Master in High Performance Computing

Object-oriented design

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SISSA Scuola Internazionale Superiore di Studi Avanzati

The Abdus Salam International Centre for Theoretical Physics

Grady Booch
“Object-oriented analysis and design”
2nd edition
Addison-Wesley, 1994

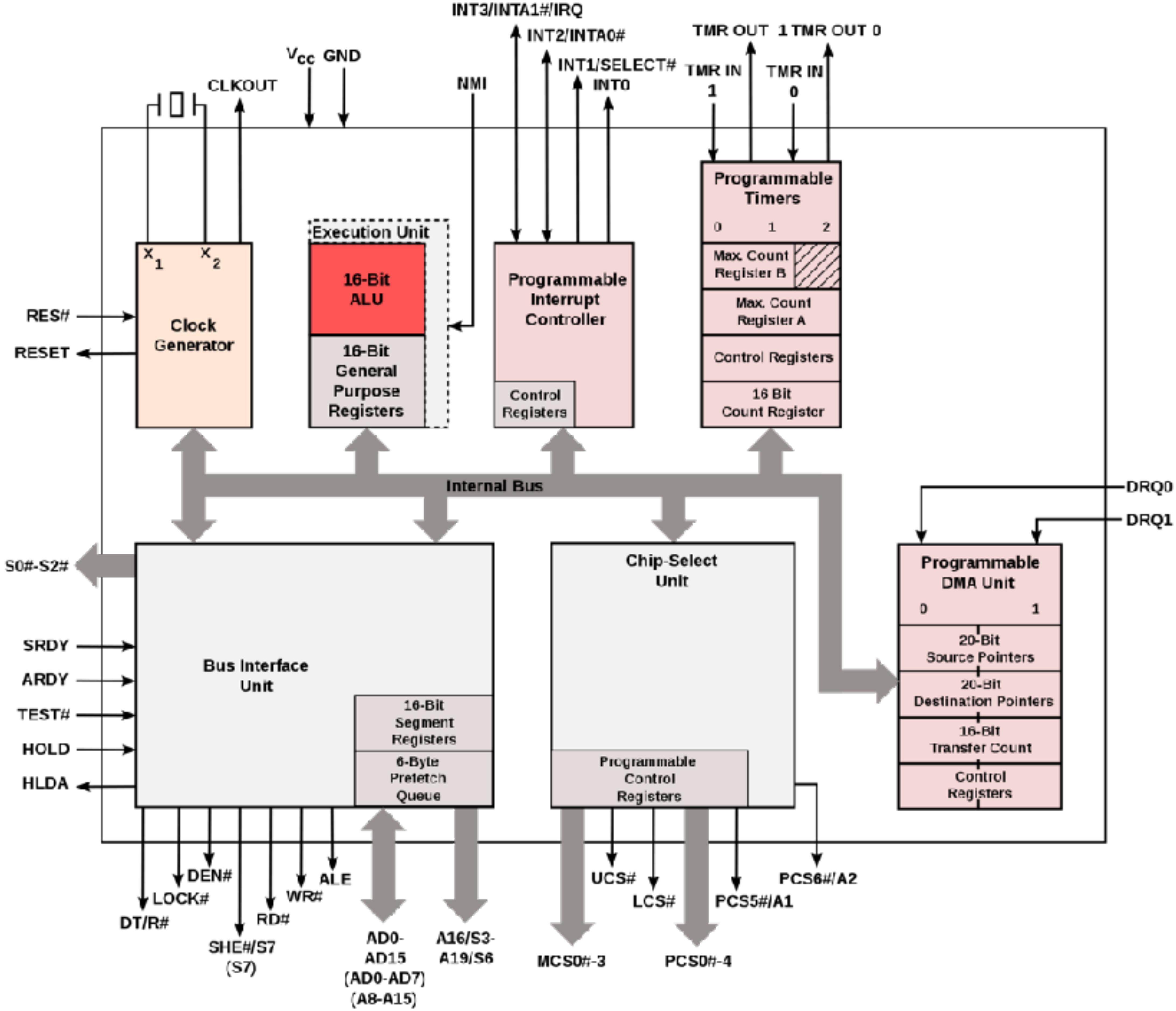
Main goal: manage complexity

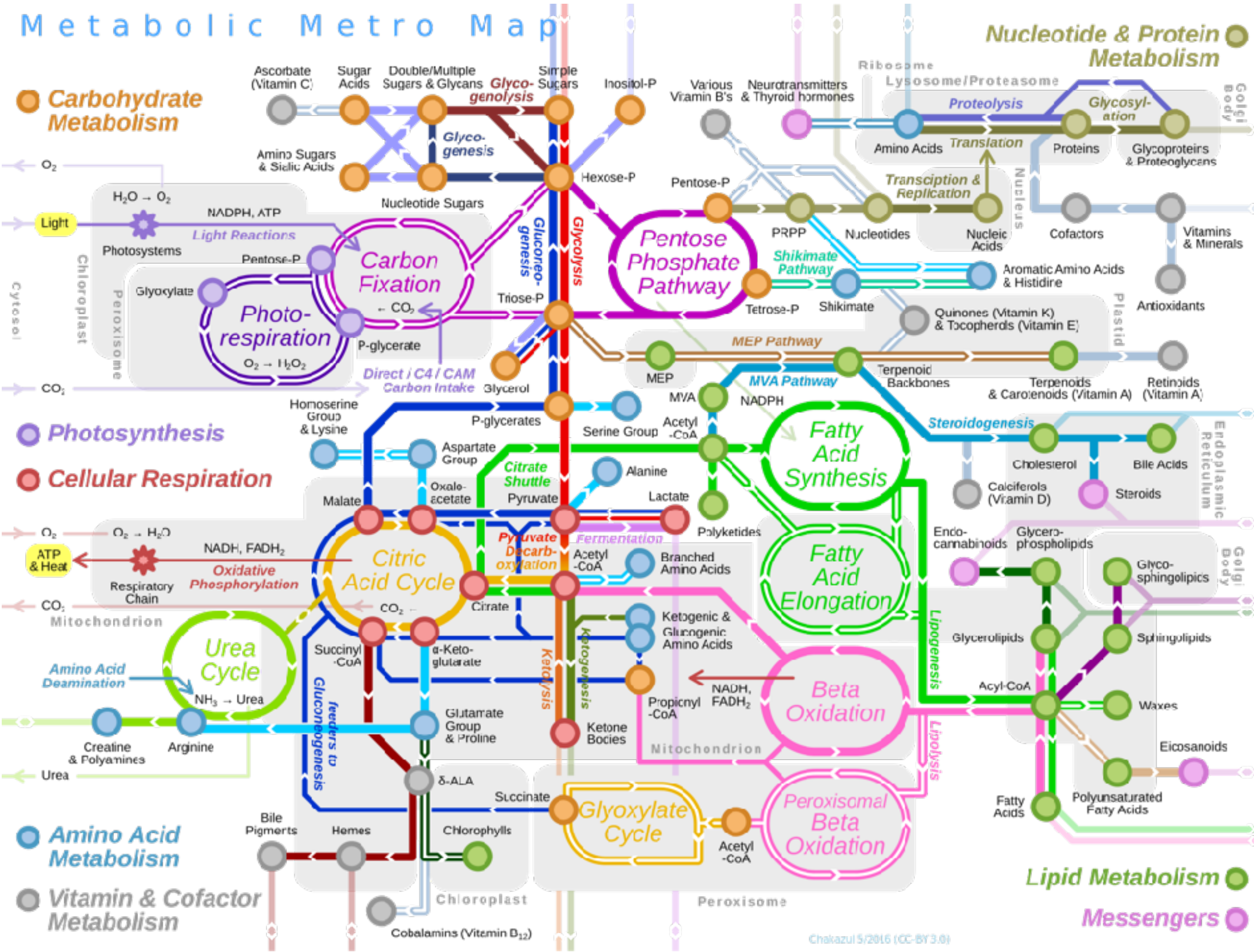
Different approaches, OO is just one of them!

see e.g. Haskell for a completely different approach to complexity handling: functional programming

* Complexity of the problem domain
  external; requires software maintenance, evolution, preservation
* Development process
  impossible for one developer to understand large projects completely
* Software is boundlessly flexible
  able to work at any level of abstraction; no fixed quality standards
* Behaviour of discrete system
  natural world physics is local and continuous
  program state is not: combinatoric, small change -> large effect

Intel 80186 / 80188 architecture




Metabolic Metro Map
Carbohydrate Metabolism
Photosynthesis
Cellular Respiration
Amino Acid Metabolism
Vitamin & Cofactor Metabolism
Nucleotide & Protein Metabolism
Lipid Metabolism
Messengers
Ascorbate (Vitamin C)
Sugar Acids
Double/Multiple Sugars & Glycans
Glycogenolysis
Simple Sugars
Inositol-P
Glycogenesis
Amino Sugars & Sialic Acids
Hexose-P
Nucleotide Sugars
Gluconeogenesis
Glycolysis
Pentose Phosphate Pathway
Pentose-P
Tetrose-P
Triose-P
Glycerol
P-glycerates
O₂
H₂O → O₂
Light
NADPH, ATP
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Light Reactions
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Carbon Fixation
← CO₂
Glyoxylate
Photorespiration
O₂ → H₂O₂
P-glycerate
Direct / C4 / CAM Carbon Intake
CO₂
Cytosol
Chloroplast
Peroxisome
Ribosome
Lysosome/Proteasome
Various Vitamin B's
Neurotransmitters & Thyroid hormones
Proteolysis
Glycosylation
Golgi Body
Amino Acids
Translation
Proteins
Glycoproteins & Proteoglycans
Transcription & Replication
Nucleus
PRPP
Nucleotides
Nucleic Acids
Cofactors
Vitamins & Minerals
Shikimate Pathway
Shikimate
Aromatic Amino Acids & Histidine
Antioxidants
Quinones (Vitamin K) & Tocopherols (Vitamin E)
Plastid
MEP Pathway
MEP
Terpenoid Backbones
Terpenoids & Carotenoids (Vitamin A)
Retinoids (Vitamin A)
MVA
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NADPH
Steroidogenesis
Homoserine Group & Lysine
Serine Group
Acetyl-CoA
Fatty Acid Synthesis
Aspartate Group
Citrate Shuttle
Oxaloacetate
Alanine
Pyruvate
Lactate
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Cholesterol
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Calciferols (Vitamin D)
Steroids
Endoplasmic Reticulum
Polyketides
Endocannabinoids
Glycerophospholipids
O₂ → H₂O
NADH, FADH₂
ATP & Heat
Respiratory Chain
Oxidative Phosphorylation
Citric Acid Cycle
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Branched Amino Acids
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Glycerolipids
Sphingolipids
Urea Cycle
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Lipolysis
Eicosanoids
δ-ALA
Succinate
Glyoxylate Cycle
Peroxisomal Beta Oxidation
Fatty Acids
Polyunsaturated Fatty Acids
Bile Pigments
Hemes
Chlorophylls
Acetyl-CoA
Chloroplast
Peroxisome
Cobalamins (Vitamin B₁₂)
Chakazul 5/2016 (CC-BY 3.0)

- Complexity is hierarchical grouping of subsystems, down to elementary components
- Choice of elementary blocks is mostly arbitrary
- Links and interactions within a component are much stronger than between components
- Hierarchy uses only a few different subsystems in different combinations
- Working complex systems evolve from working simple systems

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* Deal with complexity by decomposition
* Algorithmic decomposition:
  which steps in which order?
* OO decomposition:
  which entities are involved?
  how do they relate to each other?

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Core features of OO design

* Abstraction
* Encapsulation
* Modularity
* Hierarchy

Abstraction

* Outside view of the object
* Focus on relevant details, ignore others
* Define distinction to other objects
* No surprises, no unexpected side behaviour

Abstraction

* Identify object invariants, properties that must be true at any time
* Operations have pre- and post-conditions, they must be satisfied
* Objects should never enter inconsistent state

Abstraction

* Implementation details do not matter here
* Define public member functions
* Private section doesn't matter yet

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Encapsulation

* separates object's tasks from each other
* actual implementation of the abstraction is hidden
* allows isolated implementation changes
* internal design changes in the objects do not impact the users of the objects

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Encapsulation

* Abstractions only work well if implementation is encapsulated!

Modularity

* Grouping of classes into functionally related units. Modules should be loosely coupled externally.
* "Physical" collection of units in files, rather than abstract connections
* Difficult to get right first time, may need several redesigns during development

Hierarchy

* Abstractions form hierarchies
* Helps to think about the useful levels

Two main kinds:

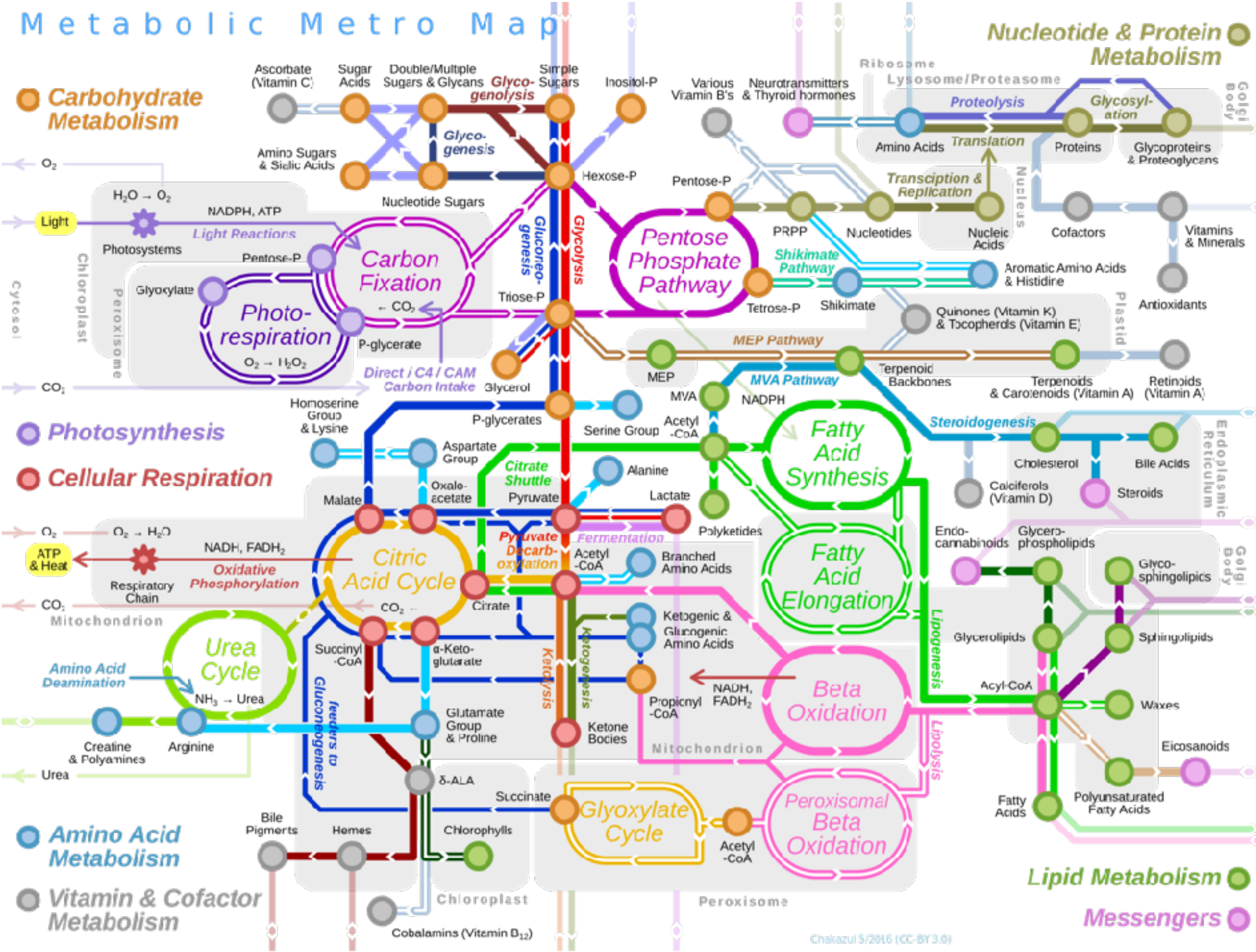
* “is-a”: cat is an animal; oak is a plant
* “has-a”: car has an engine; house has a door

Hierarchy: “is-a”

* Modelled by inheritance
* Common functionality moves to the top; applies to all classes down the hierarchy

Hierarchy: "has-a"

* Modelled by aggregation
* Objects have other objects as member variables



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Chlorophylls
Chloroplast
Peroxisome
Cobalamins (Vitamin B_{12})

Object

- **State**: inner structure with current values
- **Behaviour**: external interaction and state changes (construct / destruct // modify / select / iterate)
- **Identity:** distinct to all other objects
  It's not the name, one object can have many names!
  Identity considerations are relevant when looking at copying, lifetime and ownership behaviour.

Class

Objects with common structure and behaviour belong to a **class**. The class defines both.

An object is an **instance** of a class.

Design exercise