

# ANALYTICAL TABLE OF CONTENTS

## VOLUME I

<i>Preface</i>	xxxiii
i. The Book	xxxiii
ii. The Background	xxxvii
<b>1. SETTING THE SCENE</b>	<b>1</b>
1.i. Mind and its Place in Nature	1
a. Questions, questions . . .	2
b. How to find some answers	3
c. Never mind minds?	8
1.ii. The Scope of Cognitive Science	9
a. Of labels and cans	10
b. Two footpaths, many meadows	12
c. Why computers?	14
d. What's in, what's out	16
1.iii. <i>Caveat Narrator</i>	18
a. Beware of Whig history	19
b. Losing the Legend	21
c. The counter-cultural background	26
d. The counter-cultural somersault	31
e. Hardly hero worship	37
f. Discovering discoveries	39
g. So what's new?	42
h. Rhetoric and publication	46
i. An explanatory can of worms	49
1.iv. Envoi	50
<b>2. MAN AS MACHINE: ORIGINS OF THE IDEA</b>	<b>51</b>
2.i. Machine as Man: Early Days	52
a. Ancient automata and Dark Age decline	53
b. In fashion again	54

2.ii. Descartes's Mechanism	58
a. From physics to physiology	59
b. Science as cooperation	61
c. Cartesian cooperation develops	64
d. Descartes on animals—	68
e. —but just what did he mean?	69
f. Vivisection revived	71
g. Human bodies as machines	73
2.iii. Cartesian Complications	74
a. The mind is different	74
b. Birth of a bugbear	76
c. The prospects for AI	80
2.iv. Vaucanson's Scientific Automata	81
a. Fairs and flute-players	82
b. Theories in robotic form	84
c. Robotics, not AI	86
2.v. Mechanism and Vitalism	87
a. Animal experiments: Are they needed?	87
b. Holist chemistry	89
2.vi. The Neo-Kantian Alternative	90
a. Kant on mind and world	91
b. Biology, mechanism, teleology	93
c. Philosophies of self-realization	95
d. Goethe, psychology, and neurophysiology	96
e. The birth of morphology	99
f. Goethe's eclipse	101
2.vii. The Self-Regulation of the Body	102
a. Automatic equilibria	102
b. The embarrassing embryo	104
c. Creative evolution	105
2.viii. The Neurophysiological Machine	107
a. Getting on one's nerves	107
b. Reflections on the reflex	108
c. From nerves to neurones	110
d. Integration in the nervous system	114
e. How do neurones work?	115
f. Brains and machines	117

2.ix. Strictly Logical Automata	119
a. Early gizmos	119
b. Logic, not psychology	122
2.x. Psychology as Mechanism—But Not as Machine	123
a. Visions of a scientific psychology	123
b. Non-empiricist psychologies	128
<b>3. ANTICIPATORY ENGINES</b>	<b>131</b>
3.i. Miracles and Mechanism	132
a. Babbage in the round	132
b. Religion and science	135
3.ii. Differences that Made a Difference	138
a. Division of labour, again	138
b. Design and disappointment	140
3.iii. Analytical Engines	142
a. From arithmetic to algebra	142
b. Programs . . . and bugs	144
3.iv. Had Wheelwork Been Taught to Think?	146
a. For Lovelace read Babbage throughout	146
b. What Lovelace said	149
c. Babbage and AI	151
3.v. Electronic Babbage	152
a. A soulmate in Berlin	152
b. Call me MADM	155
c. Intimations of AI	157
d. Turing's invisibility	158
e. Von Neumann's contribution	160
3.vi. In Grandfather's Footsteps?	162
a. Conflicting evidence	163
b. So what's the verdict?	167
<b>4. MAYBE MINDS ARE MACHINES TOO</b>	<b>168</b>
4.i. The Turing Machine	169
a. Turing the man	169

b.	Playing the game	171
c.	What computation is	173
d.	Only programs, not computers	176
4.ii.	From Maths Towards Mind	177
a.	Computers and computers	177
b.	Commitment to the claim	179
c.	But what about the details?	181
4.iii.	The Logical Neurone	182
a.	McCulloch the Polymath	182
b.	Experimental epistemology	184
c.	Enthused by logic	186
d.	The young collaborator	189
e.	Mind as logic machine	190
f.	Initial reception	193
4.iv.	The Functionalist Neurone	195
a.	From calculus to computer	195
b.	Function, not implementation	197
4.v.	Cybernetic Circularity: From Steam-Engines to Societies	198
a.	Feedback, way back	198
b.	Infant interdisciplinarity	200
c.	Biological roots	202
d.	Information theory	204
e.	Bateson, Pask, and a sip of Beer	205
4.vi.	Brains as Modelling Machines	210
a.	A Cambridge cyclist	211
b.	Similarity isn't enough	214
c.	Craik and cognitive science	215
d.	Might-have-beens	217
4.vii.	Feedback Machines	218
a.	Purposes of war	218
b.	Post-war projects	220
4.viii.	Of Tortoises and Homeostats	222
a.	Robots at the festival	223
b.	Of wheels and whiskers	225
c.	Less sexy, more surprising	228
d.	How the Homeostat worked	230

4.ix. Schism	232
a. All too human	233
b. Adaptation or meaning?	235
<b>5. MOVEMENTS BENEATH THE MANTLE</b>	<b>237</b>
5.i. Newtonianism	238
a. The six assumptions	238
b. What sort of revolution was it?	240
5.ii. Psychology's House	241
a. Sitting tenants with personality	242
b. Sitting tenants with knowledge	247
c. Sitting tenants with biology	252
5.iii. Soft Centres	257
a. Mentalism goes underground	257
b. Behaviourism softens	260
c. Behaviourist machines	262
5.iv. Neurology Creeps In	264
a. Hierarchies in the brain	265
b. Connectionism named	268
c. The cell assembly	271
d. Beyond perceptual learning	274
e. Hebb's originality?	276
f. Loosening the mantle	278
<b>6. COGNITIVE SCIENCE COMES TOGETHER</b>	<b>282</b>
6.i. Pointers to the Promised Land	283
a. Informed by information	283
b. Miller and magic	286
c. Going with the flow	289
d. Information and computation	293
e. Chomsky comes on the scene	296
6.ii. The New Look	298
a. Coins and cards	299
b. A study of thinking	304
c. Computational couture	307
d. Costume change	311
e. Will seeing machines have illusions?	313

x ANALYTICAL TABLE OF CONTENTS

6.iii. From Heuristics to Computers	317
a. The economics of thought	318
b. A meeting of minds	320
c. A new dawn	323
6.iv. The Early Church	328
a. Consciousness raising	328
b. A trio of meetings	330
c. The manifesto	336
d. The first mission station	343
e. Missionary outposts	348
f. The sine qua non	351
6.v. Spreading the Word	354
a. Training sessions	354
b. Library tickets	356
c. Journal-ism	363
<b>7. THE RISE OF COMPUTATIONAL PSYCHOLOGY</b>	<b>366</b>
7.i. The Personal Touch	368
a. The return of the repressed	369
b. Argus with 100 eyes	373
c. From scripts to scripts	376
d. Emotional intelligence	381
e. Architect-in-waiting	385
f. Of nursemaids and grief	388
g. Free to be free	394
h. Some hypnotic suggestions	397
i. An alien appendage	402
7.ii. The Spoken Word	404
a. Psychosyntax	405
b. Up the garden path	406
c. You know, uh, well . . .	409
d. Meaning matters	412
7.iii. Explanation as the Holy Grail	416
a. Competence and performance	417
b. Three levels, two types	419
c. The sweet smell of success	421
d. Chasing a will-o'-the-wisp?	422

7.iv. Reasoning and Rationality	427
a. Simon's ant	429
b. Productions and SOAR	430
c. The ACTs of Anderson	435
d. Models in the mind	439
e. The marriage of Craik and Montague	442
f. Irrationality rules—or does it?	444
g. Evolved for success	446
h. Give thanks for boundedness	449
7.v. Visions of Vision	451
a. Icons of the eyes	451
b. Vision from the bottom up	456
c. Maths and multimodels	459
d. The fashion for Mexican hats	462
e. Direct opposition	465
f. Let battle commence!	469
7.vi. Nativism and its Vicissitudes	472
a. The words of Adam and Eve	473
b. Some surprises from ethology	475
c. From Noam to Nim	477
d. Modish modules	481
e. But how many, exactly?	484
f. Theory of Mind	486
g. The third way	492
h. What makes higher thinking possible?	496
i. The modularization of modules	499
7.vii. Satellite Images	503
a. A telescopic vision	504
b. Forking footpaths	507
c. The Newell Test	509
d. Low focus	512
e. The bustling circus	513
<b>8. THE MYSTERY OF THE MISSING DISCIPLINE</b>	<b>515</b>
8.i. Anthropology and Cognitive Science	516
a. The beginnings of cognitive anthropology	517
b. Peoples and prototypes	519
c. Hopes and a hexagon	522
d. More taxonomies (and more Darkness than light)	523
e. And modelling, too	526

8.ii. Why Invisibility?	530
a. Psychology sidelined	531
b. Skirmishes in the science wars	534
c. Top dogs and underdogs	537
d. What's in a name?	539
e. Barkow's baby	540
8.iii. Minds and Group Minds	543
a. Models of seamanship	544
b. Networks of navigation	547
8.iv. Mechanisms of Aesthetics	549
a. From Savanna to Sotheby's	549
b. The seductiveness of symmetry	552
c. Universality in variety	553
8.v. Cultural Evolution	556
a. Evolution in the third world	556
b. A new mantra: BVSR	558
c. The meme of memes	562
d. Cloak uncloaked	565
8.vi. The Believable and the Bizarre	568
a. An epidemiology of belief	569
b. Religion as a cultural universal	573
c. Symbolism	577
d. The extraordinary out of the ordinary	579
e. Anything goes?	583
f. The impurity of induction	587
<b>9. TRANSFORMING LINGUISTICS</b>	<b>590</b>
9.i. Chomsky as Guru	592
a. The tenfold Chomsky myth	592
b. A non-pacific ocean	593
9.ii. Predecessors and Precursors	594
a. Why Chomsky's 'history' matters	594
b. The rationalist background	596
c. The puzzle of innate ideas	597
9.iii. Not-Really-Cartesian Linguists	600
a. Descartes's disciple	600
b. Arnauld and the abbey	602

c. The Port-Royal <i>Grammar</i>	602
d. Deaf-mutes and Diderot	605
9.iv. Humboldt's Humanism	606
a. Language as humanity	607
b. Languages and cultures	609
c. Humboldt lives!	610
d. A fivefold list	611
e. Origins	612
f. Creativity of language	614
g. The inner form	616
9.v. The <i>Status Quo Ante</i>	618
a. Two anti-rationalist 'isms'	618
b. The shock of structuralism	620
c. The formalist Dane	622
d. Tutor to Chomsky	624
e. Not quite there yet . . .	626
9.vi. Major Transformations	627
a. Chomsky's first words	627
b. The need for a generative grammar	628
c. Beyond information theory	631
d. Transformational grammars	634
e. So what?	637
9.vii. A Battle with Behaviourism	638
a. Political agenda	639
b. That review!	641
c. Nativist notions	643
d. Universal grammar?	645
9.viii. Aftermath	647
a. Polarized passions	648
b. Revisions, revisions . . .	650
c. Semantics enters the equation	652
9.ix. Challenging the Master	654
a. Linguistic wars	655
b. Who needs transformations?	656
c. Montagovian meanings	657
d. Transformations trounced	660
e. Why GPSG matters	662
f. Computational tractability	665
g. Linguistics eclipsed	666

9.x.	The Genesis of Natural Language Processing	669
	a. Ploughman crooked ground plough plough	669
	b. Shannon's shadow	671
	c. Love letters and haikus	674
	d. Wittgenstein and CLRU	674
	e. Is perfect translation possible?	677
	f. Is adequate translation achievable?	678
9.xi.	NLP Comes of Age	680
	a. MT resurrected	681
	b. Automatic parsing	683
	c. 'What I did on my holiday'	688
	d. Semantic coherence	689
	e. The seductiveness of semantic networks	692
	f. Whatever will they say next?	695
	g. A snippet on speech	698

## VOLUME II

<b>10.</b>	<b>WHEN GOFAI WAS NEWFAI</b>	<b>701</b>
10.i.	Harbingers	702
	a. When is a program not a program?	702
	b. The first AI program— not!	705
	c. How a program became a program	708
	d. First-footings	710
	e. The book of Samuel	713
	f. Programmatics	715
	g. First 'Steps'	719
	h. The harbinger in the Bush	725
	i. Spacewar	729
	j. The empty chair at the banquet	730
10.ii.	Establishment	731
	a. First labs	731
	b. The ripples spread	736
	c. New waves	739
10.iii.	The Search for Generality	739
	a. SIP spawns KR	741
	b. A resolution to do better	749
	c. Planning progresses	752

d. Early learning	759
e. 'Some Philosophical Problems'	769
10.iv. The Need for Knowledge	775
a. A triumph, and a threefold challenge	776
b. Clearer vision	781
c. Expert Systems	794
10.v. Talking to the Computer	799
a. Psychology outlaws binary	799
b. Entering the lists	801
c. LISPIng in 'English'	805
d. Virtual cascades	808
e. NewFAI in parallel	811
f. It's only logical!	814
10.vi. Child's Play	817
a. The power of bugs	817
b. Complication and distribution	820
c. Pointers to the future	821
<b>11. OF BOMBS AND BOMBSHELLS</b>	822
11.i. Military Matters	823
a. Nurtured in war	825
b. Licklider as a military man	828
c. Star Wars and AI qualms	832
d. <i>Les mains sales?</i>	835
11.ii. Critics and Calumnies	838
a. The outsider	838
b. Scandal	841
c. After Alchemy	846
d. Dreyfus and connectionism	848
e. The neighbour	850
f. A sign of the times	852
g. The unkindest cut of all	855
11.iii. A Plea for Intellectual Hygiene	857
a. The insider	858
b. Natural Stupidity survives	861
11.iv. Lighthill's Report	864
a. A badly guided missile	865
b. Clearing up the rubble	869

11.v. The Fifth Generation	873
a. A warning shot from Japan	873
b. Self-defence in the USA	875
c. Lighthill laid to rest	879
11.vi. The Kraken Wakes	881
a. Small fry and sleeping draughts	881
b. Competition	881
<b>12. CONNECTIONISM: ITS BIRTH AND RENAISSANCE</b>	<b>883</b>
12.i. Lighting the Fuse	885
a. A long gestation	885
b. Turing and connectionism	886
c. 'How We Know Universals'	887
d. From logic to thermodynamics	890
12.ii. Infant Implementations	892
a. B24 bricolage	893
b. Self-organizing networks	894
c. Connections with the Ratio Club	897
d. Pandemonium	898
e. The perceptron	903
f. Excitement, and overexcitement	907
g. Enter the Adaline	909
12.iii. Attack Without Apology	911
a. The devilish duo	911
b. The opening salvo	912
c. Intransigence	916
d. The hybrid society of mind	917
e. Were they to blame?	921
12.iv. Lamps Invisible	923
a. Relegation to the background	924
b. Run and twiddle	926
c. Reinforcement and purpose	926
12.v. Behind the Scenes	928
a. Left alone to get on with it	928
b. A problem shared . . . ?	930
c. How large is your memory?	931
d. Disillusion on distribution	934
e. Linear associative memories	935

f. The physicists have their say	936
g. The power of respectability	940
h. Hinton relaxes	942
i. Passing frustrations	943
12.vi. Centre-Stage	945
a. The bible in two volumes	945
b. Bowled over by Boltzmann	948
c. Backprop hits the headlines	952
d. Backprop anticipated	953
e. Wonders of the past tense	955
f. Escaping from the black box	957
12.vii. The Worm Turns	959
a. Joyful jamborees	959
b. DARPA thinks again	962
12.viii. <i>A la recherche . . .</i>	963
a. Emulating the ancestors	965
b. Recurrent nets	966
c. Start simple, develop complex	968
d. Pathways for representation	969
e. The importance of input history	972
12.ix. Still Searching	972
a. Assemblies of cell assemblies	973
b. Hands across the divide	975
c. Constructive networks	979
d. What had been achieved?	980
12.x. Philosophers Connect	982
a. A Pulitzer prelude	982
b. Connectionist concepts	984
c. The proper treatment of connectionism?	986
d. The old ways defended	989
e. Microcognition and representational change	991
f. Non-conceptual content	993
g. An eye to the future?	996
12.xi. Pointing to the Neighbours	1000
<b>13. SWIMMING ALONGSIDE THE KRAKEN</b>	1002
13.i. Later Logicism	1003
a. Less monotony	1003

b.	More naivety	1006
c.	The AI en-CYC-lopedia	1007
13.ii.	Choppy Waters	1013
a.	Apostasy	1013
b.	Can the fox catch the rabbit?	1015
c.	Matters-in-law	1020
d.	Judgements about judges	1024
13.iii.	Advance and Attack	1027
a.	Gelernter revived	1027
b.	Planning attacked—	1029
c.	—and defended	1035
d.	Agents and distributed cognition	1038
e.	Social interaction and agents	1043
f.	Technology swamps psychology	1046
13.iv.	Explaining the Ineffable	1052
a.	Creativity ignored	1053
b.	Help from outside	1054
c.	In focus at last	1059
13.v.	Outreach to Everyman	1069
a.	Papert and the media lab	1069
b.	The H in HCI	1072
c.	Good ideas in hibernation	1074
d.	The human face of the interface	1076
13.vi.	Virtual Reality	1081
a.	Intimations of VR	1082
b.	VR as a practical aid	1084
c.	VR in art and play	1087
d.	Computerized companions	1092
e.	Psychology and avatars	1096
13.vii.	Coda	1100
a.	Is AI a discipline?	1100
b.	Has GOF AI failed?	1105
<b>14.</b>	<b>FROM NEUROPHYSIOLOGY TO COMPUTATIONAL NEUROSCIENCE</b>	<b>1110</b>
14.i.	Notes on Nomenclature	1111
a.	The naming of neuroscience	1112
b.	The computational species	1113

14.ii.	Very Non-Neural Nets	1114
	a. Too neat	1114
	b. Too simple	1115
	c. Too few	1116
	d. Too dry	1117
14.iii.	In the Beginning	1121
	a. Computational questions	1121
	b. Computations in the brain	1125
	c. Formal synapses	1128
14.iv.	A Fistful of Feature-Detectors	1130
	a. Bug-detectors	1130
	b. And more, and more . . .	1134
	c. But how?	1136
	d. Monkey business	1138
14.v.	Modelling the Brain	1140
	a. The Mars robot	1140
	b. The musician in the spare room	1143
	c. Secrets of the cerebellum	1145
	d. Audience reaction	1149
	e. Beyond the cerebellum	1151
	f. A change of tack	1154
14.vi.	Realism Rampant	1157
	a. A voice in the wilderness	1158
	b. Adaptation—and feature-detectors	1161
	c. ARTful simulations	1164
	d. Avoiding the black box	1167
14.vii.	Whole Animals	1169
	a. CNE—what is it?	1169
	b. A wizard from Oz	1170
	c. <i>Rana computatrix</i> and its scheming cousins	1172
14.viii.	Representations Galore	1177
	a. What's the problem?	1178
	b. From probabilities to geometries	1179
	c. Emulation and subjectivity	1184
	d. The philosophers worry	1187
14.ix.	Computation Challenged	1189
	a. Structure without description	1189
	b. Dynamics in the brain	1193

c. Epigenesis	1196
d. Neural selection	1199
e. Grandmother cells	1205
f. Modelling modulation	1210
g. Time blindness—and glimmers of light	1213
<b>14.x. Cartesian Correlations</b>	<b>1216</b>
a. Consciousness comes in from the cold	1216
b. Cognitive neuroscience	1220
c. The \$64,000 question	1224
d. Philosophical contortions	1230
<b>14.xi. Descartes to the Tumbrils?</b>	<b>1236</b>
a. Describing the mind, or inventing it?	1237
b. A computational analysis	1237
c. The other side of the river	1240
d. Lions and lines	1242
e. Hung jury	1244
<b>15. A-LIFE IN EMBRYO</b>	<b>1247</b>
<b>15.i. Life, Mind, Self-Organization</b>	<b>1249</b>
a. Life and mind versus life-and-mind	1249
b. Self-organization, in and out of focus	1249
<b>15.ii. Biomimetics and Artificial Life</b>	<b>1251</b>
a. Artificial fish	1251
b. What is A-Life?	1253
<b>15.iii. Mathematical Biology Begins</b>	<b>1254</b>
a. Of growth and form	1254
b. More admiration than influence	1258
c. Difficulties of description	1259
<b>15.iv. Turing's Biological Turn</b>	<b>1261</b>
a. A mathematical theory of embryology	1261
b. History's verdict	1264
<b>15.v. Self-Replicating Automata</b>	<b>1268</b>
a. Self-organization as computation	1268
b. Why the delay?	1271
<b>15.vi. Evolution Enters the Field</b>	<b>1274</b>
a. Holland, and mini-trips elsewhere	1274
b. Awaiting the computers	1278

c. The saga of SAGA	1280
d. Open-ended evolution	1284
15.vii. From Vehicles to Lampreys	1286
a. Valentino's vehicles	1287
b. Of hoverflies	1289
c. Playing cricket	1292
d. Evolving lampreys	1298
15.viii. Parallel Developments	1299
a. Artificial ants	1300
b. New philosophies of biology	1304
c. Dynamical systems	1307
15.ix. Order and Complexity	1309
a. The four classes of CA	1309
b. K for Kauffman	1310
c. Morphology revived	1313
d. Discussions in the desert	1316
15.x. Naming and Synthesis	1317
a. The party	1317
b. Simulation or realization?	1322
15.xi. After the Party	1325
a. Resurrection of the Homeostat	1325
b. Analysing dynamics	1327
<b>16. PHILOSOPHIES OF MIND AS MACHINE</b>	<b>1334</b>
16.i. Mid-Century Blues	1337
a. Interactionist squibs	1337
b. Puffs of smoke and nomological danglers	1338
c. Dispositions and category mistakes	1339
d. Questions of identity	1343
16.ii. Turing Throws Down the Gauntlet	1346
a. Sketch of a future AI	1346
b. The gauntlet spurned	1349
c. The Turing Test: Then and now	1351
16.iii. Functionalist Freedoms	1356
a. Just below the surface	1357
b. The shackles loosened	1359

16.iv.	Three Variations on a Theme	1362
	a. Content and consciousness	1363
	b. From heresy to scandal	1367
	c. Must angels learn Latin?	1369
	d. Fodorian frills	1374
	e. Eliminative materialism	1376
16.v.	Counter-moves	1379
	a. Gödel to the rescue?	1379
	b. Consciousness and zombies	1381
	c. That room in China	1382
	d. Neuroprotein and intentionality	1385
	e. How multiple is multiple?	1387
	f. Subconsciousness attacked	1388
16.vi.	Betrayal	1389
	a. Friendly fire	1390
	b. Crossing the river	1392
16.vii.	Neo-Phenomenology—From Critique to Construction	1394
	a. Where Dreyfus was coming from	1395
	b. Hands-on Heideggerians	1398
	c. Flights from the computer	1399
	d. Computation and embodiment	1404
16.viii.	Mind and “Nature”	1407
	a. No representations in the brain	1407
	b. Mind as second nature	1410
	c. Mind and VR-as-nature	1412
16.ix.	Computation as a Moving Target	1414
	a. Three senses of computation	1414
	b. Physical symbol systems	1419
	c. From computation to architecture	1420
	d. The bit in “three and a bit”	1422
	e. A philosophy of presence	1423
	f. The moral of the story	1428
16.x.	What’s Life Got To Do With It?	1429
	a. Life in the background	1430
	b. Functionalist approaches to life	1434
	c. The philosophy of autopoiesis	1438
	d. Evolution, life, and mind	1440

<b>17. WHAT NEXT?</b>	1444
17.i. What's Unpredictable?	1444
17.ii. What's Predictable?	1447
17.iii. What's Promising?	1448
17.iv. What About Those Manifesto Promises?	1451
<i>References</i>	1453
<i>List of Abbreviations</i>	1587
<i>Subject Index</i>	1593
<i>Name Index</i>	1613