid in 20 of 21 (median 1700 against a limit of 401); apparent pH higher by 0.3.	A different tube, a different chemistry, the same twenty-one products: low free amino acids, citrate, free sugars and fat carried into the water. Among the reference classes that profile sits closest to processed American slices, and a blend of grated cheese with a vegetable-fat cheese analogue would account for all of it. That reading is plausible, not established — a single emulsified product made with some cheese would fit as well. The spectrum does not give the proportion of cheese and it does not give the curing time; both were claimed in version 2.0 and both are withdrawn.	**Supported** markers agree in 21 of 21; area fractions, not concentrations; the same laboratory and the same single extraction	§6.1–6.3 · §8.3 · Fig. 17 · Tables 15, 20
6	**The mineral witness** *calcium and magnesium by cesium EDTA — partly struck from the record*		**δ 2.565 ppm** s, N-CH₂-CH₂-N of Ca–EDTA, with Mg-EDTA s 2.70 and the free ligand at s 3.2–3.5 and 3.55–3.86	Reportable for 30 of the 36 products titrated. Provisional soluble calcium, mg per 100 g: ripened reference cheeses 240–600; six category C retail products 73–98; four retail products with milk fat 217–367; fresh mozzarella 70; a processed single 116. Soluble phosphorus runs the other way: 103–159 in category C against 50–68 in category A.	EDTA makes the metals visible to a proton spectrometer, and the two bound fractions need no intensity standard. Low calcium with raised phosphate is what phosphate emulsifying salts would produce; dilution alone would not raise the phosphorus. But the witness was caught out once. In all seven products titrated twice, the spectrum in which the ligand had run dry gave a calcium index 19–39 % too high. An exhausted titration is neither a measurement nor a lower bound; six results were withdrawn, the absolute scale is provisional, and fifteen of the 21 category C products were never titrated at all.	**Plausible** ten retail products of categories A to C; scale awaits the stock concentration; ratios between products are safer than the numbers	§3.8 · §6.6 · Figs 20–22 · Tables 16, 17
7	**Processed cheese** *American slices and singles — held together with emulsifying salts*		**δ 1.28 ppm** CH_2)$_n$ of dispersed lipid — under the lactate doublet (d 1.33, 6.9 Hz) and bigger than it	Dispersed-lipid index about 2000 (ripened reference classes 50–240), with broad olefinic and methyl resonances of the same origin; citrate 12–129; lactose 70–290; free amino-acid index 1–4; soluble calcium 116 mg per 100 g and Mg-EDTA 0.50 in the one that was titrated.	Emulsifying salts disperse the casein, the casein keeps the fat in droplets small enough to follow the water into the tube, and the result is fat in a spectrum where fat has no business. This is the nearest relative of category C in the whole lineup, with two differences: here the fat is milk fat and the sugar is lactose. The marker is not specific on its own — seven of the 16 retail products with milk fat and a ripened profile exceed the limit too (540–1150), as does the buffalo-milk blue. Fine grating and lipolysis also make soap. Read it with the amino acids, the citrate and the sugars, or not at all.	**Established** n = 4; emulsifying-salt chemistry is not in dispute; the marker alone is a confounder	§6.3 · §8.3 · Figs 10, 17d, 17f
8	**Emmental** *the story with holes in it*		**δ 1.05 ppm** t (7.7 Hz), propionate CH_3 — with q 2.18, an acetate singlet six times the Grana level, and most of the lactate gone	Lactate 81 against 200–740 in the other cheeses; propionate to acetate about 0.8 mol/mol (theory 2; lowered by aspartate co-metabolism and by a fit in a crowded region); free amino-acid index 48. Gruyère, where the propionic fermentation is slight: no propionate above the background, normal lactate.	Propionibacteria turn three lactates into two propionates, an acetate and the carbon dioxide that blows the eyes. The triplet sits beside the valine doublet and the quartet under the α-CH_2 triplet of free butyrate at δ 2.155, so the fit returns "propionate" of 20–40 in several lipolyzed cheeses that contain none. Propionate is therefore reported only where both multiplets are resolved: in Emmental, and in two plant-based analogues that show it at a fifth of the Emmental level and got theirs from an ingredient list — there are no eyes in a plant-based slice.	**Exhibit** n = 1; textbook fermentation chemistry	§6.5 · Figs 18, 19

False confessions

six ways this case could have convicted the wrong signal

1. The lodger in region B
Region B (δ 0.918–0.982) is booked as butyrate, but it also takes in the flank of the terminal methyl triplet and 72 % of the n-3 methyl triplet, whose low-field line at δ 1.000 sits outside. Only 66 % of its area in milk fat is butyrate. The published integral schemes therefore return 13 mol % "butyrate" for milk fat and 3 mol % for palm oil, which has none; the fitted triplet returns 9.1 and a blank below 1. Fed to the dilution model unfitted, the short-chain class would have said 37 % where the fit says 50.

2. The border that cuts both triplets
The G_2 | G_1 divide at δ 2.786 was drawn so that linolenate would not be counted as linoleate. It does not separate them: 22 % of the linolenate triplet, its low-field line, falls in G_1, and 13–19 % of the n-3 triplet falls in G_2. The window G_1 reports 1.18 mol % of linolenate for milk fat where the fit finds 0.69, and 1.3 mol % for palm oil, which has almost none. G_1/G_2 cannot fall much below 0.3 whatever the fat, and it never reached its three-sigma limit in any of the 22. It hints at the type of fat; it does not detect one.

3. Water in region D
Dissolved water is a singlet at δ 1.55, inside the β-CH_2 region D. In moist extracts — fresh, processed and plant-based products — it moved the published descriptor D by as much as three units for reasons that have nothing to do with fat. Swap region D for region F, which also counts two protons per chain, and the scatter of D1 in the reference population falls from 4.1 % to 1.4 %; the water-robust D1w then separates every flagged product (12.45–12.87 against 11.65 ± 0.17). Dry the extract, or do not ask region D.

4. A ratio needs a denominator
Every water-room number is a share of total spectral area, so it falls whenever something else adds area — dispersed fat, sugar, citrate. The free amino acids of category C are 28 % of those of the retail products with milk fat as a share of area, 54 % relative to lactate, 35 % relative to TSP-d₄ and mass. Lower on every basis, by a factor between two and four; which factor depends on the mixture. And TSP-d₄ binds to protein: its share of the spectrum ran from 0.3 % to 7 % across the set, so it referenced shifts and quantified nothing.

5. The titration that ran dry
A calcium figure from a spectrum with no free EDTA left looks like a lower bound. It is not. Seven products were titrated at 100 µL and again at 200 µL, and in all seven the exhausted 100 µL spectrum gave a calcium index 19–39 % above the one with ligand to spare, while accounting for only about half of the EDTA that went in. Six of 36 titrations were struck out, three of them category A retail products. Look for the free-ligand singlets at δ 3.2–3.9 before believing the one at 2.565.

6. Repeat offenders in different hats
Forty-three further lipid spectra, never used to set the rule, gave the same picture: 19 flagged at 44–62 % (median 51), 18 milk fat, five lipolyzed, one dairy-free product without a milk-fat marker. It reads like an independent test and is not one. The 19 flagged spectra are five products of four store brands, 17 of them separate lots of three products, and three of the four brands are already in the main set. What the lots do give is the only reproducibility figure in the study: butyrate varied between lots by 0.21–0.47 mol %, the estimate by 1.3–4.5 points.

The jury that read the same newspaper

Seven classifiers, four one-class models, 292 preprocessing recipes, and one honest number per question. With every choice — representation, normalization, scaling, classifier, hyperparameters — made inside the training folds, balanced acc