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Digital On-Demand Computing Organism
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Startkolloquium – DFG SPP 1183 “Organic Computing”

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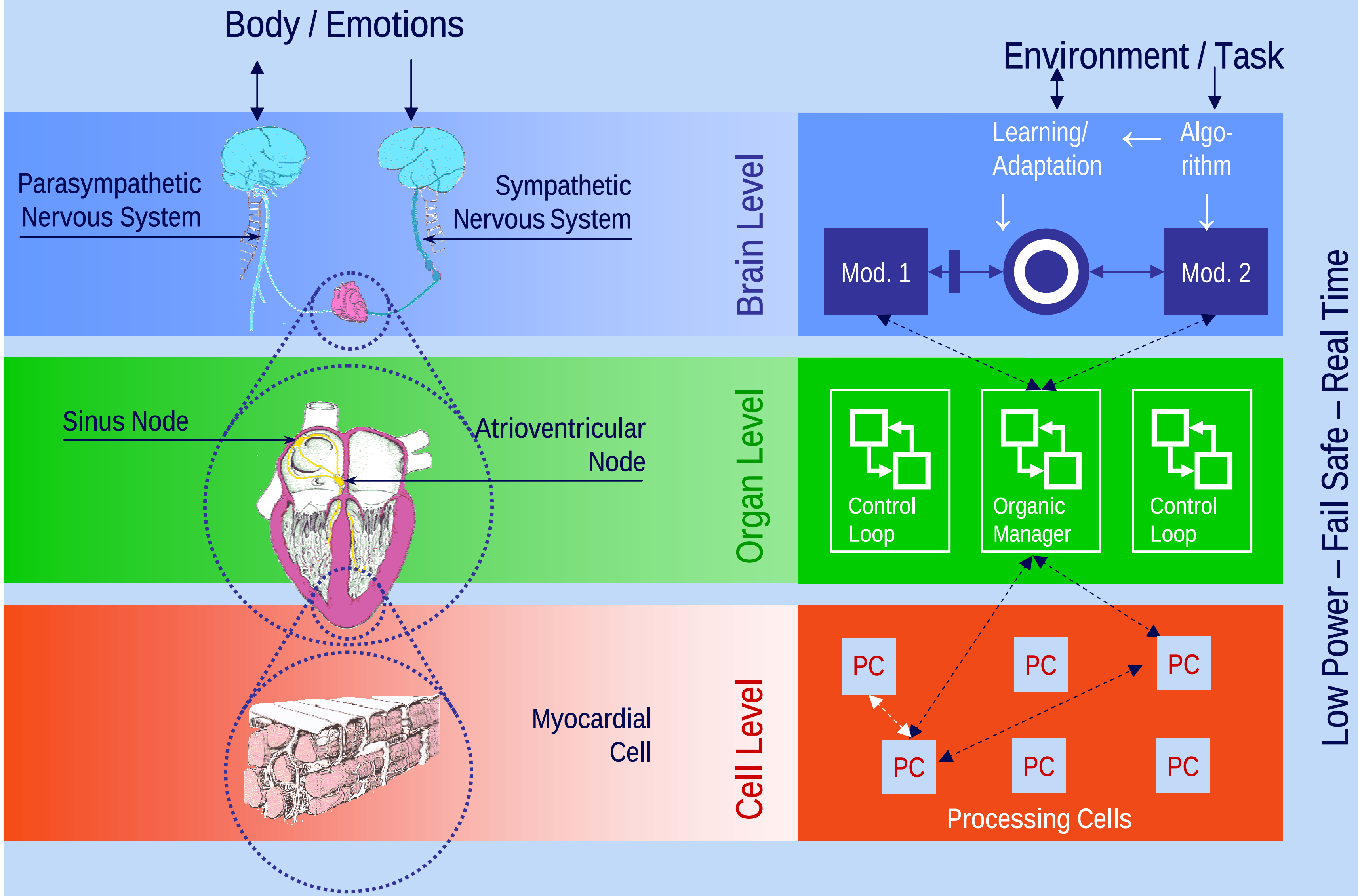
Jürgen Becker [1], Kurt Brändle [1], Uwe Brinkschulte [2], Jörg Henkel [2], Wolfgang Karl [2], Heinz Wörn [2]

[1] Fakultät für Elektrotechnik und Informationstechnik

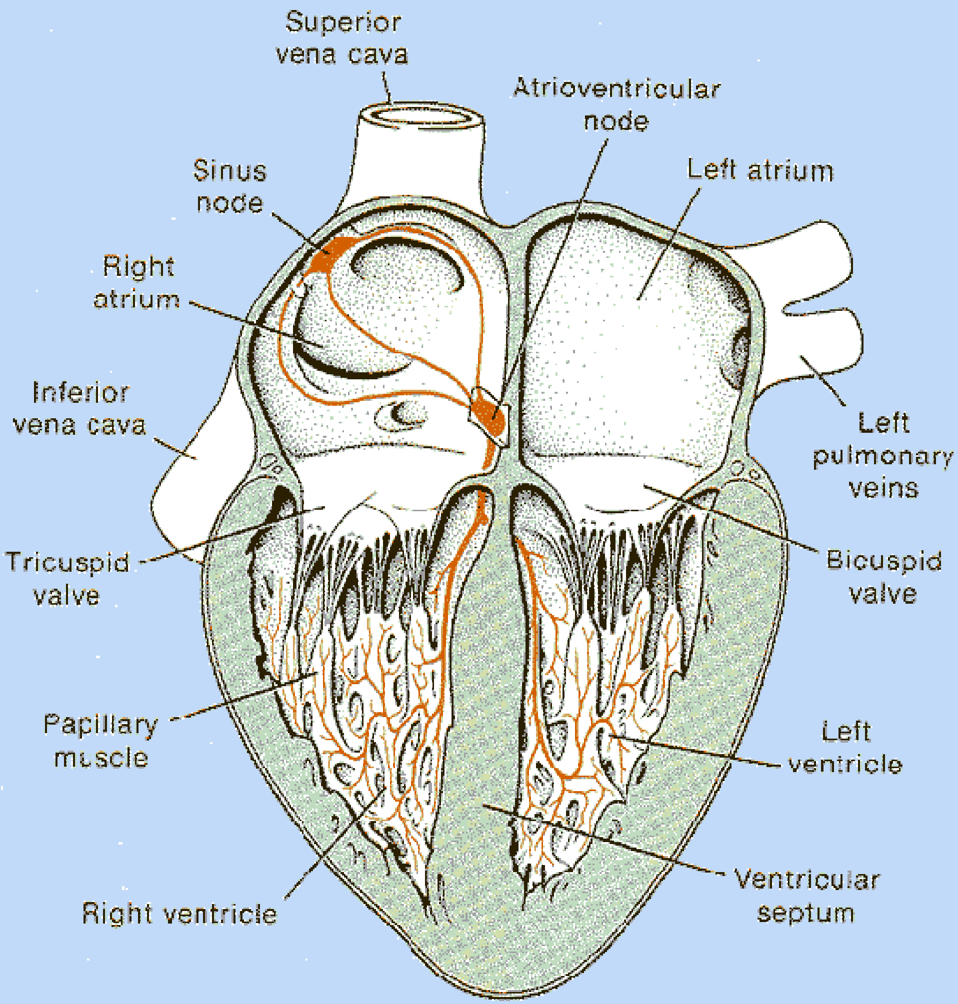
[2] Fakultät für Informatik

Universität Karlsruhe (TH)

From Biology towards an Organic Computing System



The Mammalian Heart
Anatomy



Mammalian heart as model for DodOrg research application

- Matches the proposed hardware structure very well
- Hierarchical order of functionality
- Some features overlap all levels, such as low power consumption and fail safe

Inspired by nature, but not copying it

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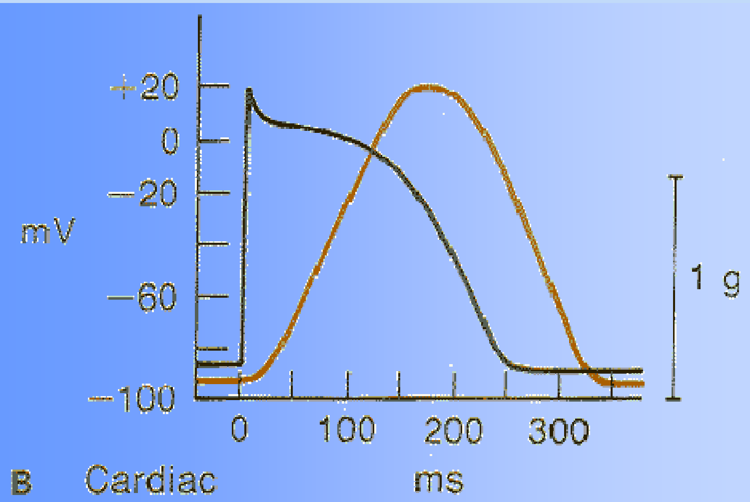
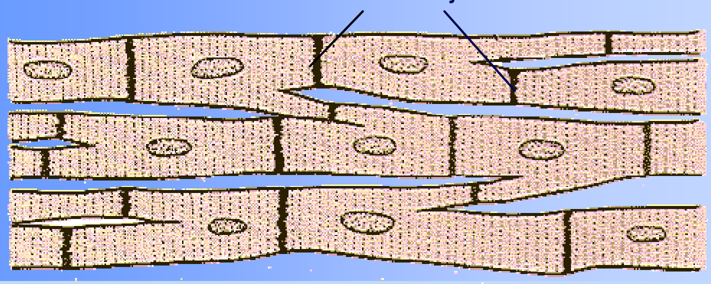


Relationship between electrical (black) and mechanical (brown) activity of cardiac muscle fibers (below)



Lowest level: Cardiac muscle fibers

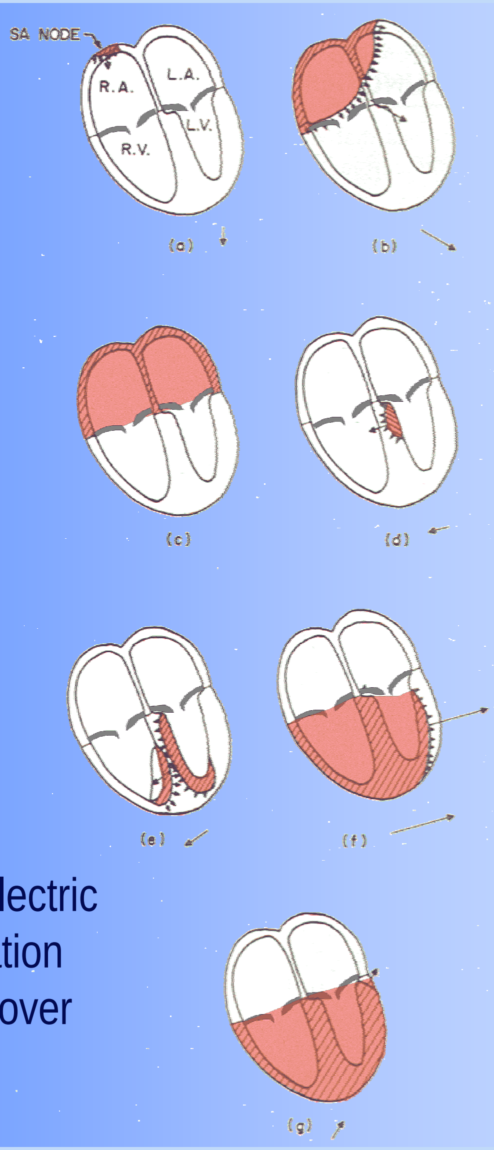
Task: Contraction in response to electric stimulation

- Specific autonomous functionality
- Inflexible response in course and time to electric depolarization of the cellular membrane
- Depolarization transmitted to neighbor cells

"Self-healing"

- In case of malfunction or failure neighbor cells will take over the tasks

Comparable to Processing Cells



Wave of electric depolarization sweeping over the heart

Middle level: Coordination of the contraction of different myocard areas

Task: Achieve pumping movement

- Sinus node initiates contraction of atria
- Electric excitation spreads over the muscles of both atria to the atrio-ventricular node
- Atrio-ventricular node passes wave of excitation via the His bundle to the tip of the heart
- Contractions of the ventricles start from the tip and expand towards the ventricular basis

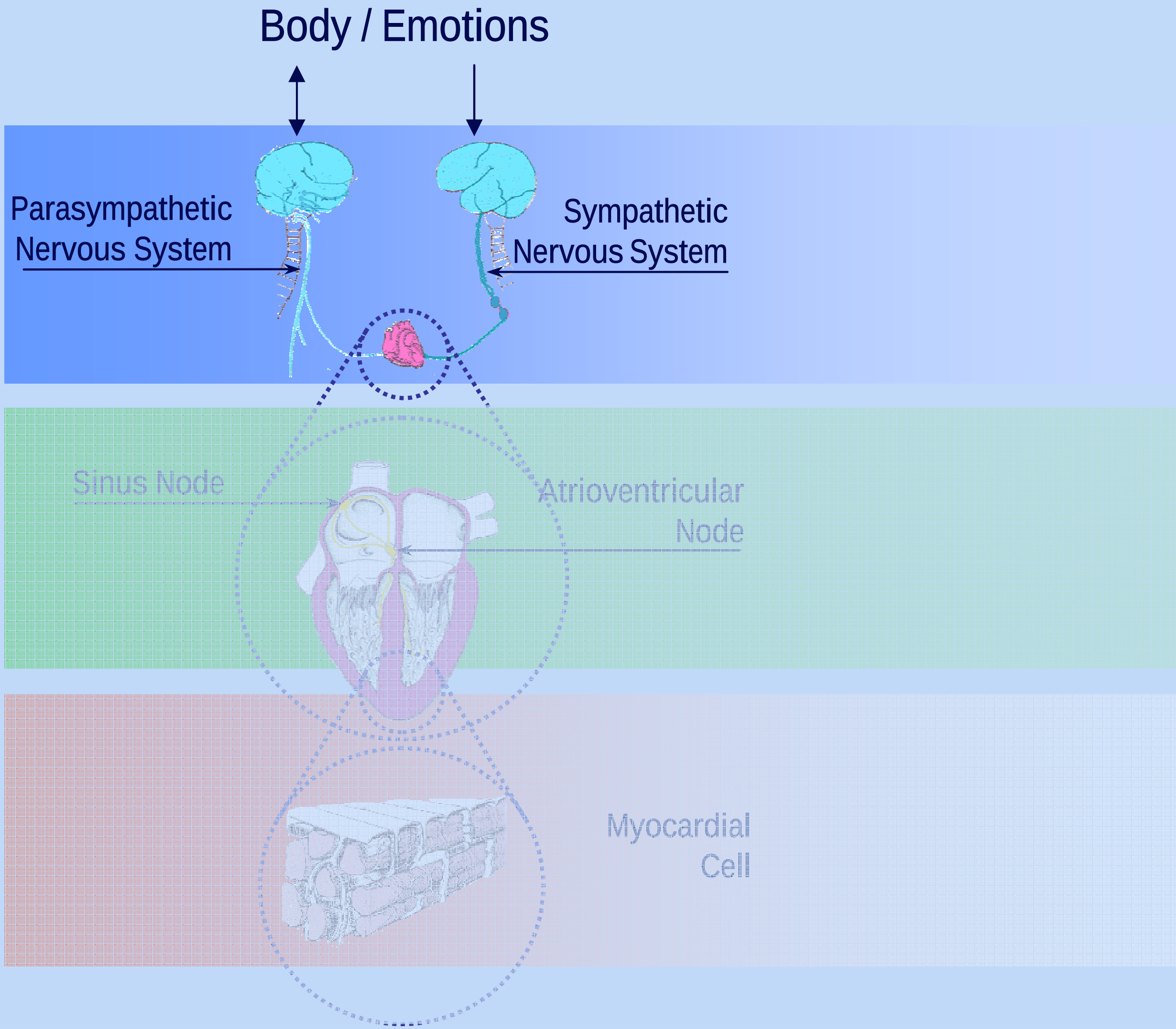
Comparable to middleware

Top level: Outside events can influence heart action

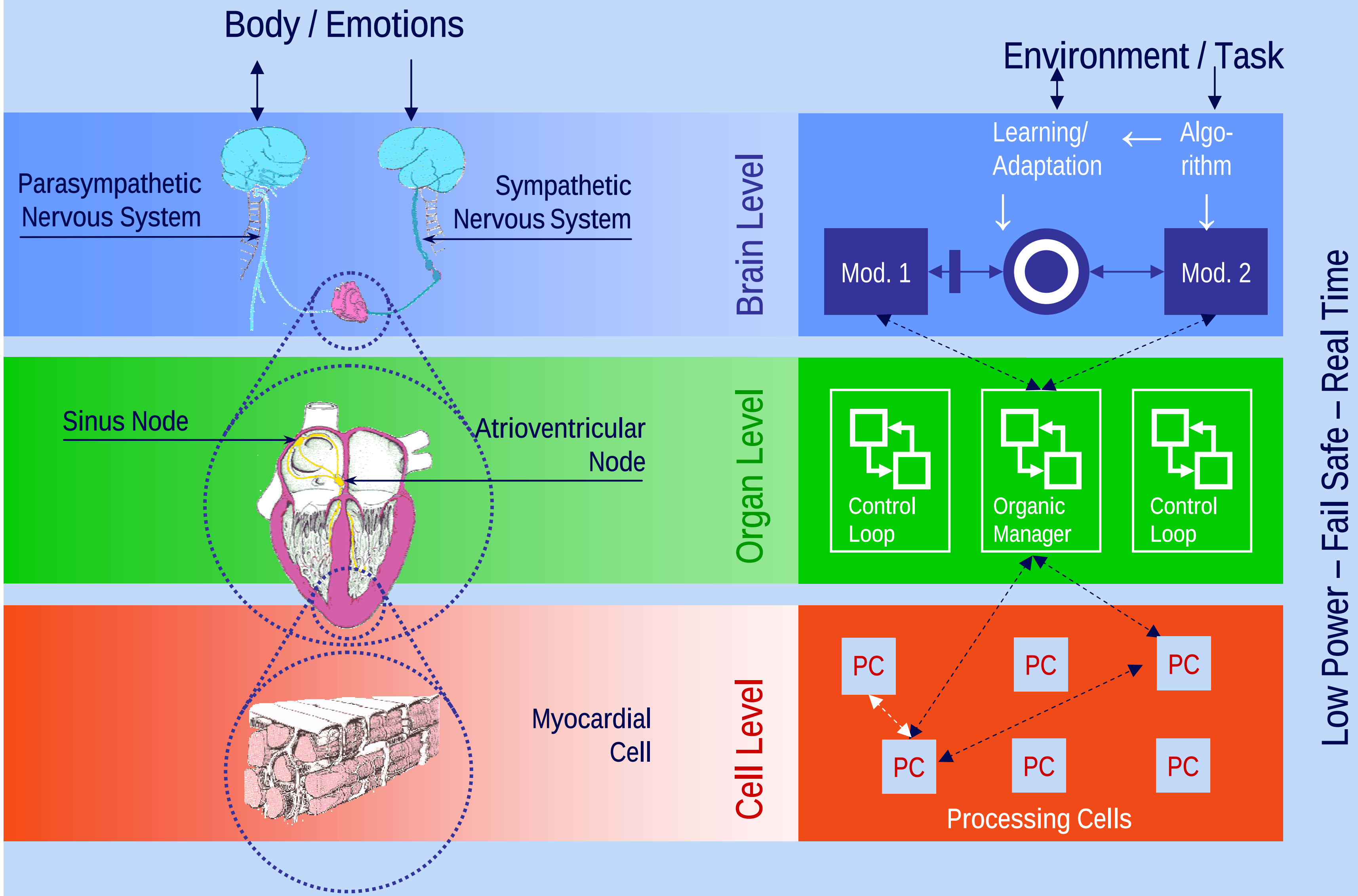
Task: Nervous control of the heart function by the vegetative nervous system

- Sympathetic nervous system increases heart rate and stroke volume
- Parasympathetic nervous system decreases heart rate and stroke volume

Comparable to controlling application



From Biology towards an Organic Computing System



Organization of Sub-Projects

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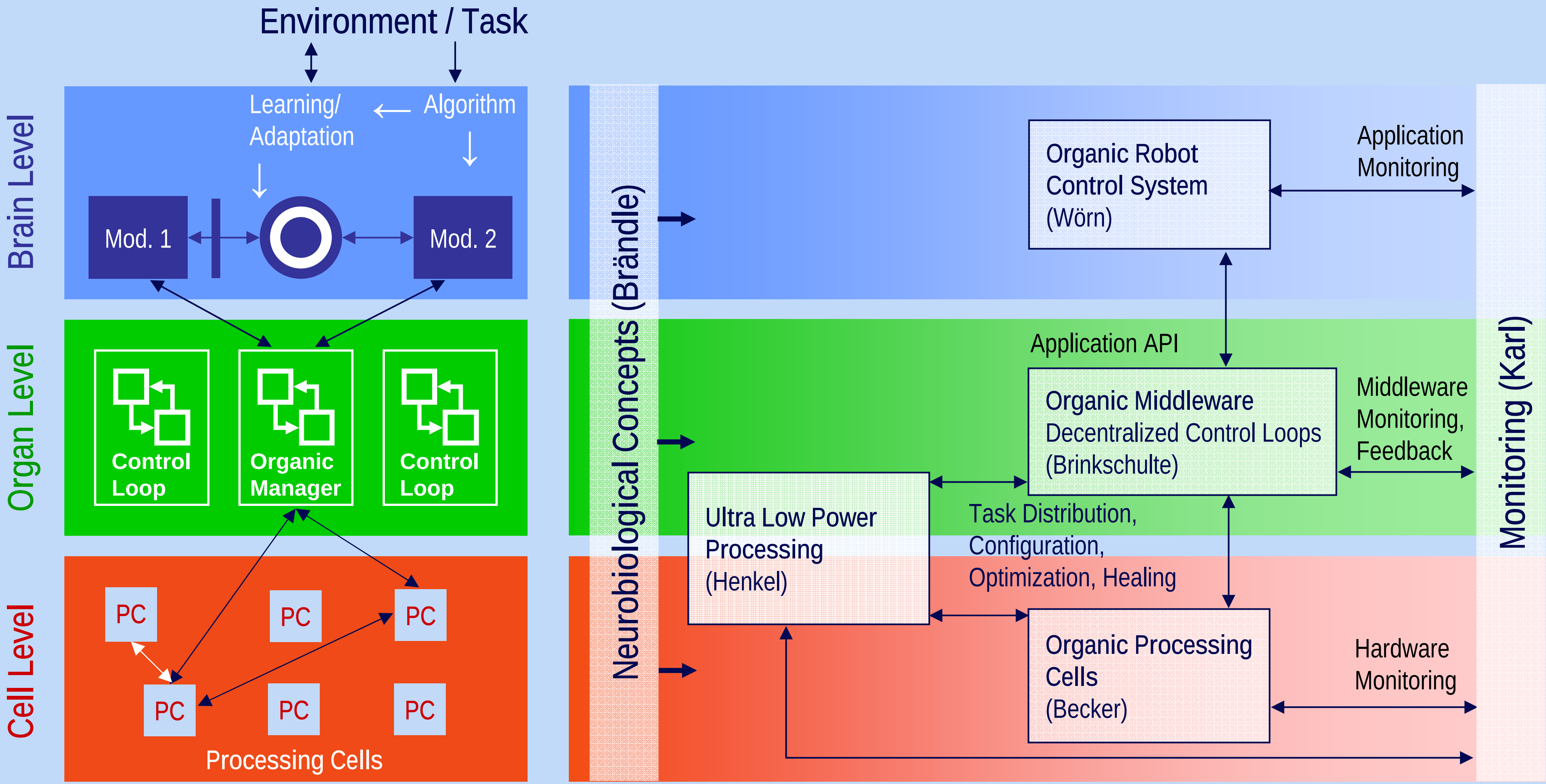

Sub-Project "Organic Processing Cells" (Prof. Becker)

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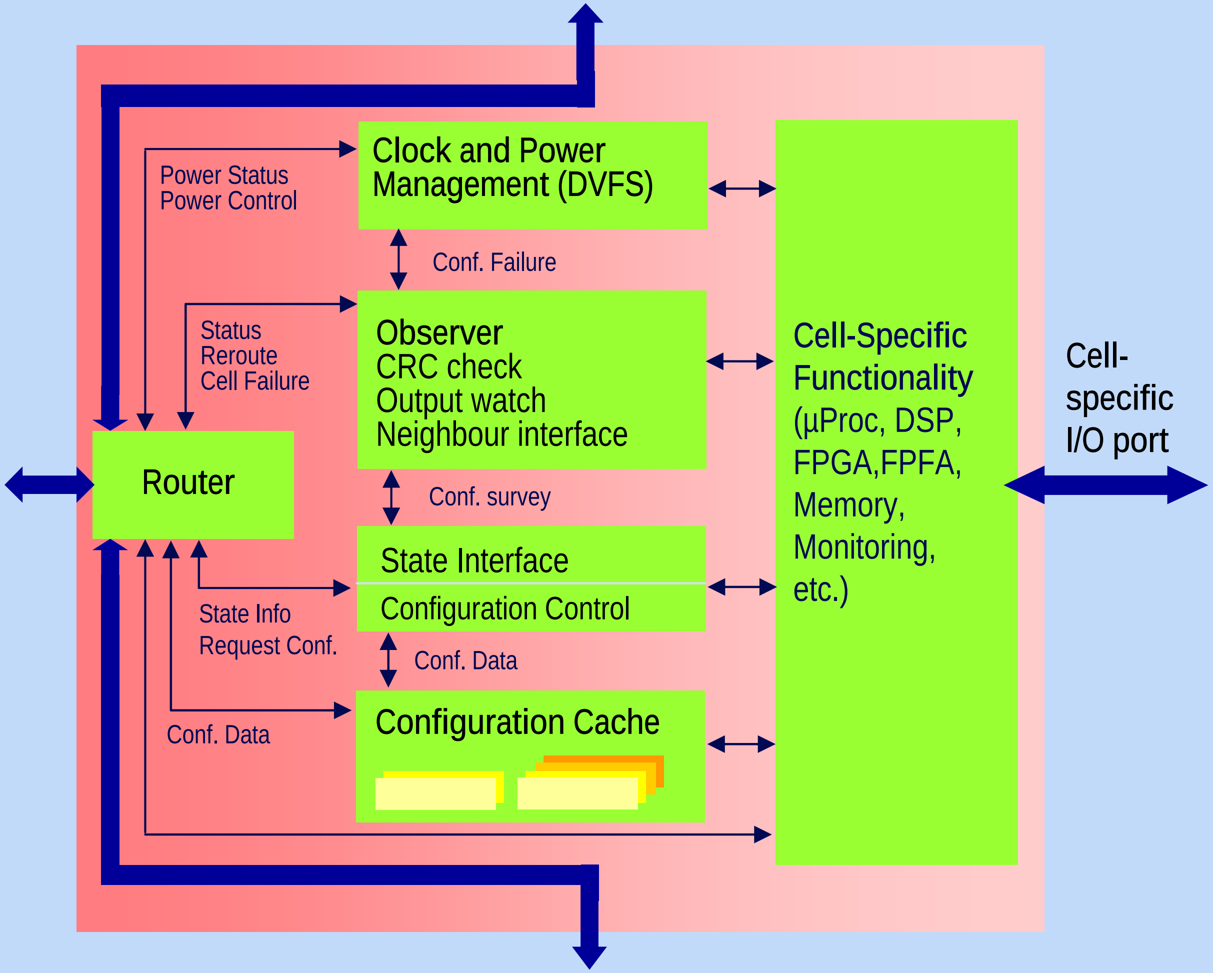
Modularity

- Same "blue print" for all cells
- Common infrastructure
- ▶ Cells can easily take over for defective neighbors
- ▶ Interface for higher-level functions (middleware, monitoring) stays the same

Local intelligence

- Power management
- Basic monitoring facilities
- Configuration
- Router
- Built into each cell

Biological cells are also based on common "blue print" / differentiate only during development



Sub-Project "Organic Processing Cells" (Prof. Becker)

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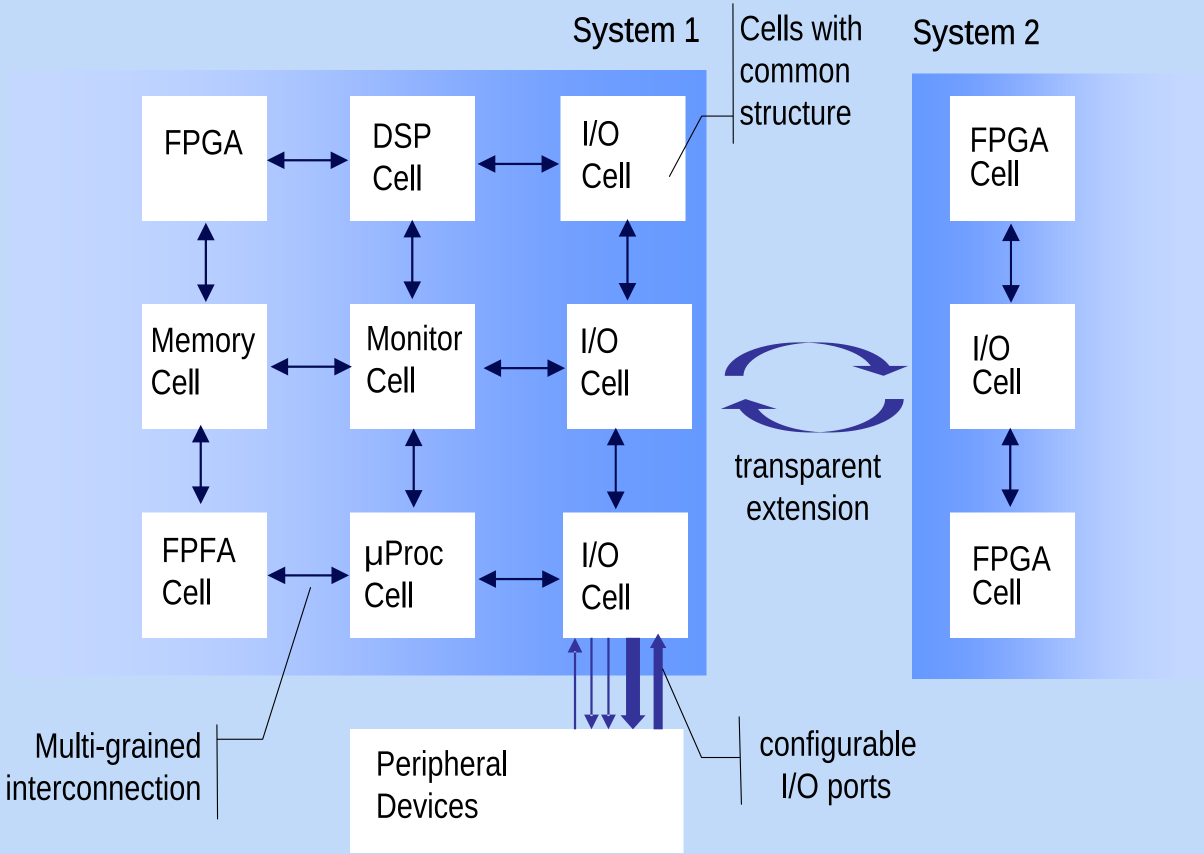
Limited set of cell-specific types of functionality
- Microprocessor / DSP
- FPGA / FPFA
- I/O

Trade-off possible with respect to flexibility of overall system

Multiple implementations of algorithms
- "Self-healing"
- Example: FPGA cell might need to take over from microprocessor cell

Communication facilities transparent across Systems

Basis for organic middleware



Sub-Project “Low power through swap-based system architecture” (Prof. Henkel)

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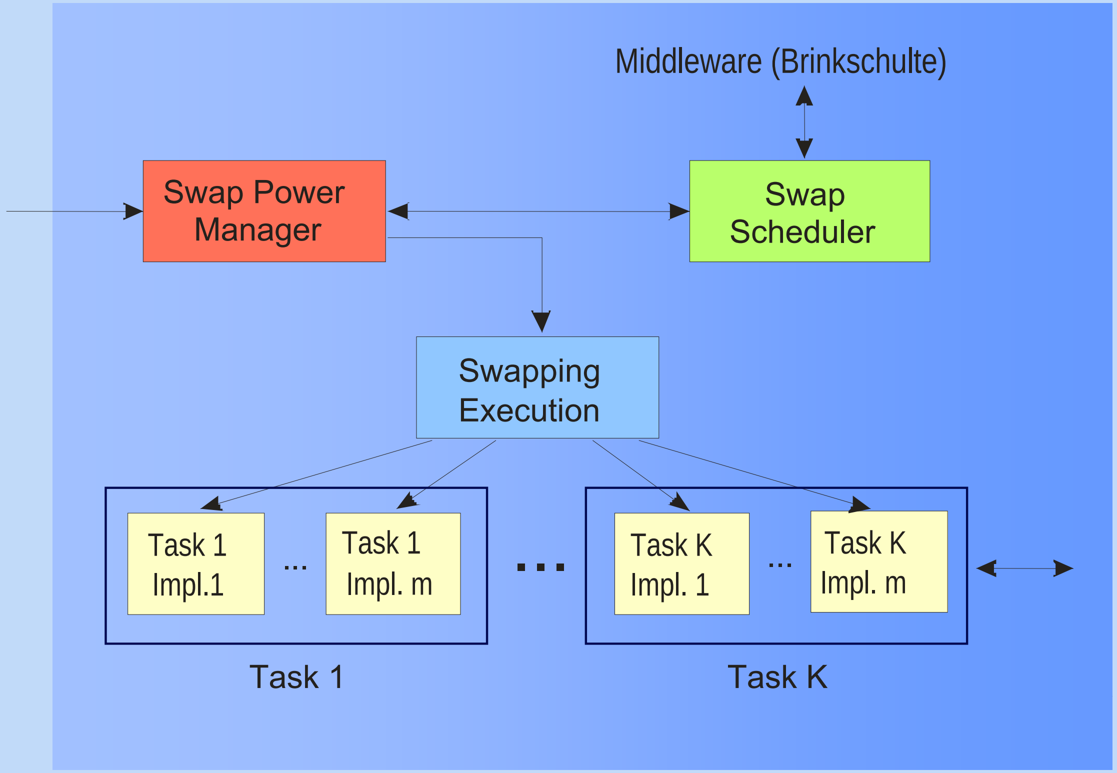
Basic idea

- System should be able to adapt to:
  - Varying (over time) requirements in terms of performance, functionality etc
- The adaptation through “swapping-on-the-fly” ensures that the system is running at any time with minimum resource requirements (ideally without any overhead)

► minimizes power consumption

- Info about system state is retrieved through monitoring



Requirements

- Multiple implementations of one and the same task need to be at the system’s disposal
- At most one of them is in running state at a certain time

Swapping options

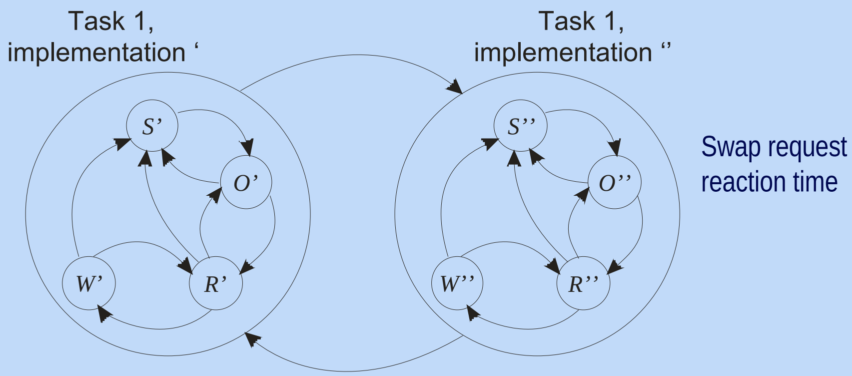
1. A physical implementation can be: software (RAM-based), custom hardware, re-configurable hardware etc. and combinations thereof
2. Alternative algorithmic implementations

- Algorithmic and physical implementation differ significantly in relevant characteristics like power consumption, performance etc.

Core components

- <u>Swap Power Manager</u>: Determines which of multiple task implementations is active and which state that task should assume (see fig below)
- <u>Swap Scheduler</u>: Determines a low power schedule for the swapping process considering partial overlaps, swap process time etc.
- <u>Swap Execution</u>: Seamless swapping of diverse (physical, algorithmic) implementations

“Swapping-on-the-fly” components are located between organic middleware and organic reconfigurable fabric



	Power States	Implementation ‘’			
		S”	O”	R”	W”
Implementation ‘	S’	(x)	(x)	x	x
	O’	(x)	(x)	x	x
	R’	x	x	-	-
	W’	x	x	-	-

Sub-Project "Monitoring"
(Prof. Karl)

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Monitoring Approach

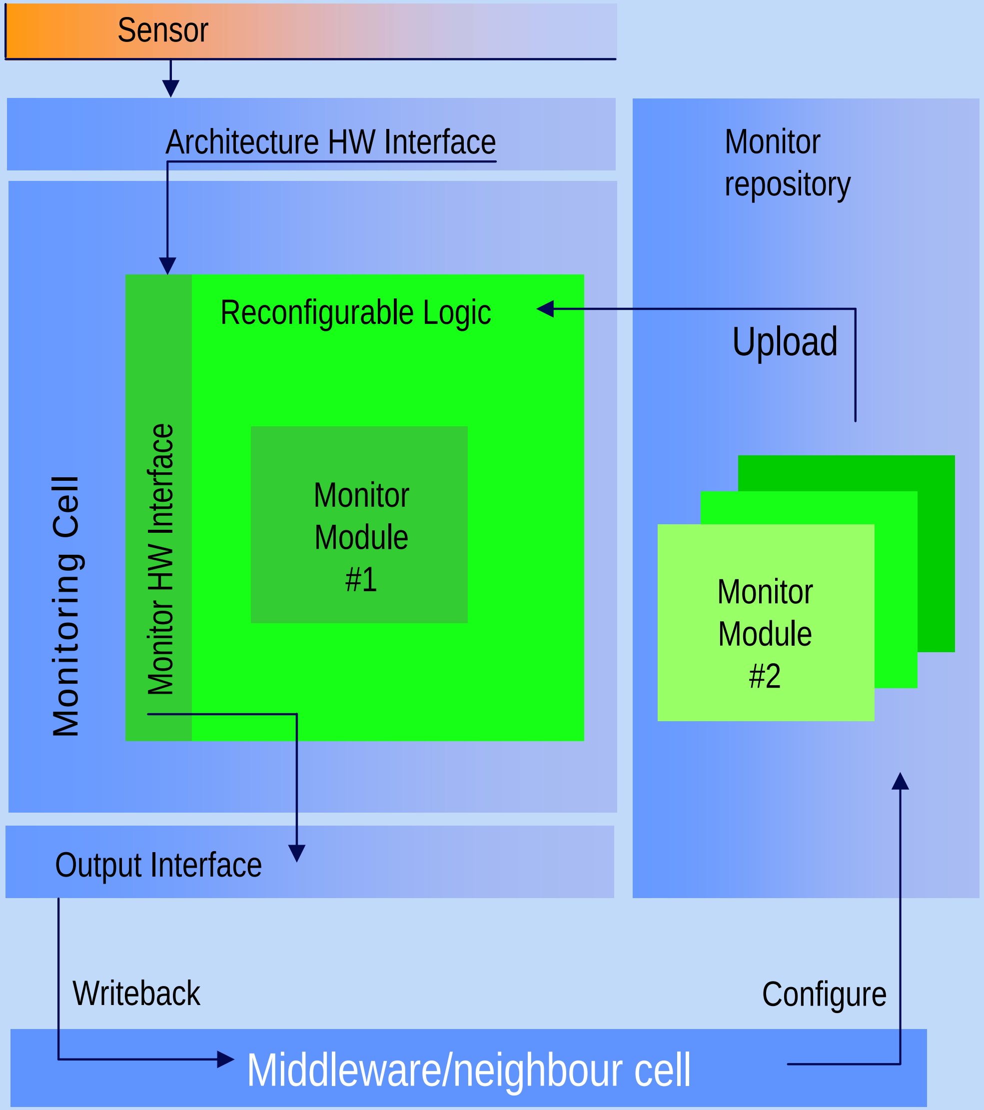
A generic and standardized monitoring cell capable of holding an adaptable, reconfigurable monitoring device

Domain-specific Monitor Analysis Modules

- To be loaded into the cells
- Extract, process, and store system status at its source
- Generate all information needed by the middleware to conclude a more reasonable configuration

Correlation of monitoring information from several sources to assemble global system state

A standardized API to query monitoring information across monitoring cells



Sub-Project “Monitoring”
(Prof. Karl)

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Monitoring Challenges

- Reconfigurability and adaptability of the monitoring itself
- Ability to hold any signals and to process status information at all levels and from all components of the system
- Efficient processing of raw data, at the data source
- Presentation of a single API
  - Allowing the middleware to access any system performance data

Monitoring Framework

- Wide and uniform base for access to monitoring information
- Efficient data pre-processing
- Correlation in space and time
- Problem-specific data aggregation

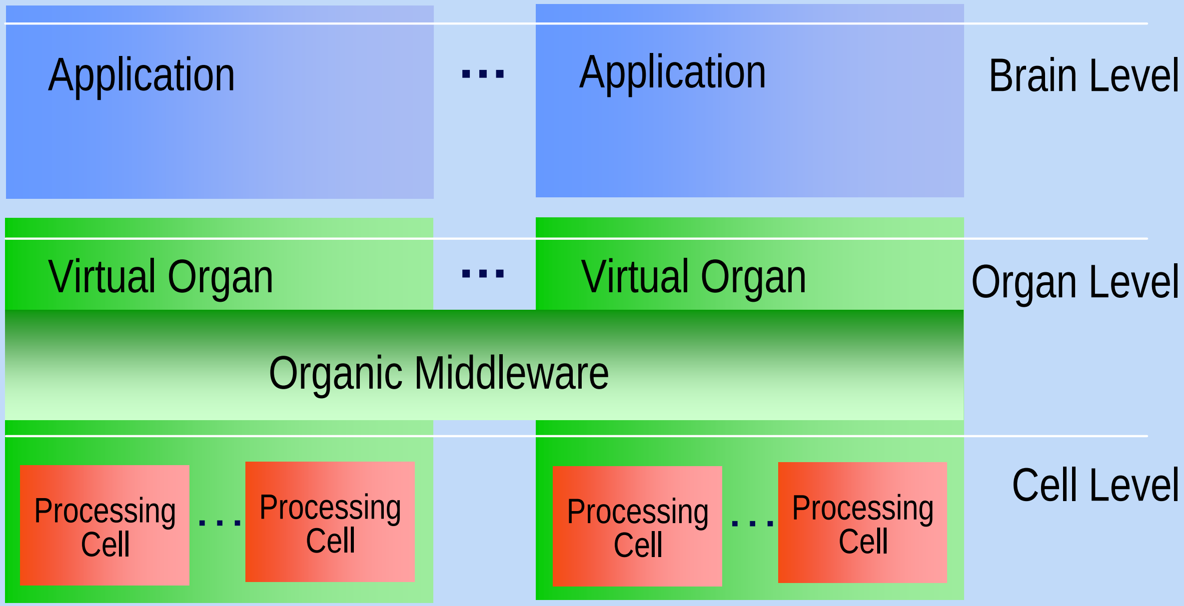
Interaction between single processing cells is coordinated by organic middleware

- ▶ The organic middleware forms virtual organs in this way.

Since there are **continuous modifications** in the system (by the environment and also by the brain level), the organic middleware must have the possibility to interfere in the system at each point of time (configuration, optimization).

▶ The organic middleware implements control loops, which fulfill these functionalities.

▶ There are de-central control loops to compensate the failing of single components and to ensure continued operation of the whole system.



Sub-Project "Organic Robot Control" (Prof. Wörn)

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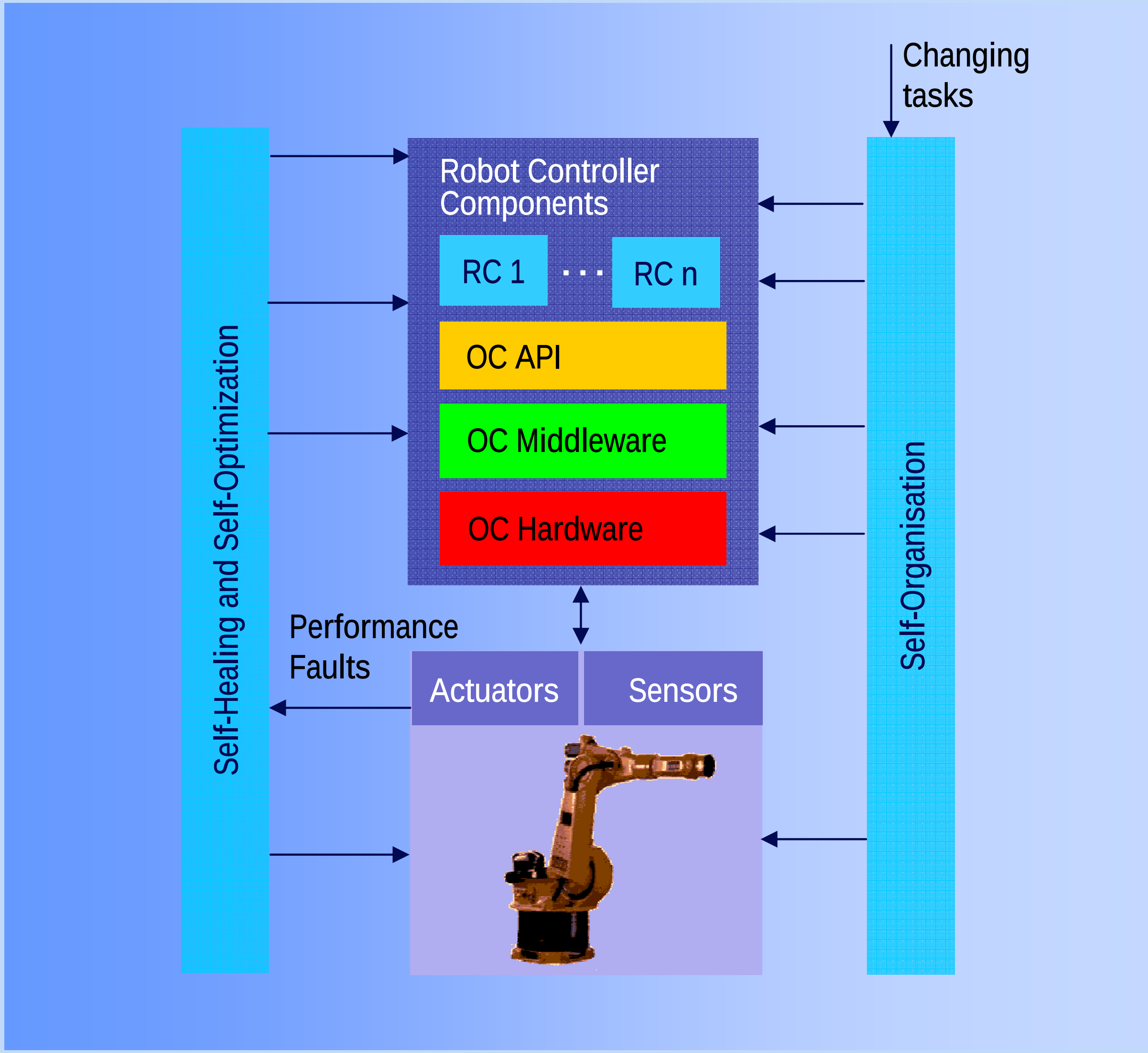
Monolithically structured robot controls can only be adapted and enhanced with high efforts

Frequent reconfiguration in factory automation necessary

- Short product life cycles, mass customization
- Flexibility when material and resource bottlenecks occur
- High availability, fault tolerance

Research approach

- Self-configuration and self-organization based on knowledge and on rules
- Component-based architecture
- Extensibility and interchangeability of components from different vendors (plug and work)



Sub-Project "Organic Robot Control" – "Organic Robot Swarm" (Prof. Wörn)

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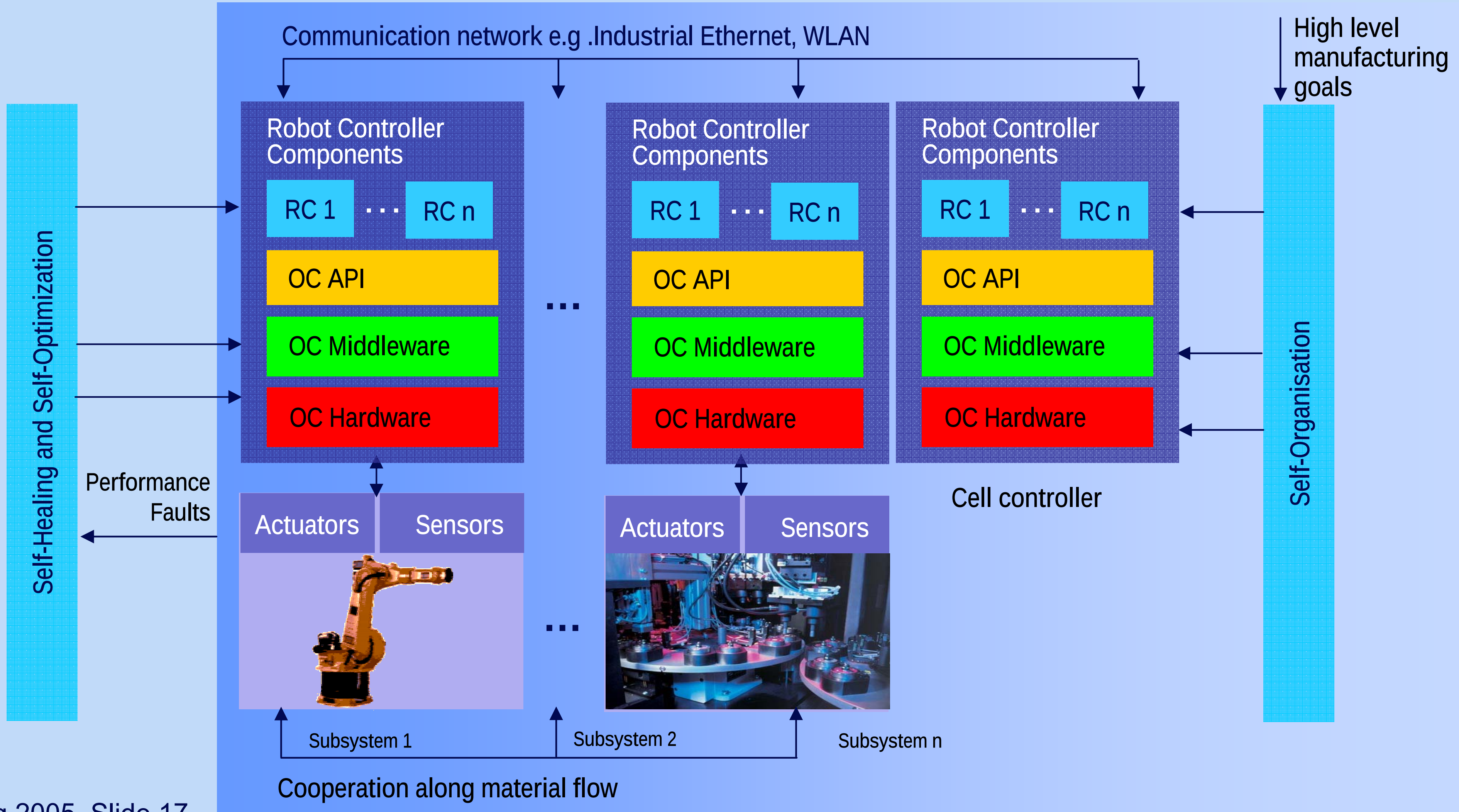
Development of swarm strategies and models for cooperating robots
(will be done in a later phase of the project)



Conclusion and Outlook

Heart as a model to learn from

- Hierarchical approach
- Cross-hierarchy features
- Neural control

Comprehensive project comprising hardware, middleware and application

- Multiple cells with common interface allow for basic self-healing/self-(re)configuration
- Low-power swapping and scheduling techniques for optimal resource usage
- Middleware shows emergent behavior through accelerator/suppressor concept
- Monitoring ensures system stability on all levels
- Application demonstrates feasibility for large-scale real-world examples

Research challenges

- Self-x and predictable behavior
- Ease observation of emergent behavior through adaptive monitoring
- Adaptation towards varying power/performance constraints
- Common interface/protocol specification
- Decentralized control loops
- Use digital organisms to control robots/robot swarms