

This is a section of [doi:10.7551/mitpress/14723.001.0001](https://doi.org/10.7551/mitpress/14723.001.0001)

Gradient Expectations

Structure, Origins, and Synthesis of Predictive Neural Networks

By: Keith L. Downing

Citation:

Gradient Expectations: Structure, Origins, and Synthesis of Predictive Neural Networks

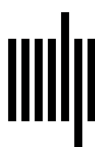
By: Keith L. Downing

DOI: 10.7551/mitpress/14723.001.0001

ISBN (electronic): 9780262374675

Publisher: The MIT Press

Published: 2023



The MIT Press

Index

- Abbott, Larry, 128
Action generation, 43–48, 125
Adaptation, 5–7
 via competition and cooperation, 129–130, 147, 173, 186
 and emergence, 6, 17, 62, 115, 117–118
Ahmad, Subutal, 102–104, 132
Ahmadi, Ahmadreza, 170
Albus, James, 41
AlphaGo, 164
Artificial general intelligence (AGI), 158, 169, 177, 185, 191
Attneave, Fred, 93–94, 116

Backpropagation, 8, 62, 73, 86, 109–115, 150–153, 158, 164–165, 184, 191
Bacteria. *See* Gradient: following
Ballard, Dana, 99, 112, 143
Basal ganglia, 55–58, 118, 120, 136–137
Beer, Randall, 165–168
Bengio, Yoshua, 73
Berra, Yogi, 1, 193
Bogacz, Rafal, 112, 115, 116, 159
Boltzmann machine, 65–70
Brooks, Rodney, 138
Buzsaki, Gyorgy, 1, 143, 175, 186

C. elegans. *See* Gradient: following
Cerebellum, 39–43, 59
Clark, Andy, 2, 89, 90, 133, 134, 138–139, 186
Constructivism (neural), 132–133, 174–176, 182
Continuous Time Recurrent Neural Network (CTRNN), 164–165
 Multi-timescale version (MTRNN), 169
 POE variants, 171–176
Contrastive Hebbian Learning (CHL), 68–70
Cortex. *See* Neocortex

D’Arcy (adaptive neural network model), 176–184
 development (ontogeny), 178–181
 evolution (phylogeny), 177–178
 learning (epigenesis), 181
 neuromodulation, 183–184
Darlington, Richard, 130, 160
Dayan, Peter, 61, 80

Deacon, Terrence, 130, 160
Deep learning, 7, 8, 18, 70, 73, 90, 150, 152, 153, 158
Deep reinforcement learning, 164
Derivative. *See* Gradient
Dickens, Charles, 193
Displacement theory, 130, 160, 176, 179, 189

Edelman, Gerald, 33, 41, 95, 130, 132, 147, 162
Eliasmith, Chris, 30, 32–34, 59, 60
Encephalization, 5, 122
Enerbility, 62
Energy Landscapes, 62, 69
Evolving artificial neural network (EANN)
 AutoML-Zero, 155
 CoDeepNEAT, 153–155
 D’Arcy, 176–184
 DEACANN, 160–163, 181
 and deep learning, 151–158
 HyperNEAT, 173
 NEAT, 153
 phylogenetic, ontogenetic, epigenetic (POE) variant, 159–164
 and predictive coding, 158–159
Expectation. *See* Prediction
Expectation maximization algorithm (EM), 80–81

Facilitated variation, 118–121, 125, 140, 148, 189, 190
Finlay, Barbara, 130, 160
Free energy principle (FEP), 86–90
Friston, Karl, 86–90
Functional fractalization, 186, 188
Fuster, Joaquin, 130

Gärdenfors, Peter, 20
Gerhart, John, 118–121
Gould, Stephen Jay, 117
Gradient
 definition, 7–8, 14–16
 examples, 16–18
 following, 29–32
 in minimally-cognitive agents, 167–168
 from neurons, 30–37
 for prediction, 15–16
 and sequences, 18–20

- Hawkins, Jeff, 2, 102–104, 132
- Hebb, Donald, 104–105
- Helmholtz machine, 80–87
- Hinton, Geoffrey, 65, 70, 72–73, 80, 150, 158, 184
- Hippocampus, 48–55, 58, 101
 conceptual embedding in, 51–55
 phase precession in, 144–145
 prediction in, 48–51, 59–60
- Hopfield, John, 62
- Hopfield network, 62–65
- Intelligence emerging (book), 6, 7, 117, 159, 190, 191
- Kirschner, Marc, 118–121
- Kuhn, Thomas, 149
- Kurzweil, Ray, 192
- Lamprey, 123–124
- Laughlin, Simon, 24
- LeCun, Yann, 73
- Lillicrap, Timothy, 158
- Llinas, Rudolfo, 2, 4, 122, 125, 143, 186
- Marr, David, 25–26, 41
- Miikkulainen, Risto, 151, 153
- Miller, Julian, 173
- Moser, Edvard, 51, 54
- Moser, May Britt, 51, 54
- Mountcastle, Vernon, 101
- Mumford, David, 99
- Nakajima, K., 131
- Natural evolutionary strategies (NES), 156–157
- Neocortex, 48, 49, 58, 59, 101–104, 141–143
- Neural Darwinism, 130, 132, 147, 160, 162, 180, 189
- Neural gradient representation by activity difference (NGRAD), 159
- Neurotransmitters, 120–121
- O’Keefe, John, 51
- Oscillations (neural), 127, 128, 130
 in neocortex, 141–143
 and learning, 140–143, 175–176
 origins of, 122–123, 146
- Postinhibitory rebound, 123–125, 142
- Prediction
 by averaging, 20–21
 in basal ganglia, 55–58
 in cerebellum, 39–43
 basic concept, 1, 11
 and control, 21–24, 37–39
 emergence of, 117–148
 and error, 12
 and goals, 12–14
 via gradients, 15–16
 in hippocampus, 48–51, 59–60
 and movement, 3–5
 in neocortex, 101–104
 and neural tuning, 104–109
 procedural versus declarative, 58
 and sequences, 18–20
- Predictive Coding, 93–116
 for backpropagation, 112–115
 basic concept, 24–25
 and corollary discharge, 127
 in hierarchical controller, 133–140
 in neocortex, 101–104, 139–140
 origin of term, 94
 for machine learning, 109–115
 Rao and Ballard model, 99
 in retina, 96–98
 spatial versus temporal, 95–97
 in spinomuscular circuits, 125–127
- Quartz, Steven, 132–133
- Rao, Rajesh, 99, 112
- Real, Esteban, 155
- Reinforcement Learning (RL), 55–57
- Restricted Boltzmann Machine (RBM), 70–73
- Risi, Sebastian, 160
- Salakhutdinov, Ruslan, 72–73
- Salimans, Tim, 156–157, 171–172
- Sejnowski, Terrence, 132–133
- Selectionism (neural), 41, 132–133, 174
- Singularity, 192
- Soltoggio, Andrea, 160
- Spike-timing dependent plasticity (STDP), 104, 107, 117, 140, 142–145, 189
- Srinivasan, Mandyam, 94, 95
- Stanley, Kenneth, 151, 152, 160, 172–173
- Sterling, Peter, 24
- Stone, Peter, 129
- Subtal, Ahmad, 102–104
- Tani, Jun, 168–171
- Thompson, D’Arcy, 176–177, 185
- Tononi, Giulio, 33, 95
- Tripp, Bryan, 30, 32–34, 59, 60
- Vinge, Vernon, 192
- von Helmholtz, Herman, 61
- Whittington, James, 112, 115, 116, 159

© 2023 Keith L. Downing

This work is subject to a Creative Commons CC-BY-NC-ND license. Subject to such license, all rights are reserved.



The MIT Press would like to thank the anonymous peer reviewers who provided comments on drafts of this book. The generous work of academic experts is essential for establishing the authority and quality of our publications. We acknowledge with gratitude the contributions of these otherwise uncredited readers.

This book was set in Times New Roman by Westchester Publishing Services.

Library of Congress Cataloging-in-Publication Data

Names: Downing, Keith L., author.

Title: Gradient expectations : structure, origins, and synthesis of predictive neural networks / Keith L. Downing.

Description: [Cambridge, Massachusetts] : The MIT Press, [2023] | Includes bibliographical references and index.

Identifiers: LCCN 2022037237 (print) | LCCN 2022037238 (ebook) |

ISBN 9780262545617 (paperback) | ISBN 9780262374682 (epub) |

ISBN 9780262374675 (pdf)

Subjects: LCSH: Deep learning (Machine learning) | Neural networks (Computer science) | Conjugate gradient methods.

Classification: LCC Q325.73 .D88 2023 (print) | LCC Q325.73 (ebook) |

DDC 006.3/2—dc23/eng20230302

LC record available at <https://lcn.loc.gov/2022037237>

LC ebook record available at <https://lcn.loc.gov/2022037238>