

The art of mathematical models

capturing dynamics



- THE IMPRESSIONISTS SOUGHT TO "CAPTURE THE MOMENT" IN THEIR ART
- IMPRESSIONISTS EMPHASIZED LIGHT IN A SCENE AND INTERPRETED OTHER ELEMENTS AS TEXTURED COLOR
- MATHEMATICAL MODELS ARE DESIGNED TO EMPHASIZE SPECIFIC FEATURES, WITH UNKNOWN ASPECTS REPRESENTED BY "NOISE" THAT PROVIDES A BACKGROUND TEXTURE TO THE DYNAMICS

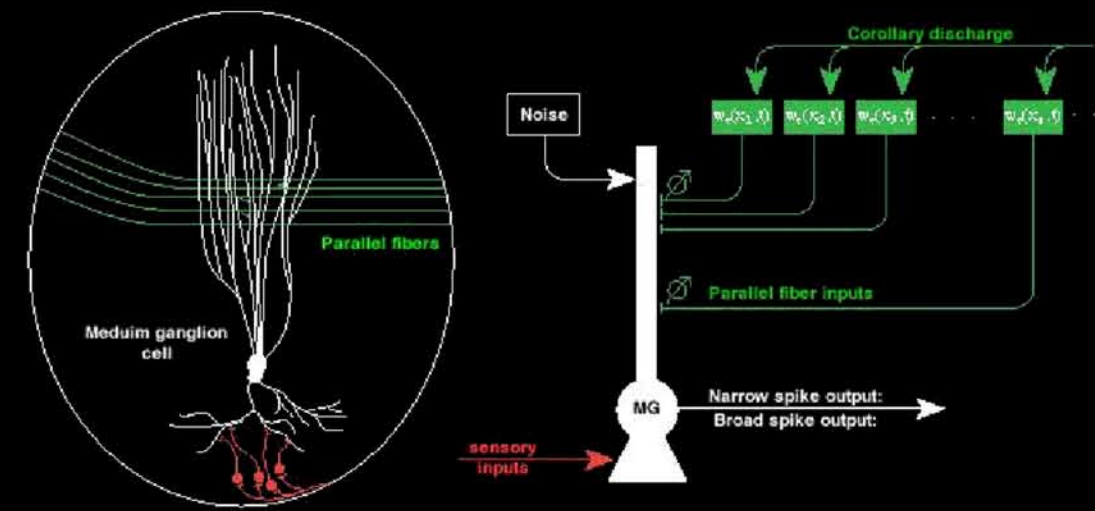
CLAUDE MONET, MUSEE D'ORSAY
CAPTURING THE MOMENT

EVERY MOMENT HAS A PARTICULAR ARRANGEMENT OF FEATURES



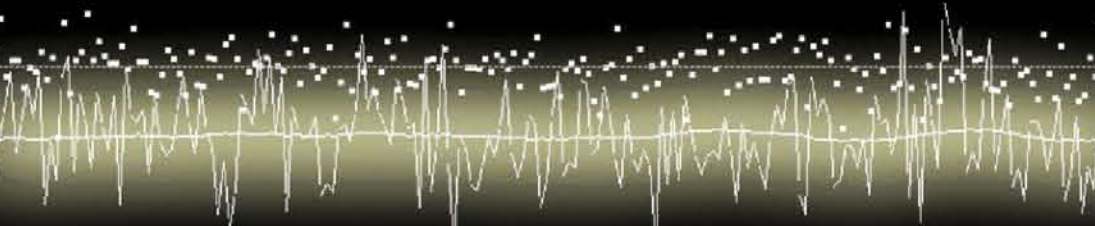
AUGUSTE RENOIR, MUSEE D'ORSAY

TO CAPTURE A MOMENT OF THE DYNAMICS IN OUR MODELS, WE SIMPLIFY TO EMPHASIZE SPECIFIC FEATURES, LIKE THE TIMING OF SPIKES. THE DE-EMPHASIZED DETAILS ARE REPRESENTED BY ADDING "NOISE" TO THE MODEL.



SIMPLIFY MODEL TO EMPHASIZE SPECIFIC FEATURES

IF THE MEMBRANE POTENTIAL OF THE MODEL NEURON IS GREATER THAN THE SPIKE THRESHOLD, THEN A SPIKE IS GENERATED AT THAT PARTICULAR MOMENT.



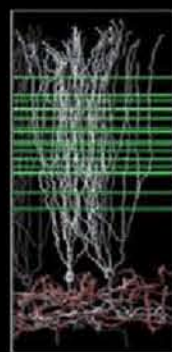
EVERY ARRANGEMENT OF FEATURES HAS A PROBABILITY THAT CAN BE CALCULATED

THE PROBABILITY TELLS US THE CHANCE THAT THE NEURON WILL GENERATE A SPIKE. USING MATHEMATICS TO CALCULATE PROBABILITIES, WE CAN PREDICT THE CHANCE OF A PARTICULAR OUTCOME FOR OUR EXPERIMENTS OR CLINICAL APPLICATIONS.



THE IMPRESSIONISTS CAPTURED ATMOSPHERIC MOMENTS IN TIME

MATHEMATICAL MODELS PREDICT THE OUTCOME OF SPIKE MEASUREMENTS (MOMENTS) IN TIME



capturing dynamics

patterns from nature



abstract models

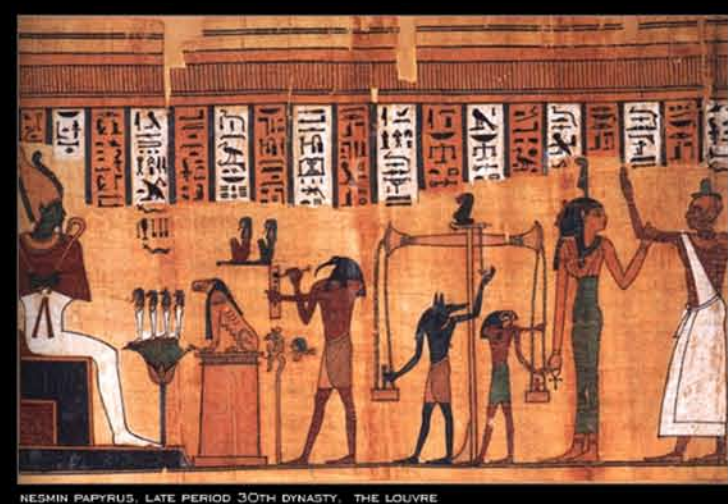
abstract models



- UNIVERSALITY THROUGH SIMPLIFICATION
- SIMPLIFIED IMAGES CAN BECOME ICONS AND EVEN LANGUAGE
- SIMPLE MODELS CAN BE REPRESENTED BY MATHEMATICAL SYMBOLS
- GENERAL PRINCIPLES ARE DISCOVERED BY USING SIMPLE MODELS



ICONS CAN DEVELOP INTO LANGUAGE. WE CAN COMBINE DIFFERENT LEVELS OF ABSTRACTION. THEY CAN REFER TO EACH OTHER



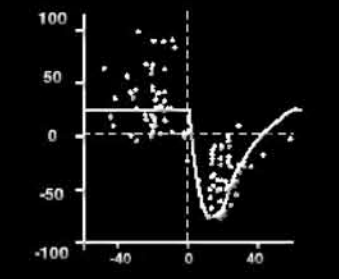
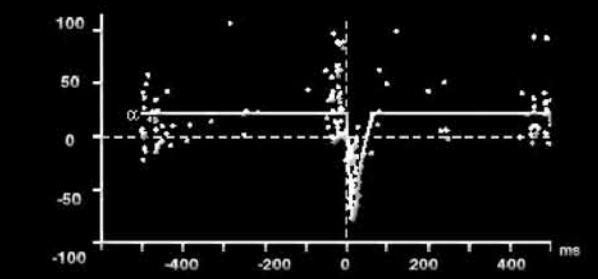
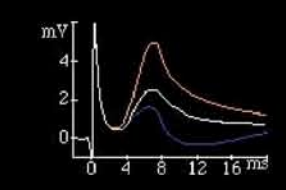
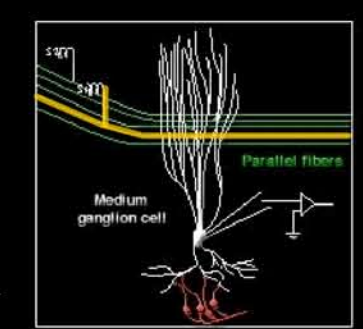
NESENI PAPYRUS, LATE PERIOD 30TH DYNASTY, THE LOUVRE

EXPERIMENTAL DATA CAN BE ABSTRACTED TO CREATE A GENERAL RULE.

ABSTRACTIONS OF DATA BECOME THE BUILDING BLOCKS OF A MODEL'S FORMULA AND SIMULATIONS.

THE TEMPORAL LEARNING RULE

C. BELL, HAN Y. SUHSHINE AND K. GRANT (1997). SYNAPTIC PLASTICITY IN A CEREBELLUM-LIKE STRUCTURE DEPENDS ON TEMPORAL ORDER. NATURE, 387: 278-281.

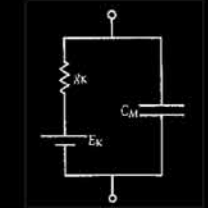
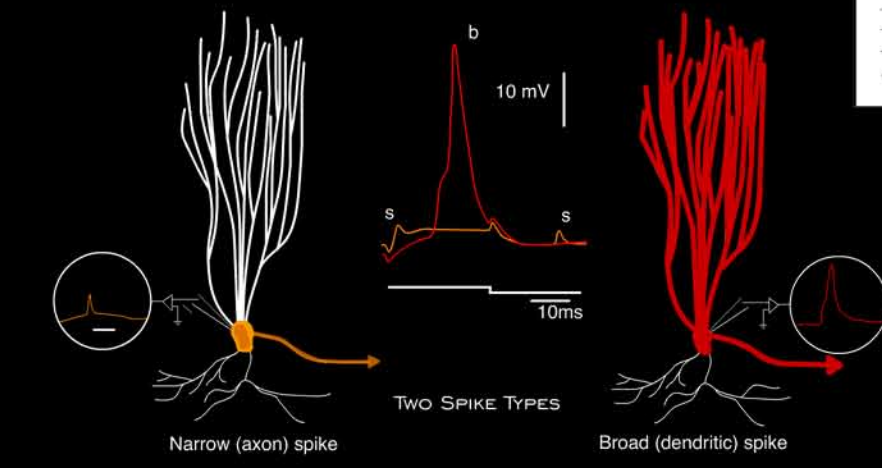


MODEL OF MUTUALLY INHIBITORY MEDIUM GANGLION CELLS



$$V_1(x_n, t) = \sum_m w^1(x_m, t)\epsilon(x_n - x_m) + v_1(x_n) + \epsilon \sum_m f_2(x_m, t)\epsilon(x_m - x_n)$$

WHEN WE ABSTRACT AN IMAGE WE'RE NOT SO MUCH ELIMINATING DETAILS AS WE ARE FOCUSING ON SPECIFIC DETAILS



EVERYTHING COMES FROM THE GREAT BOOK OF NATURE. ANTONIO GAUDI

MATHEMATICAL MODELS OF THE BRAIN ADD PRECISION TO OUR UNDERSTANDING OF THE COMPLEX PROCESSES THAT ENABLE THE NERVOUS SYSTEM TO FUNCTION.

THIS SERIES OF PANELS DEMONSTRATES SIMILARITIES OF APPROACHES TO COMPLEX PROBLEMS IN ART AND SCIENCE.

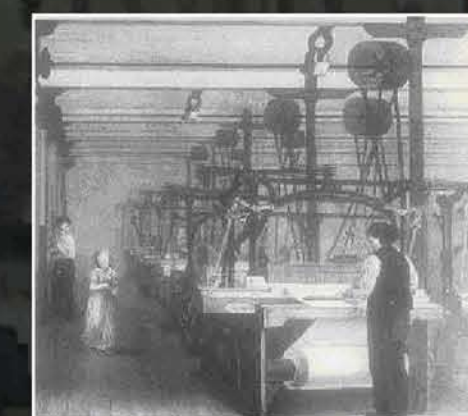
ARTISTS CREATE ARTWORKS TO INTERPRET AND EXPRESS THEIR UNDERSTANDING OF THE WORLD. THEY DRAW INSPIRATION FROM THEIR OBSERVATIONS AND APPLY CONTEMPORARY TECHNIQUES TO THEIR OWN DISCOVERY.

THEORETICAL NEUROSCIENTISTS CONSTRUCT ABSTRACT MODELS TO PREDICT HOW THE BRAIN WORKS. THESE MODELS ARE BASED ON PATTERNS FROM NATURE AND USE MATHEMATICS THAT DESCRIBE HOW THE ACTIVITY OF THE BRAIN CHANGES IN TIME TO CAPTURE THE DYNAMICS OF BRAIN FUNCTION.

patterns from nature



- ART NOUVEAU MOVEMENT REACTED AGAINST MACHINE AGE DESIGN OF THE 19TH CENTURY
- THEORETICAL NEUROSCIENCE HAS BEEN DOMINATED BY METAPHORS FROM ENGINEERING AND COMPUTER SCIENCE
- DEEPER INSIGHTS ARE OBTAINED IF WE BASE OUR MODELS ON THE NATURAL FORM



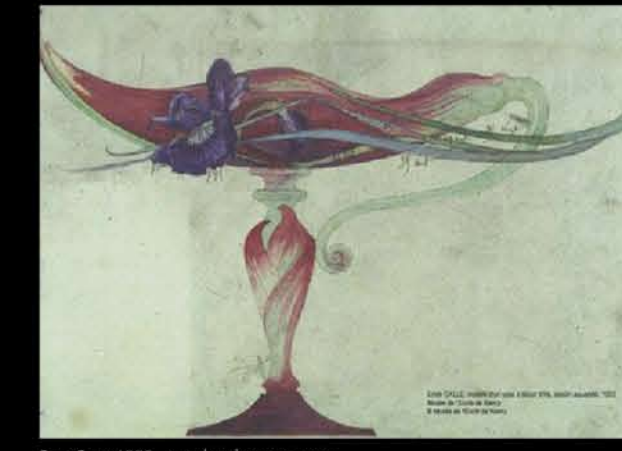
THE INDUSTRIAL REVOLUTION GAVE THE PHYSICAL MEANS TO EFFECT MASTERY OVER NATURE, UNIMAGINATIVE AND REPETITIVE DESIGN CAME FROM MACHINE PRODUCTION, AND MASS QUANTITIES.

PATTERNS FROM NATURE I

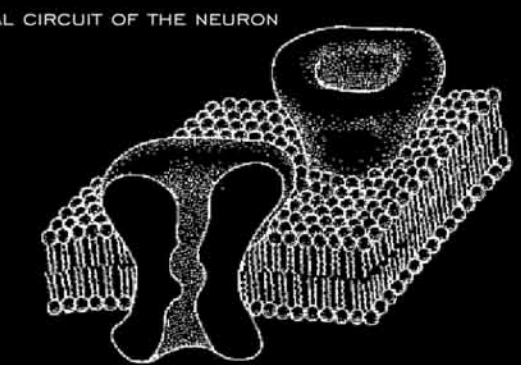
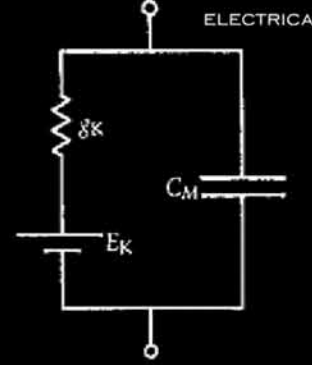
REACTING AGAINST THE MACHINE MADE PRODUCT OF THE INDUSTRIAL REVOLUTION, THE ART NOUVEAU MOVEMENT SOUGHT TO RETURN TO NATURE FOR INSPIRATION IN DESIGN AND IN ART.

"ORIGINALITY CONSISTS OF RETURNING TO THE ORIGIN"

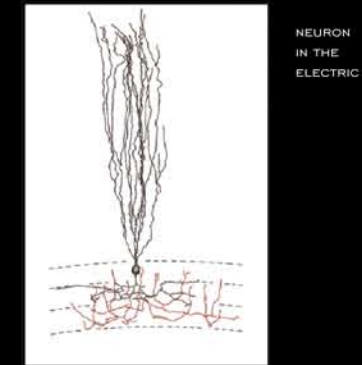
ANTONIO GAUDI (1852-1926) ART NOUVEAU ARCHITECT



ERLE GALLE 1903 MUSEE DE L'ECOLE DE NANCY



SINCE THE 1950S, ENGINEERING CONCEPTS OF ELECTRICAL CIRCUITRY AND MECHANICS HAVE DOMINATED THEORETICAL NEUROSCIENCE. NEURONS HAVE OFTEN BEEN MODELED AS SIMPLE CIRCUITS WITHOUT REFERENCE TO THEIR NATURAL FORM.



MATHEMATICAL MODELS BASED ON THE NATURAL FORM OF THESE NEURONS SHOW THAT THE TWO SPIKE TYPES ARISE FROM THE SHAPE OF THE NEURONS. WHEN WE UNDERSTAND HOW THINGS WORK, WE CAN CORRECT THE PROBLEMS WHEN THEY DON'T WORK.