The Unified System, 1970

A cell. A lung cell. Tobacco smoke swirls by in the spired and foliated channel the cell faces. Its job is to take in oxygen from breath and keep out everything else, and on the whole it does well filtering the usual impurities in air: but this is not a designed mechanism, put together for a function by conscious plan, it is a dumb iteration of all the features which have proved by trial and error to serve lung cells well in the past. The past did not include deliberately-breathed smoke. We could count an amazing number of different chemicals in the blue-grey vapour snaking through the tissue, altogether too many of which the cell does not know how to exclude. Formaldehyde, acetaldehyde, catechol, isoprene, ethylene oxide, nitric oxide, nitrosamine, the aromatic amines – not to mention the quinones, the semiquinones, the hydroquinones, a whole family of polycyclic aromatic hydrocarbons. We are watching for one of these last. Here it comes now, a drifting, tumbling molecule of benzopyrene. It sails into the cell's bulging curtain wall of fats and sticks there, like an insect caught in glue; then, worse, is dragged through, because the fat curtain is spiked here and there by receptors, and one of these has the benzopyrene in its grip. The receptor winches the benzopyrene through the curtain, hand over hand, atom over atom, wrapping it as it comes in a fold of the curtain, and then closing the fold behind it, so that when it reaches the inside, a little fatty envelope buds off from the inner wall of the cell with the benzopyrene sealed inside it. And floats free, into the warm liquid workspace where the body builds its proteins.

But it's all right. The cell has no specific defence against benzopyrene, but it is not defenceless. It has the powerful standard equipment all mammalian cells deploy when foreign bodies turn up where they're not supposed to. The package of fat is a flag, a label, an alert. Detecting it, up comes an enzyme to metabolise the contents. The enzyme munchs the benzopyrene into pieces of epoxide which other bits of the cellular machinery can flush safely away.

This has happened over and over again, every time Sergei Alexeyevich Lebedev lights a cigarette. There are billions of cells in the lungs. Lebedev has smoked sixty unfiltered Kazbek a day for fifty years. So this has happened thousands of billions of times.

*

Lebedev is wearing his medals. They jingle on his jacket like a drawerful of cutlery. Hero of Socialist Labour, Order of the Red Banner of Labour, two Orders of Lenin, assorted military and scientific honours. Red enamel, nickel, ribbons. So many of them that they drag down his suit on that side. He'd swear he can feel their weight. He used to have more chest to hang them on. The flesh is coming off him so fast now that he seems to be all teetering superstructure, just bones leaning together. A wobbling tower. A tripod grating in a cold wind.

The medals are supposed to be a claim for respect. And outside, they work. They get him a pension, rent reductions, lower taxes, a seat on the metro when it's standing room only. His life has been easier than the overwhelming majority of Soviet lives, because of them. But in here of all places, in this lightless corridor of the Kremlin, they're a devalued currency. Everyone has some. The General Secretary has so many, he's on the TV so frequently being awarded the Order of This or That or The Other, that, as the joke says, if a crocodile ate him, the poor creature would be shitting medals for a fortnight.

'The Minister does know I'm waiting, doesn't he?' says Lebedev.

*

Another lung cell. The machines that Lebedev has made all build up their complicated behaviours from absolutely predictable little events, from valves and then transistors turning on and off. Definitely on; definitely off. Without any shading of degree. Without any ambiguity. The machine that makes Lebedev is different. The base layer of its behaviour, from which all the rest emerges, is various and multiple and uncertain. There is no binary simplicity. There is the slow bubble of many chemical reactions all happening at once, each continuing until a task is mostly done, probably done, done enough to satisfy a programme which was itself only whittled out of randomness just well enough to get by. The enzyme's destruction of benzopyrene, for example, only flushes most of it away. A fraction of the epoxides react again with the enzyme and become diol epoxides. That's what's happened here; instead of nice, inert, detoxified molecules, we have a version of the same thing which is lacking one electron on one of its atoms, and which consequently yearns to stick to any other molecule which will share an electron with it. The diol epoxides are aggressive gloop.

Aggressive? One electron's worth of electric charge doesn't tow a molecule very fast through the soupy interior of a cell: it doesn't send the diol epoxides streaming along at the speed of light like the electrons in a vacuum tube. But it does exert a tiny, persistent pull on them. It draws them along towards molecules they might stick to. It draws them everywhere in the cell, and so it draws some of them towards the cell nucleus, which has another wall of fats around it, but unfortunately is designed to let molecules rather like the diol epoxides in and out on the cell's ordinary business. The hungry, electron-seeking blob of gloop slips through, and there in front of it are floating twenty-three pairs of tempting targets: the huge, fat, friendly, electron-rich chromosomes of human DNA.

No one in the world in 1970 understands in any detail how they work, and the ignorance is particularly bad in the Soviet Union, thanks to Lysenko. But the chromosomes work whether they are understood or not. The gloop drifts in; and at any and every point along the endless coiled helix where it happens to make contact, the gloop locks on. Where it jostles forward with its missing electron to embrace one of the DNA's electrons, there's a little chemical reaction, and the electron in question bonds to both the DNA and the gloop. The gloop is now an 'adduct', glued to the helix. But the helix is changed too, by having the blob of tobacco residue stuck to it. At the position where the adduct sits, the information in the DNA has been corrupted. Instead of the G, T, C or A that should be there, in the four-letter alphabet of the genome, it reads as one of the other letters instead. The adduct has written an error into the code.

But it's all right. In the vast majority of positions along the genome where goo might attach itself at random, altering one letter won't produce any significant mutation, even if the alteration lasts. The genome is Lebedev's software, but unlike software written by humans, it is not a set of procedures packed end-to-end, all of which at least purport to do something. It is a jumble of legacy code spread out in fragments through a whole voluminous library of nonsense. Almost always, a random change of letter will either hit some existing nonsense, or turn some sense into new nonsense. And because the chromosomes come in pairs, with a version of every chromosome contributed by Lebedev's mother floating there opposite a version from his father, if some sense on the version on one side turns to nonsense, the equivalent piece on the other version will go on making sense just fine. Dangerous mutations usually only happen in the rare cases where sense is

accidentally turned into different sense. Which is not what has happened here. Here, the arriving molecule has glued itself where it makes no difference at all.

This has happened billions of times.

*

'Minister Kosygin is extremely busy,' says the woman behind the desk. She is in her late thirties, with a cynical droop to her mouth. Nevertheless, she is made up like a plump doll, with pink circles on her cheeks and eyelids painted metallic blue. The curls of her hairdo shine as if they were parts of a single piece of plastic. 'As I told you, he can't say when he will be free. He apologises for not keeping your appointment, but suggests you might prefer to return another day.' Almost word for word, she is repeating what she said when Lebedev arrived, an hour or more ago.

'It's fine,' said Lebedev. 'I'm happy to wait.'

She compresses her lips; sniffs. The door she keeps is at the end of a panelled passage lost to sunlight. When it opens, as it does occasionally, some pale reminder of day slips out, and the sound of typing, but the rest of the time it might as well be midnight where Lebedev is sitting, on a bench by the wall. The lamp on her desk glows in the gloom like the lantern radiating at the centre of some very brown old painting, the kind where the human figures almost vanish into the soot and the varnish. Lebedev wishes the thin cushion beneath him were thicker, for these days his buttocks seem to have been replaced, for sitting, by two sore angles of bone like the outer corners of a coat hanger. He aches. He waits. There isn't much to look at. It's a wonder that the rubber plant survives down here: perhaps it has found some alternative to photosynthesis. On her desk she has only the appointment book, a telephone and a bowl of peppermints to be offered to favoured passers-by. He has not been given one. She turns the pages of her magazine with short pink fingers. When he coughs she clicks her tongue disgustedly. True, it is a disgusting noise he makes. It begins as a commonplace wheeze in his throat, but tumbles down into his chest where it hacks and rattles and audibly moves clots of viscous wet stuff around, till the wet stuff has been dragged up into his airway, and he's in a gasping, gargling struggle to get it off his epiglottis, and out, so that he can breathe again. He spits into his handkerchief, clean this morning, now stiff and crusty, stained with nameless emulsions. He's

been bringing up the traditional jade mayonnaise of bronchitis every winter for as long as he can remember, but this is something different, something thicker and redder and meatier, like liquescent liver. He folds the handkerchief away, and tries to muster his persuasive powers.

*

Another lung cell. The soft rainfall of gloop onto Lebedev's DNA continues. By chance, this particular sticky drop in the statistical rain is one of the small minority that is going to land somewhere that matters. By chance, it is falling onto a stretch of code on Chromosome number 11 which scientists will know later as the gene *ras*, or *hRas*. The electrophile noses in; it suckers on; the guanine (G) it has suckered onto on the helix now reads, for all intents and purposes, as cytosine (C). And this time, it happens that changing G to C creates sense, not nonsense, in the code. *Ras* with a C in it at this specific position is a viable and functional piece of software. But much more of a change is in prospect than there would be if someone substituted a new programme for the one that was supposed to be running in a computer. Human-made software is only an informational ghost, temporarily given possession of the machine and allowed to change 0s to 1s and vice versa. The software of humans, on the other hand, actually builds the hardware it runs on. It creates the machine. So a mutation in the code means a mutation in the body too, if the error endures.

Ras is one of the genes that control cell growth and cell division. In adults, it switches on and off periodically to govern the normal cycle of the cell's existence. You wouldn't want it switched on all the time. Foetuses in the womb run *ras* continually to generate all the new tissue that the Build-A-Human programme demands when a human is being first assembled. Otherwise, cell multiplication must happen when, and only when, the body part the cell is in needs a new cell. But it's the switch that has been altered by having C where G used to be in this mutant version of *ras*. C instead of G at this one particular point jams the *ras* gene at 'on' – throws the lever for unstoppable growth, and then breaks the lever.

But it's all right. This copy of *ras* may be corrupted, but the cell has a failsafe mechanism built into the shape of the DNA molecules. The helix is a double helix. On the other side of the double corkscrew there runs another strand of Gs, Ts, Cs and As which carries all the information of the genome,

only in reverse, like the negative of a photograph or the mould a jelly was turned out of; and the cell, which is used to operating in an environment of small chemical accidents, operates a handy editorial enzyme that moves up and down the chromosomes checking that the two strands remain perfect opposites. The editorial enzyme doesn't find absolutely all of the changes the adducts gummed to Lebedev's DNA have made, but it finds most of them, the harmless and the harmful alike, methodically correcting each little mutation. It finds this one. The new C in the mutant version of RAS on one side clashes with the existing C on the reverse side. C against C isn't a legitimate opposite. A quick editorial snip, and there's the original G again. Lebedev's factory settings have been restored.

This has happened millions of times.

*

'Minister,' says Lebedev inside his head, 'I know that the decision has already been taken, but I must draw your attention – I must ask you to consider – I must question the wisdom – I must – I must –'

What's this? A bulky middle-aged man is strolling up the corridor towards them, brush-cut black hair gleaming in the lamplight, hands the size of hams playing little tunes on the air, equable smile on his face. For a moment Lebedev thinks the General Secretary himself is upon them, but it isn't; it's one of the regional Party bosses, he forgets the man's name, who thanks to the magical osmosis of power all tend to look faintly Brezhnev-ish these days, just as the littler bosses used to resemble Khrushchev, as far as they could, and before that Stalin. The cheery gaze passes over Lebedev as if the air were empty where he sits on the bench, and settles on the doorkeeper. Mr Belorussia, or is it Mr Moldavia, winks. She blushes and reaches a hand up to her meringue-hard hair.

'Hello, Frenchie,' he says. 'Is Himself available?'

Immediately she wiggles out from behind the desk and click-clacks across in her heels to open the big door for him. She is not thin and she fills the whole of her knee-length skirt. As Mr Kiev (or is it Mr Volodyavostok) steps deftly through the slot of daylight she's summoned, he whispers something that makes her giggle and drops a casually proprietorial hand onto her round behind. The simper hasn't quite left her face as she pulls the door to again, but it vanishes when she sees the direction of Lebedev's haggard gaze.

Though as gazes go, this one is virtually abstract, there being so little left in him to respond to such things.

'Hmph,' she says. *Not for you.*

'Are you French, then?' asks Lebedev. She only glowers.

*

Another lung cell. There is a way for a blob of goo to cause a *ras* mutation that persists. The gummy electron-seeking missile has to arrive, and glue G into C in the exact right place, at the exact right moment in the life of the cell when for once the enzyme cannot compare *ras* to its negative. That is, when the lung cell is already busy dividing into two lung cells. The goo floats in, and finds inside the nucleus a double helix which has been unzipped into two separate strands, each of which is going to grow back into a complete copy of the genome. Of all the random blobs of goo in the random rainstorm, here comes the blob that suckers onto Chromosome 11 in the position to create the always-on version of *ras*, just as the unzipped halves of Chromosome 11 are waving loose. It's too late for the editorial enzyme: there's nothing to correct the mutant C against. Along the strand instead travels a polymerase, a construction enzyme, steadily building out the other half of a new double helix. And when it reaches the C, it obligingly supplies a new counterpart for the other side which is a match, which is a perfect opposite. The corrupted code has reproduced itself. After a while, there are two sets of completed chromosome pairs in the nucleus. They pull away from each other. The nucleus stretches, puckers out like dumb-bells, splits into two as well. Last the outside wall of the cell repeats the split, stretching and pulling and puckering back into a pair of separate fatty spheres. One contains *ras* in its original uncorrupted form, but beside it Lebedev now has a new lung cell with *ras* switched on in it forever. And immediately *ras* takes charge of the cellular machinery and starts the build-up to superfast cell multiplication. A cell running *ras* full-time won't co-operate with nearby cells in any other task. It isn't interested, for example, in being part of a lung. Binary at last, it only wants to become two cells, four cells, eight sixteen thirty-two –

But it's all right. The body is used to occasional runaway accidents with *ras*. It has one last defence mechanism. As *ras* goes crazy, another gene, away over on Chromosome 17, detects the molecular signature of the build-

up and neatly, swiftly, initiates cell suicide. The cell dies. With it goes the mutant *ras*.

This has happened thousands of times.

*

What is the tactful, the effective way of announcing that your life's work has been wasted?

On 18 December last year Lebedev sat in a meeting at Minradioprom, the Ministry of Radio Production, and heard the assembled bigwigs of government and the Academy talk themselves into destroying the Soviet computer industry. That wasn't quite how they put it, of course. The question was what model of machine to develop for the Unified System which was supposed to manage the economy in the 1970s. On the one side lay the possibility of designing their own standardised range of next-generation mainframes. On the other was a proposal to copy the family of machines which were the standard commercial solution in the West, the IBM 360 series. Everyone at the meeting paid compliments to homegrown Soviet technology, but they had talked about it, most of them, as the risky option. They were charmed by the safety of choosing an existing product with existing, well-established software. And so they had gone with safe, despite all he could do.

But safe was an illusion. He had tried and tried and yet somehow failed to convey the simple truth that, if they chose IBM, they would not, in fact, get IBM machines. They would not get IBM software. They would not get IBM reliability. These things were not available for delivery to the Soviet Union. They would be committing themselves, instead, to reverse-engineering the IBM 360 in the dark, with limited documentation and no original model of a 360 to dismantle. It would take years. And the 360 had been introduced in 1965! It was half a decade old before the effort to copy it even began. So they would be condemning themselves not just to imitation, but to perpetual obsolescence as well. They'd be forever chasing the prospect of doing what the Americans had already done, years and years before. Oh, there would still be the special military machines to build, to guide the smashing of atoms and the launching of cosmonauts, but there'd be no general flowering. There'd be no more of the contest between the design bureaus which had kept the Institute for Precision Mechanics racing for processing speed against the

Institute of Electronic Control Machines and the Institute of Cybernetics and SKB-245. There'd be no more glorious eccentricities, like Brusentsov's trinary processor at the University of Moscow, the only one in the world to explore three-state electronics. There'd be no pushing outward at the frontier of the achievable. There'd be no design any more, properly considered; just slow, disconsolate copying.

Only a fool would choose safety on these terms. Surely Kosygin can be brought to see it? Tactfully. Effectively. 'Minister –' But Lebedev has begun to sag. He peers at his watch in the gloom. It's hours, now, that he's been waiting here in the labyrinth. Bone ache is being joined by a fever that rises up through his emaciated body like hot mist. There's a film of damp on his forehead and things inside his mind are losing their clarity and starting to melt into each other.

*

Another lung cell. Chance upon chance upon chance upon chance. Of all the billions of cells in Lebedev's lungs, there will be some millions where the diol epoxide gum from his cigarettes stuck itself, not to *ras*, but to the gene on Chromosome 17 that initiates emergency cell suicide; and of those millions there will be some thousands where the crucial blob blew in just in time to land on a strand of DNA in the midst of cell division, and got itself copied. So, scattered here and there through the billions of cells whose little bulging windows of fat face the channels of the lung, there are some thousands, randomly distributed, where the suicide gene on Chromosome 17, later to be called P53, isn't working. Here's one of them. And into it, after fifty years of delicious Kazbek smoke, there flies one more random molecule of goo, and it travels straight to *ras* to scramble the vital G into C, and it arrives just in time, too, to evade the editorial enzyme and get copied into a new cell.

And it's not all right. The new cell with mutant *ras* in charge of it is a tumour unbound, freed from the body's safety systems to multiply and multiply, unstoppably, selfishly, altogether indifferent to its effect on Lebedev's lung, and on Lebedev.

This only has to happen once.

*

Lebedev starts to cough again and this time he can't stop. There's no far side to it, no end to it; it's like putting out an arm to balance yourself and finding there's no wall to lean on any more. He tumbles down and down into the cough. It's all mucus in there, no air, no air, and he can't bring up the lump of noxious matter that's blocked his passages and he can't get out of the struggle to shift it either. He's choking. His ears roar. His vision pocks with little breeding asterisks of light, coagulated across the dim sfumato of the corridor. His head drops between his knees. Hack. Hack. Hack. Panic, and beyond panic to the threshold of a dizzy indifference. Then the obstruction comes free, drops out as a vile, metallic mouthful. Shaky-handed wiping; spitting; wiping.

'Comrade?'

His vision clears to darkness. She's standing over him, holding out her water glass, glaring at him with reluctant pity.

'You should go home,' she says.

'I'll wait,' he says. 'It doesn't matter how long.'

'No,' she says, 'you should go home. Don't you understand?'

*

The effects of carcinoma in a major airway include shortness of breath, weight loss, bone pain, chest and abdominal pain, hoarseness, difficulty swallowing and chronic coughing. Metastasis to spine, liver and brain is common: further symptoms may then include muscle weakness, impotence, slurred speech, difficulty walking, loss of fine motor co-ordination, dementia and seizures. Radiotherapy is of limited effectiveness. Fluid build-up behind the lung obstruction eventually leads to pneumonia and death.

This, unfortunately, is certain.

Notes – VI.1 The Unified System, 1970

1 **A cell. A lung cell:** the molecular biology of this chapter is accurate as far as it goes, and I am assured that the dwindling probabilities of the molecular events in it are at least of the right orders of magnitude. But it should be remembered that the chapter only follows one possible route by which one toxin in tobacco smoke can induce one variety of lung cancer. There are many other routes, other toxins, and other cancers, so a realistic path towards carcinogenesis would be much less linear than the simple illustrative zoom I have selected here. It would trace its way in massive parallel through a massively forking labyrinth of probabilities. I drew heavily on – inhaled heavily from – Theodora R. Devereux, Jack A. Taylor and J. Carl Barrett, 'Molecular Mechanisms of Lung Cancer: Interaction of Environmental and Genetic Factors', *Chest* 1996, 109; 14–19; and on Stephen

S. Hecht, 'Tobacco carcinogens, their biomarkers and tobacco-induced cancer', *Nature Reviews Cancer* 3, October 2003, pp. 733–44. I am also indebted to Dr Claerwen James for enlightenment via conversation and email.

2 **Lebedev has smoked sixty unfiltered Kazbek a day for fifty years:** I'm making up the specific numbers, but he's known to have been a persistently heavy smoker. See Malinovsky, *Pioneers of Soviet Computing*, p. 26.

3 **Hero of Socialist Labour, Order of the Red Banner of Labour, two Orders of Lenin:** Lebedev's authentic ironmongery. The Orders of Lenin are the biggest deal. For the fringe benefits of the various Soviet medals, see the Wikipedia entries for each.

4 **As the joke says, if a crocodile ate him:** authentic. See, again, Graham, *A Cultural Analysis of the Russo-Soviet* Anekdot.

5 **'The Minister does know I'm waiting, doesn't he?' says Lebedev:** this scene, up at the macro scale of the dark corridor in the Kremlin, is a fantasia generated from the single true fact (for which see Malinovsky, *Pioneers of Soviet Computing*, p. 26) that Lebedev did drag himself to a meeting with Kosygin in 1970, when he had a 'life-threatening pulmonary illness', to remonstrate about the decision in December 1969 to abandon independent Soviet computer design in favour of trailing after IBM, years late; and Kosygin did refuse to see him. But in life, the palming-off took the form of an unsatisfactory encounter with one of Kosygin's deputies, not the complete stonewalling that happens here, and no doubt it happened in bright daylight.

6 **And the ignorance is particularly bad in the Soviet Union:** for a sense of what Soviet medicine did know, clinically, about cancer in the mid-sixties, see the vivid descriptions of diagnosis and radiotherapy in Aleksandr Solzhenitsyn's banned *Cancer Ward*, translated by Nicholas Bethell and David Burg (London: Bodley Head, 1968).

7 **On 18 December last year Lebedev sat in a meeting at Minradioprom:** Malinovsky has a partial transcript of the discussion at this crucial meeting, which was complicated by political rivalries between different bureaux which stood to lose or gain depending which way the decision went, and by the fact that Lebedev and his allies' proposal to maintain native Soviet design capability came with a secondary plan to cooperate with ICL in Britain. See *Pioneers of Soviet Computing*, pp. 130–2. For the IBM-modelled 'Unified System' as it actually inched into existence in the 1970s, late at every stage, see N.C.Davis and S.E.Goodman, 'The Soviet Bloc's Unified System of Computers', *Computing Surveys* vol. 10 no. 2 (June 1978), pp. 93–122.

8 **Brusentsov's trinary processor at the University of Moscow:** see Malinovsky, *Pioneers of Soviet Computing*, pp. 134–8.

9 **Fluid build-up behind the lung obstruction eventually leads to pneumonia and death:** despite the tone of clinical certainty here, I do not know what kind of carcinoma Sergei Lebedev contracted, or even for sure that his 'serious lung disease' *was* cancer, though it seems overwhelmingly likely. But he did die of it, whatever it was, in July 1974; the fuzzy undesigned probabilistic machinery of his body did, in one fashion or another, generate the deterministic process required to shift him, conclusively, from 1 to 0.