

# Limitations

Below is a necessarily incomplete list of current limitations of Morpheus. Many of these are on our to-do list or under development.

## Lattice

Morpheus uses regular lattice discretization for all spatial processes. It does not support irregular lattices of continuous space models.

## Solvers

The solvers in Morpheus use finite difference schemes with fixed time-steps. Adaptive time-stepping schemes are not available. It does not support solving of stiff ODE systems.

## PDE

Morpheus can simulate reaction-diffusion systems, but does not support processes that depend on higher-order derivatives such as advection or chemotaxis.

## Cell motility

Morpheus supports the [cellular Potts model](#) to represent cell shape, motility and adhesion. Depending on the scale at which cell-based models are used, motility of cells may be more suitably modeled in more parsimonious formalisms, such as [interacting particle systems](#). These are currently not available in Morpheus.

## Extensibility

Morpheus is an extensible framework and provides a [plugin interface](#) to extend its features. However, this requires building from source, which is currently restricted to developers and collaborators. Therefore, in its current distribution as an application (binaries), extensibility is not supported.

## Performance

Morpheus heavily relies on [muparser](#) for parsing mathematical expressions. Although this provides fast parsing by translating into bytecode, its performance cannot compete with compiled C++ code. Thus, the flexibility gained by using parsed expression invokes a penalty on computational performance. The amount of penalty depends on the number and complexity of parsed expressions and is highly model-dependent. Therefore, in some cases, Morpheus may not be best-suited for large-scale simulations.

See the results of [performance and scalability](#) tests for more detailed and quantitative information.

## Parallelization

Morpheus uses [openMP](#) multithreading to concurrently execute several data-parallel processes. For instance, intracellular ODEs are computed concurrently for each cell, and the reaction-step in PDEs are computed concurrently per y-line. Although this is a good first approximation, it does not fully exploit parallel computing. Scalability therefore heavily depends on the specific simulation model. CPM (sub)models, for instance, are not parallelized.

See the results of [performance and scalability](#) tests for more detailed and quantitative information.

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