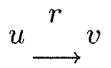
Appendix
An Overview of the Botany Knowledge Base

This appendix presents the top-level representations of objects and processes and the skeleton of the Botany Knowledge Base. Much of the detail has been omitted and some of the information on the charts is not current.

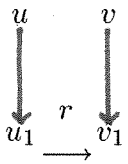
Each chart in this appendix is a network representation of knowledge about a topic in botany. A node represents either a class of objects (depicted with a box) or a class of events (depicted with an an oval). An arc represents a relation between two nodes. For example, **Flower** and **PhotosynthesisEvent** are nodes and **has-part** and **sub-event** are relations. Every node and arc in the network corresponds to a frame in the Botany Knowledge Base.

On our charts, we have adopted a few short-hand conventions. First, all arcs are directed. If the direction is not explicit then the direction is top to bottom, and left to right.

Second, although each node corresponds to a class, an arc between two nodes does *not* state a relation between the classes. Rather, the arc means that *instances* of the classes are related. Pictorially, the general form:



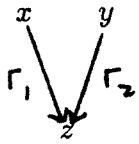
is a short-hand for:



With this convention, the classes correspond to the domain and range of the relation. The only exceptions to this convention are the relations **specialization** and **generalization** that relate classes rather than instances.

Third, if two classes are related by the **stage** relation (*e.g.,* a **seedling** is a **stage** of a **plant**) then the classes are related by **specialization** and **generalization** (*e.g.,* **seedling** is a specialization of **plant**) and the **stage** relation applies to instances of the classes.

Fourth, an important class of constraints is represented with two arcs pointing to the same node. For example:



means that the same instance of the class z must be related to an instance of x by r_1 and to an instance of y by r_2.

Finally, considerably more domain knowledge has been left off the charts than included. We omitted the:

- top-levels of the CYC knowledge base to which the Botany Knowledge Base is "attached."
- inverses of each relation.
- constraints (except domain and range) imposed on each relation.
- rules for computing or heuristically guessing values for some relations.
- relations among relations.
- qualitative values for some relations.
- changes to actors in events.
- criterial differences between pairs of classes.
- temporal relations among the sub-events of an event.

We have included some additional detail on two charts:

- Growth (Complete) – page 46 – an extension of the Growth chart.
- BLT Assimilate Assimilation (Complete) – page 69 – an extension of the BLT Assimilate Assimilation chart.

These charts provide some of the detail in the Botany Knowledge Base that has been omitted from the other charts.

Each chart represents a limited perspective of objects and events. For example, one chart gives partonomic information about flowers, while another gives developmental information about the same objects. A comprehensive view of the representation of each object requires combining perspectives across the charts.

Outline of the Botany Knowledge Base

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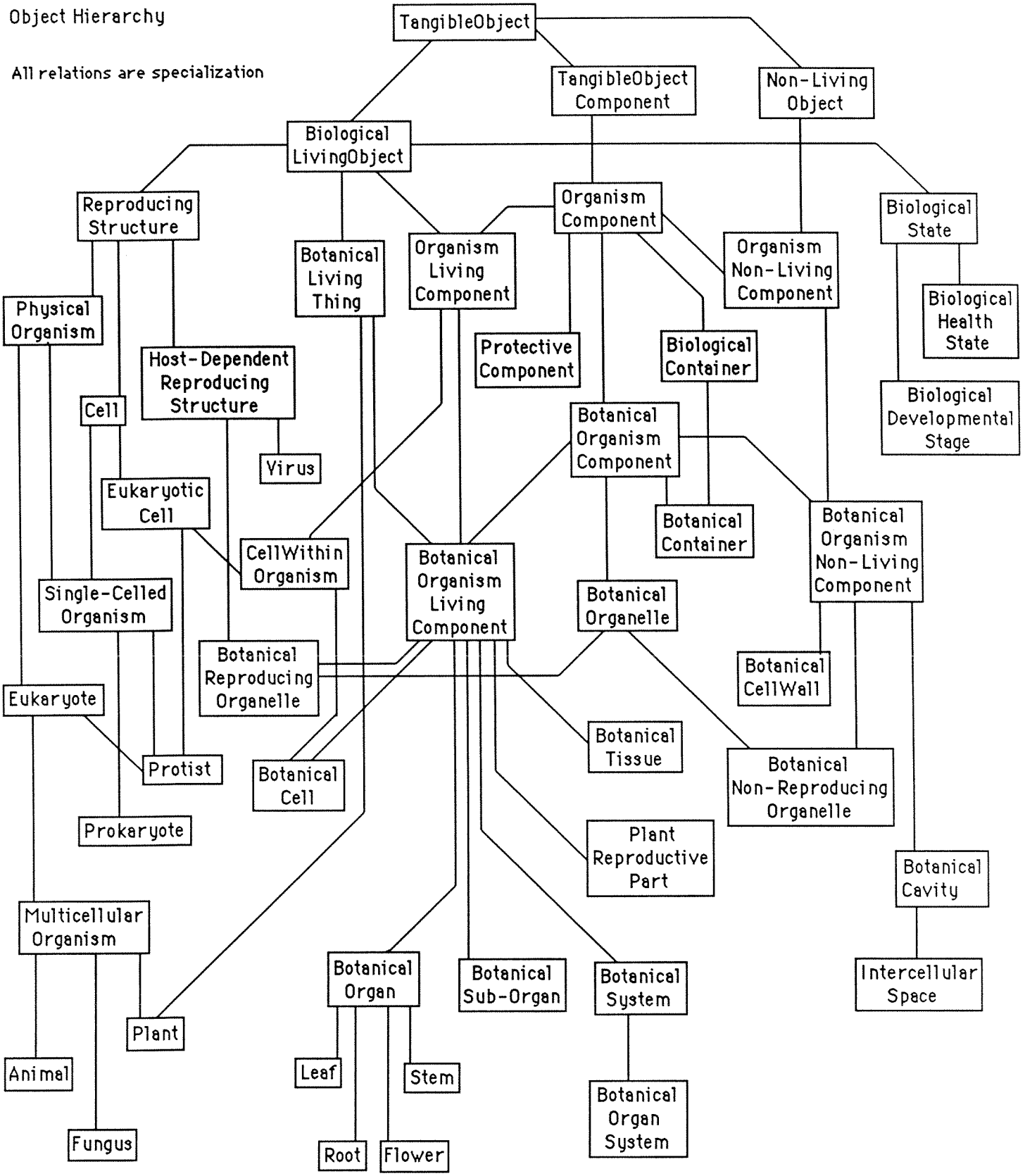
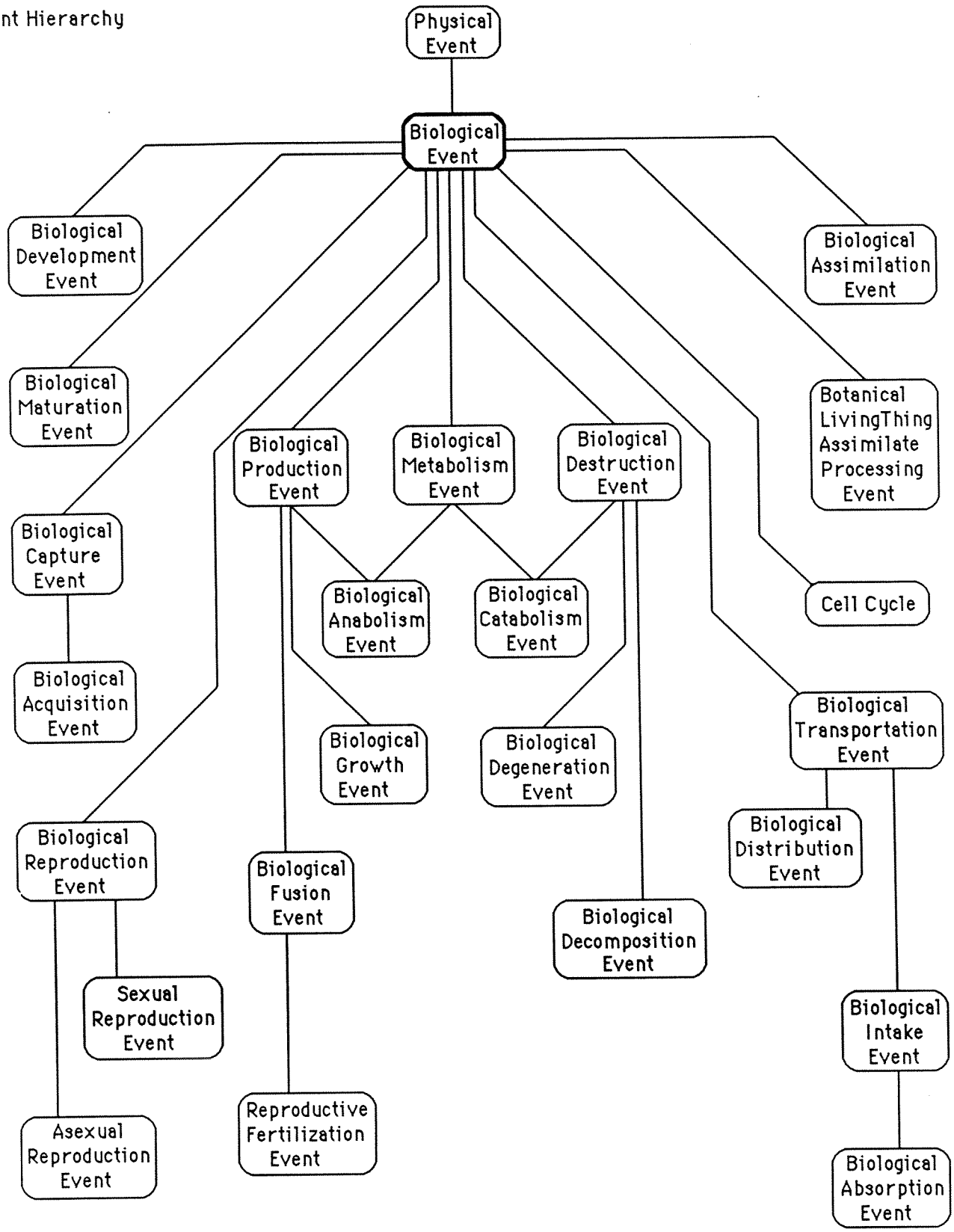
Chloroplast Light Energy Assimilation 71
Chloroplast ATP Assimilation 72
Chloroplast Small Sugar Assimilation 73
Seed Small Sugar Assimilation 74
BLT Photosynthesis 75
Chloroplast Photosynthesis 76


Object Hierarchy
All relations are specialization
TangibleObject
TangibleObject Component
Non-Living Object
Biological LivingObject
Reproducing Structure
Organism Component
Biological State
Botanical Living Thing
Organism Living Component
Organism Non-Living Component
Physical Organism
Biological Health State
Protective Component
Biological Container
Host-Dependent Reproducing Structure
Cell
Botanical Organism Component
Biological Developmental Stage
Virus
Eukaryotic Cell
Botanical Container
Botanical Organism Non-Living Component
CellWithin Organism
Botanical Organism Living Component
Botanical Organelle
Single-Celled Organism
Botanical Reproducing Organelle
Botanical CellWall
Eukaryote
Botanical Tissue
Botanical Non-Reproducing Organelle
Protist
Botanical Cell
Prokaryote
Plant Reproductive Part
Botanical Cavity
Multicellular Organism
Botanical Organ
Botanical Sub-Organ
Botanical System
Intercellular Space
Plant
Animal
Leaf
Stem
Botanical Organ System
Fungus
Root
Flower

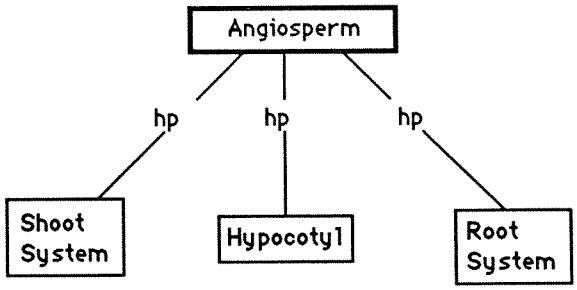
Event Hierarchy

All relations are specialization

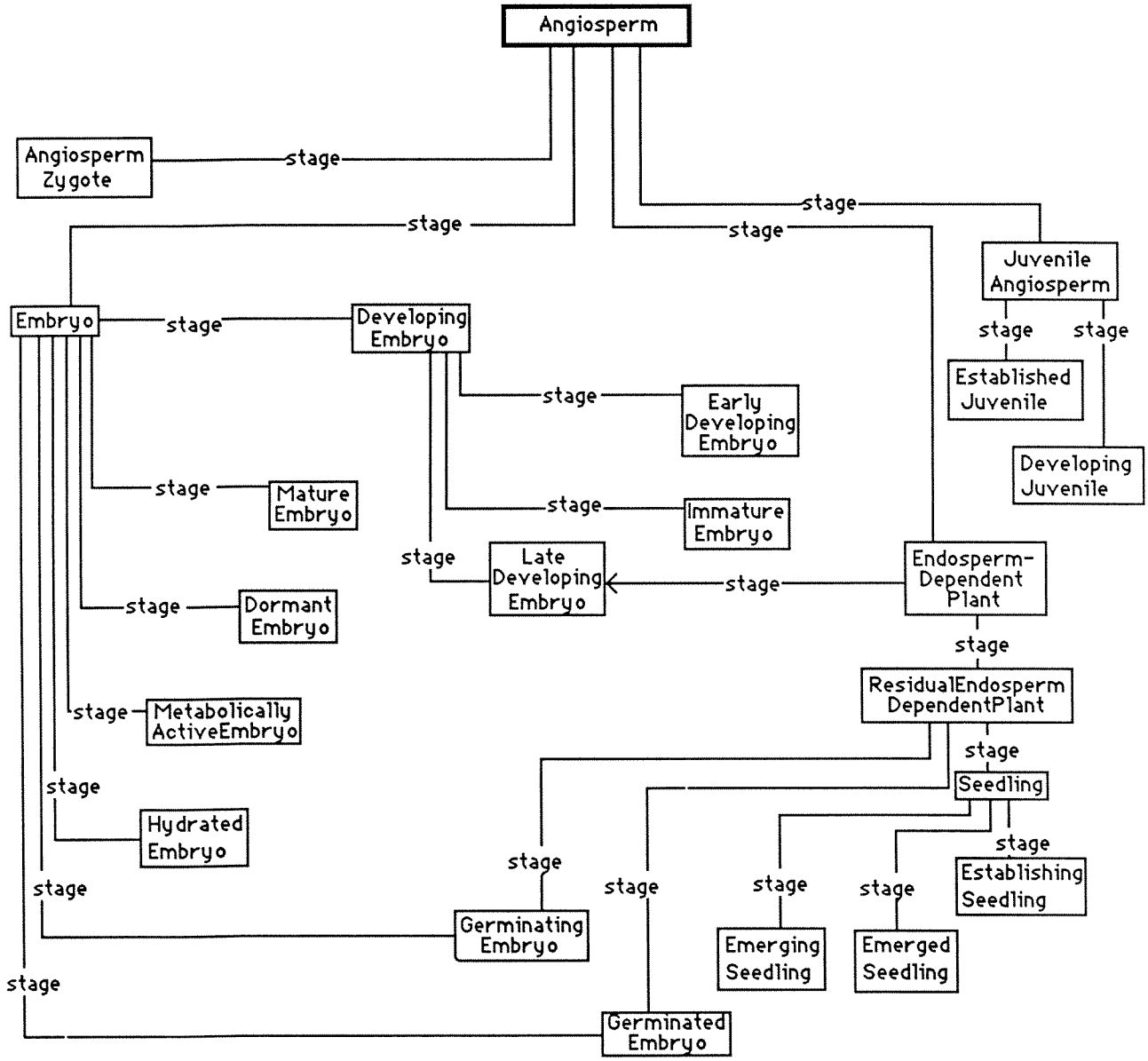


Angiosperm Parts

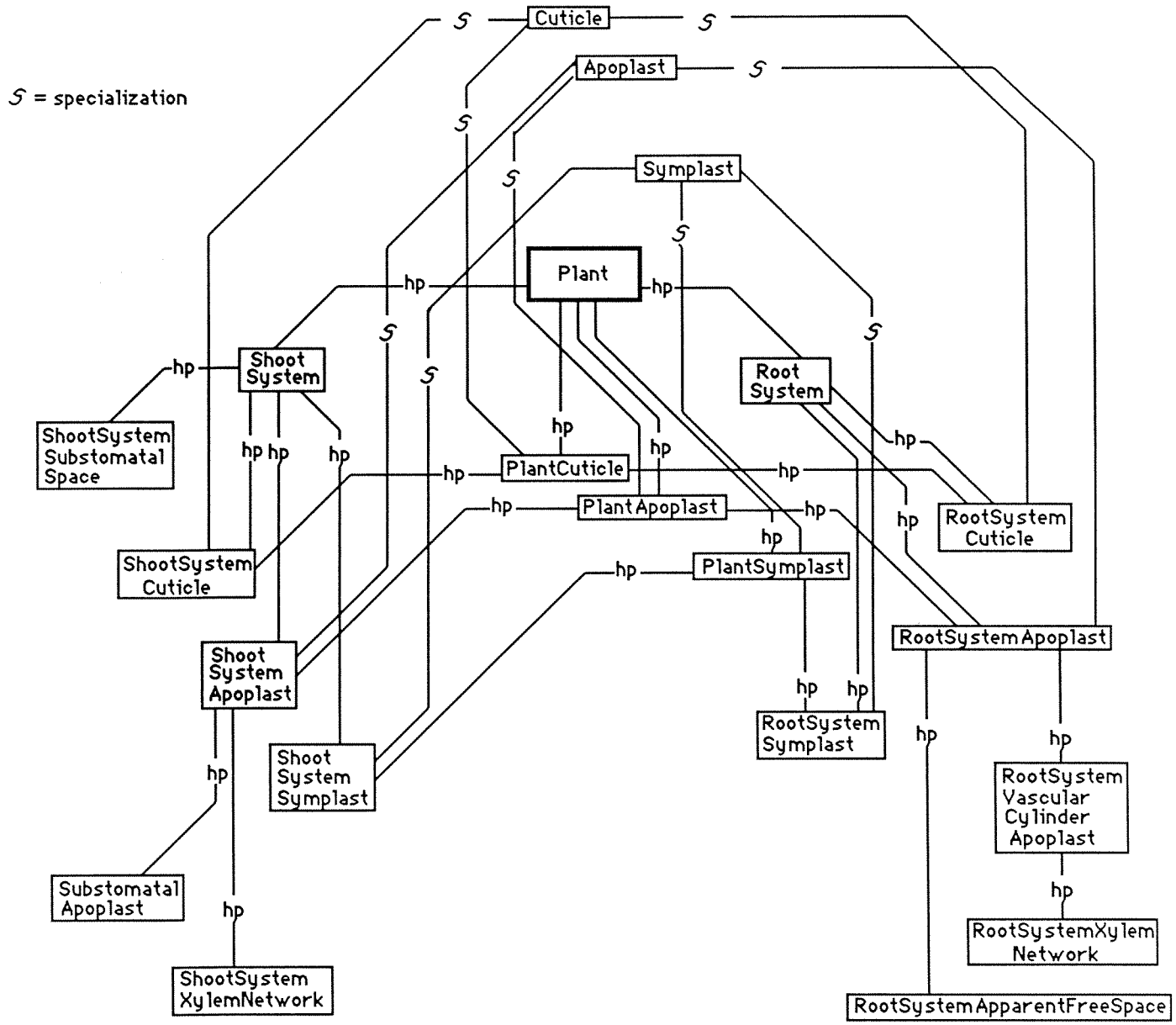
hp = hasPart



Angiosperm Stages



Plant Composition
Cuticle, Apoplast, Symplast

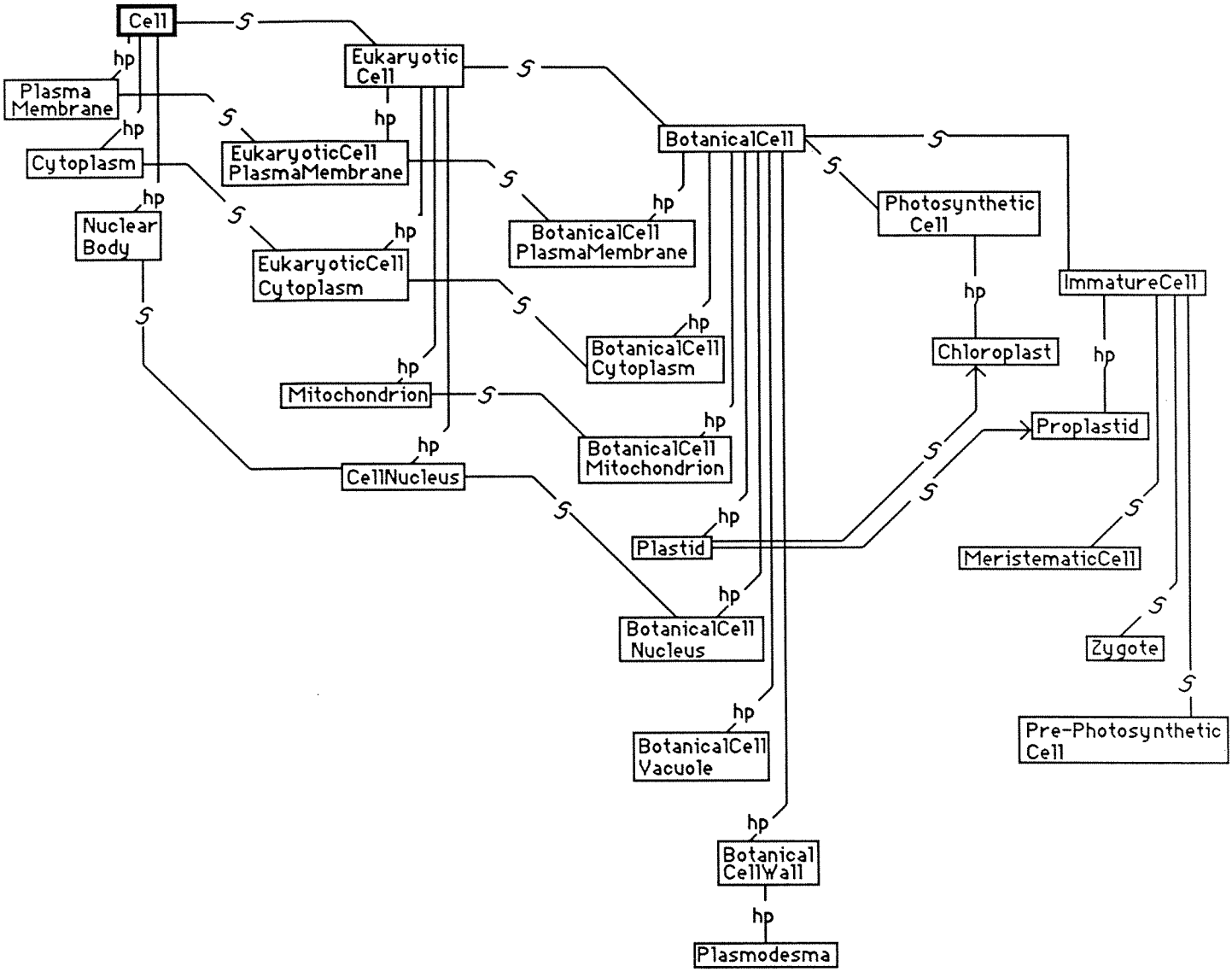


Abstract

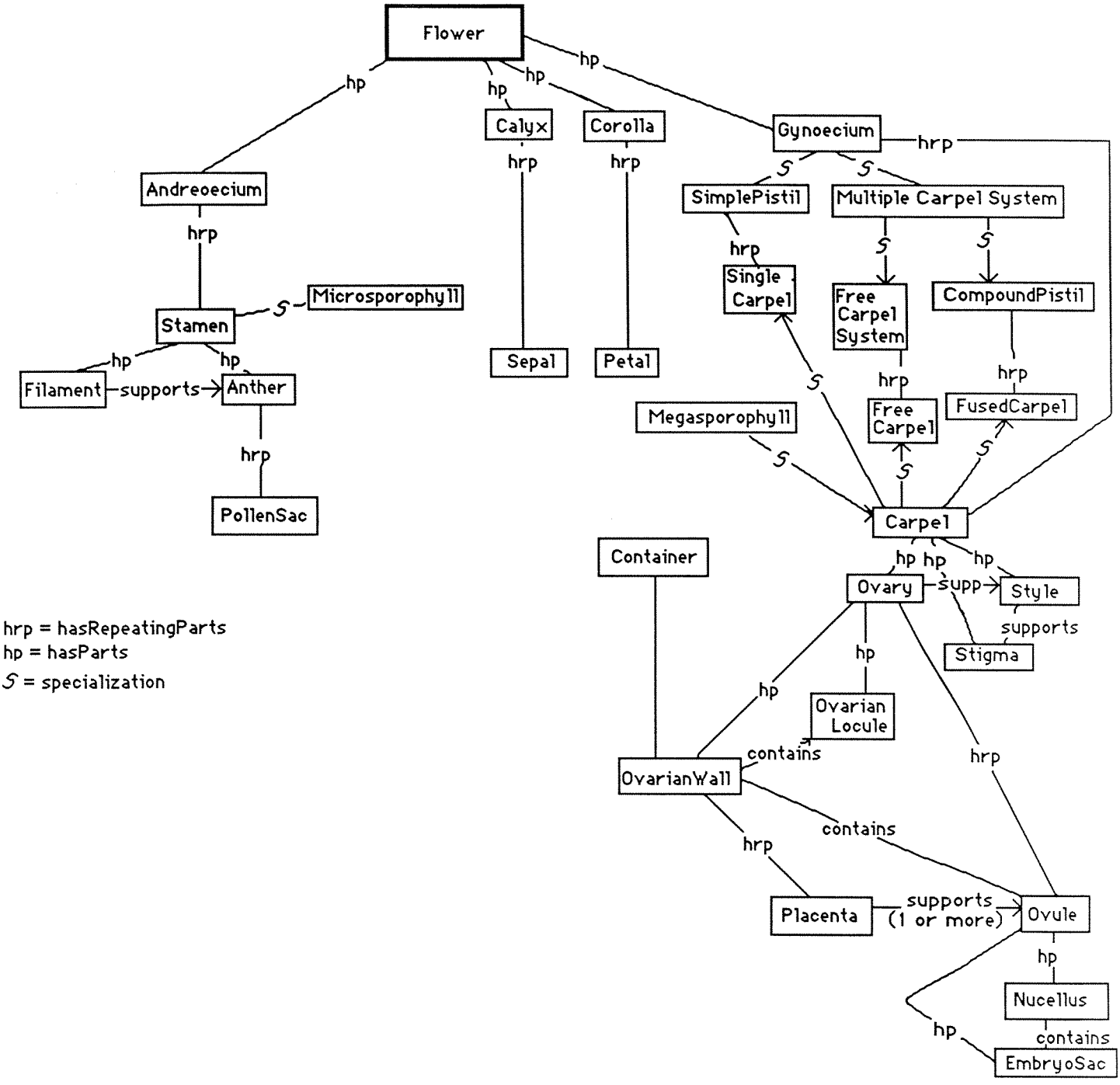
Our research applies a large-scale, multifunctional knowledge base to significant AI problems. The knowledge base encodes commonsense and expert knowledge of botany, in particular, anatomy, physiology, and development. To convey the scope of the knowledge base, we present the top-level representations of objects and processes as well as the skeletal diagramming of the knowledge base. The first applications of the Botany Knowledge Base are machine learning and tutoring. The goal of our learning research is to develop and evaluate a computational model for a new learning task – knowledge integration. This task, which might be termed "learning at the fringes of a knowledge base," involves the incorporation of new information into existing knowledge. The goal of our intelligent tutoring research is to develop knowledge representations and processes for dynamically revising teaching plans and tailoring explanations to the individual needs of a student. Our research is predicated on the knowledge principle that emphasizes the crucial role of extensive, task-independent knowledge in intelligence.

ell Parts

S = specialization

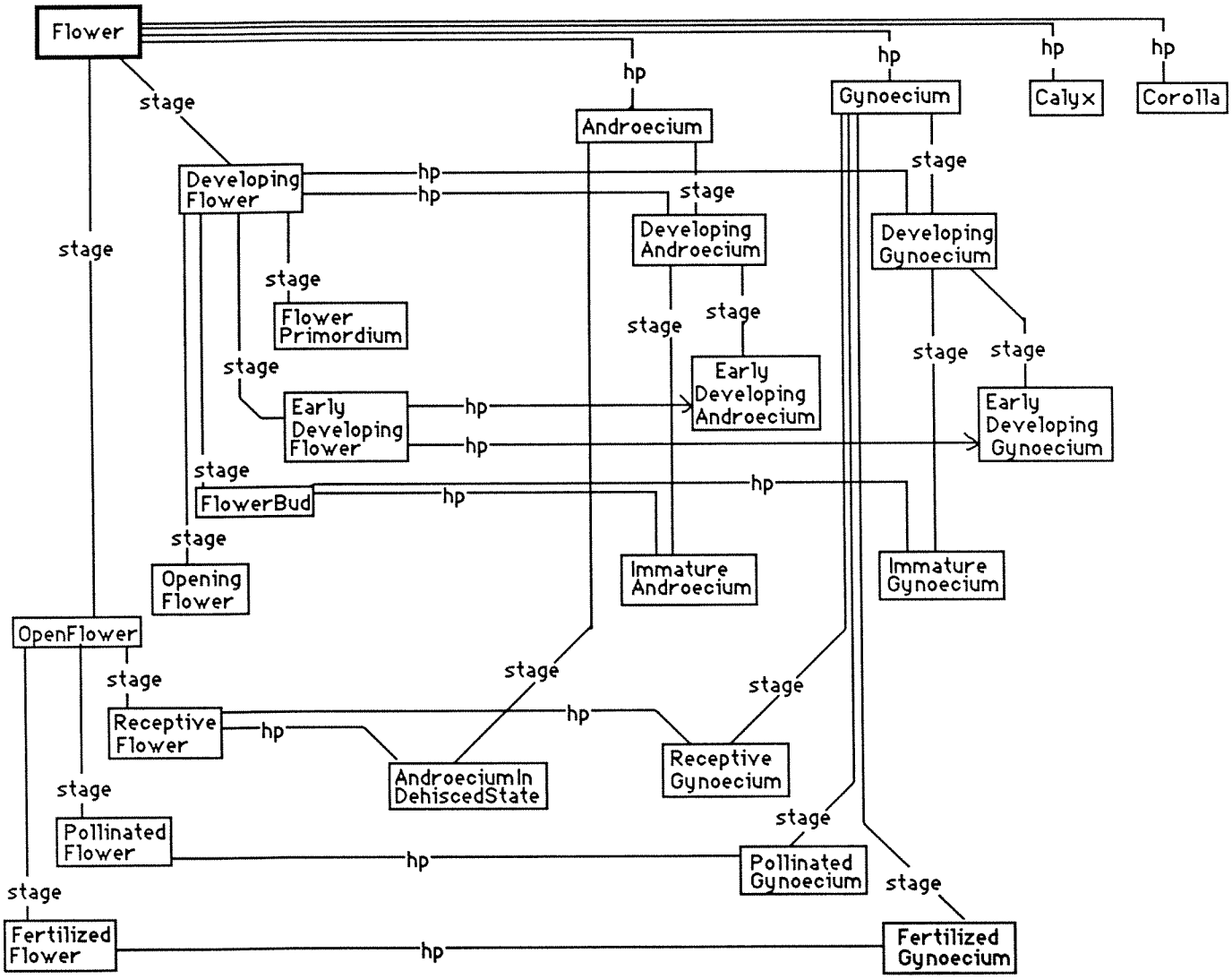


Flower
Parts



hrp = hasRepeatingParts
hp = hasParts
S = specialization

Flower Stages & Parts



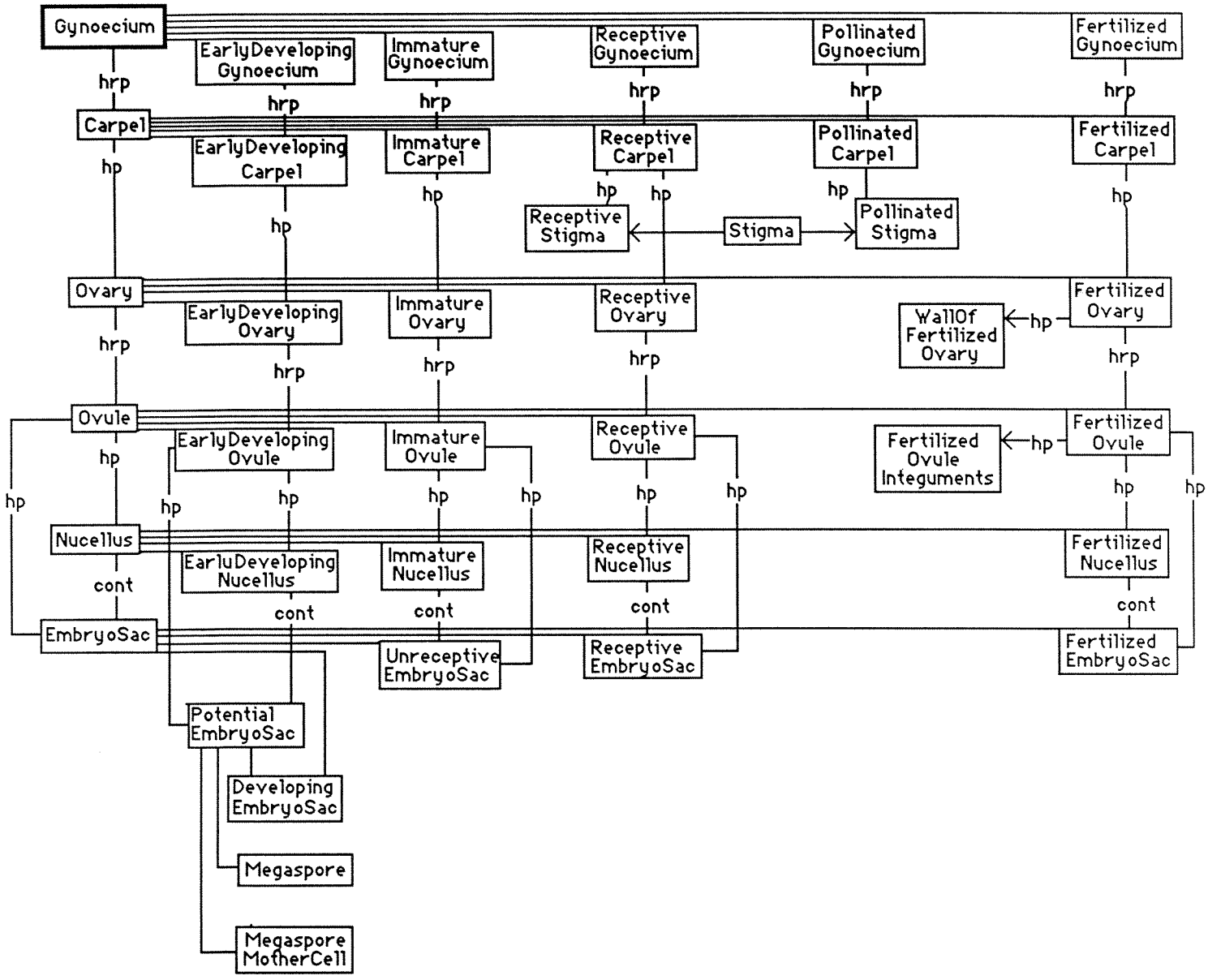
Gyoecium Stages

Unlabeled relationships= stage

hp= hasPart

hrp= hasRepeatingPart

cont=contains



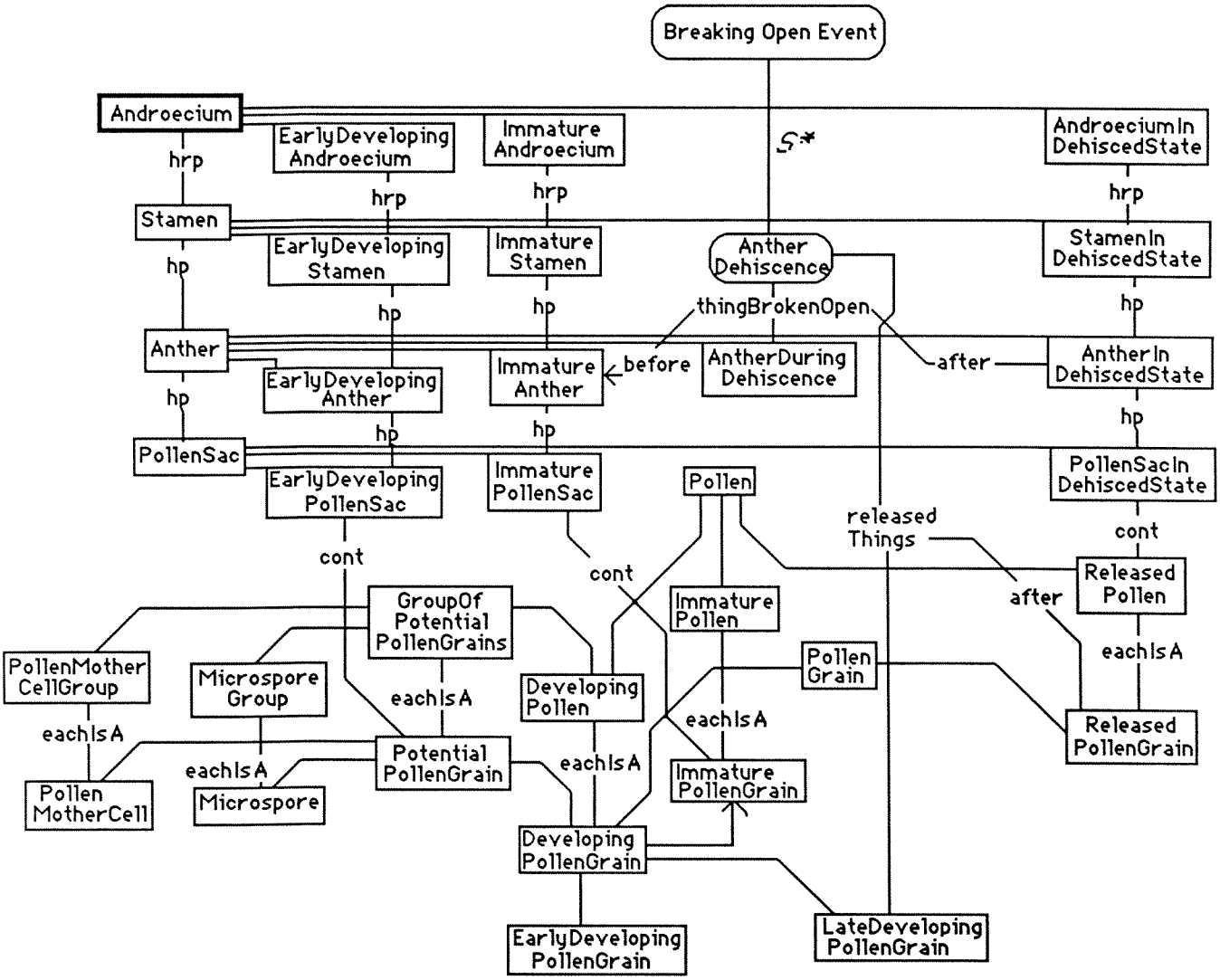
Androecium Stages

Unlabeled relationships= stage

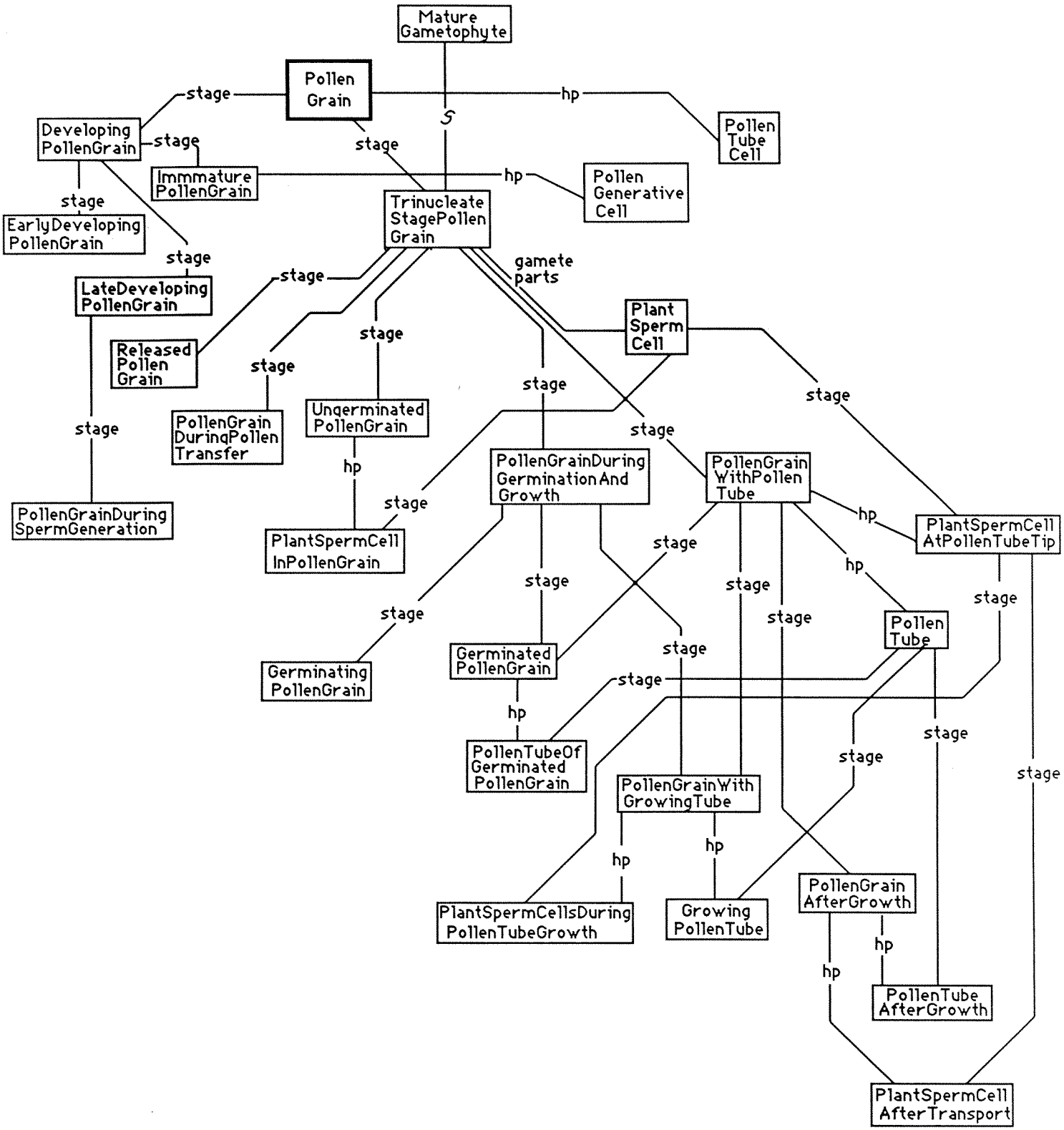
hp= hasPart

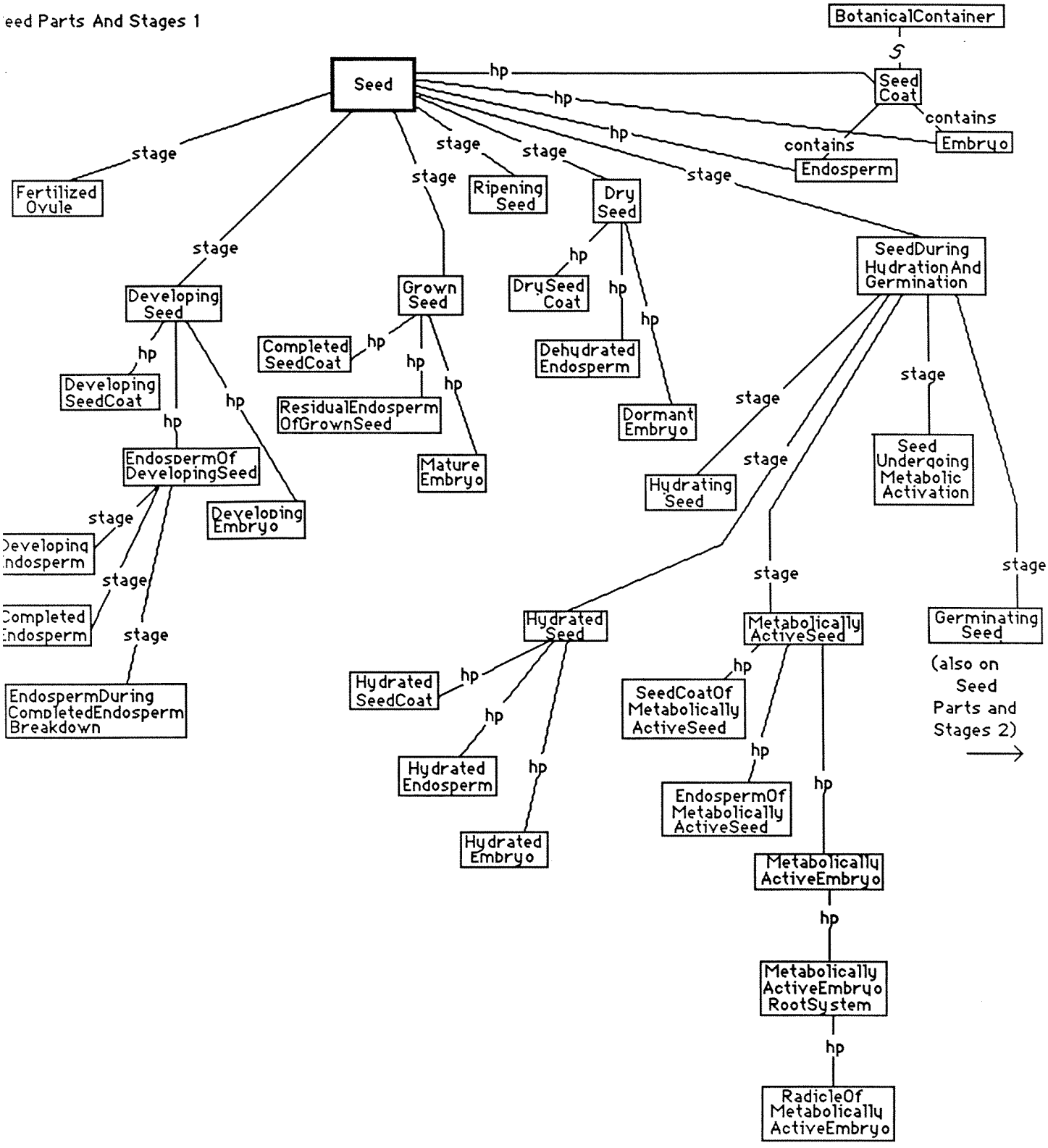
hrp= hasRepeatingPart

cont=contains

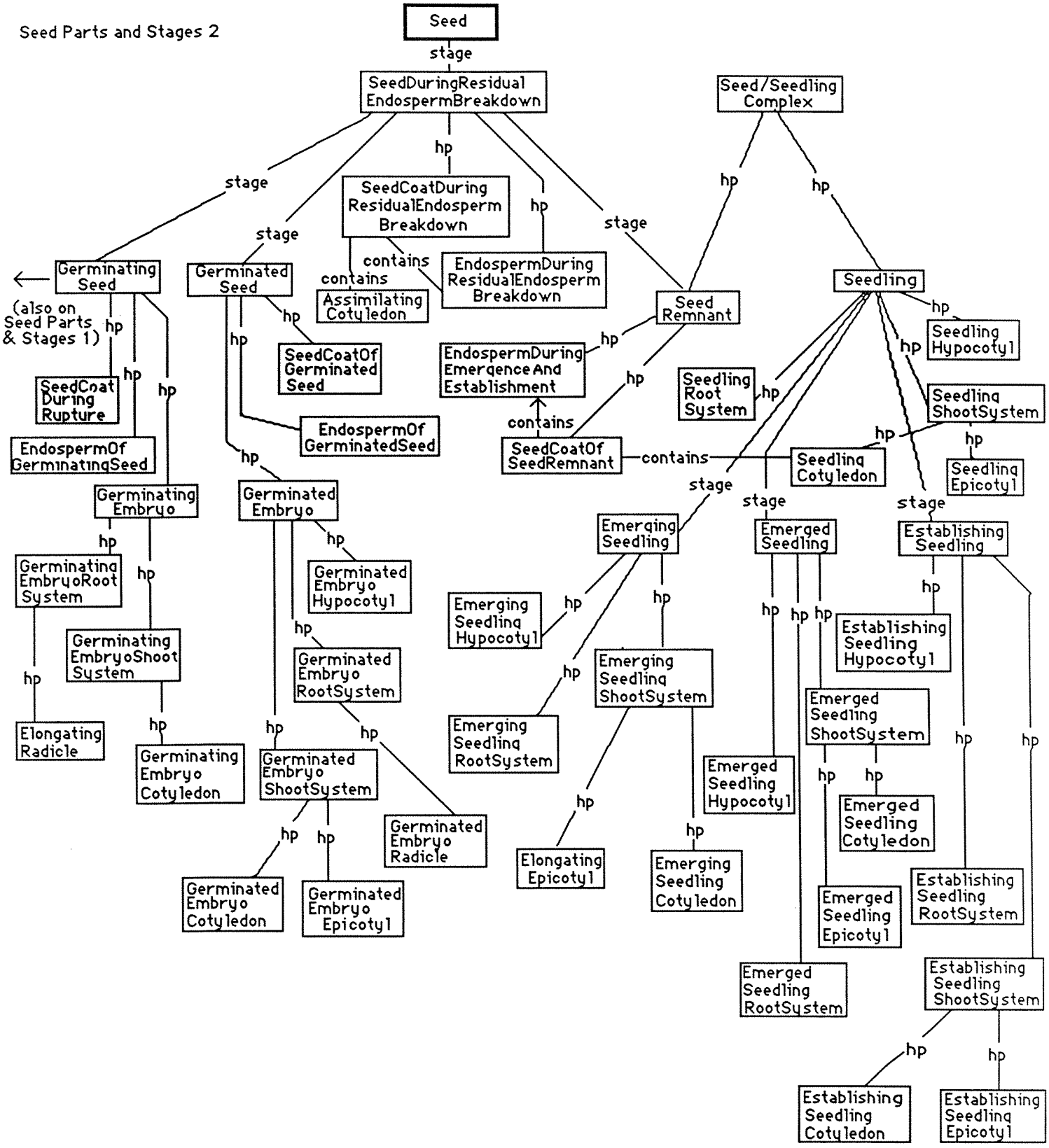


Pollen Grain Parts & Stages

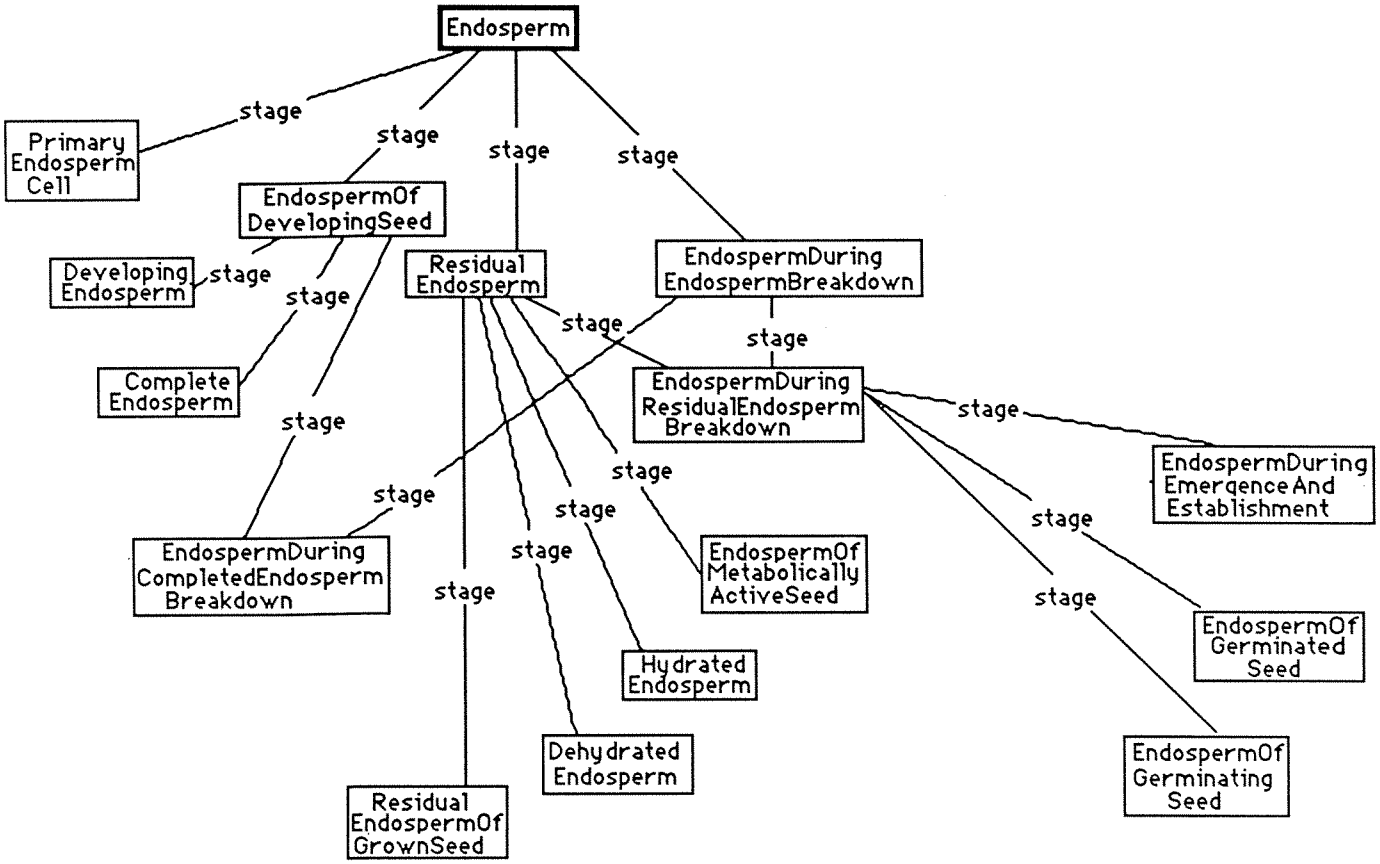



eed Parts And Stages 1
BotanicalContainer
S
Seed
Seed Coat
Embryo
Endosperm
Fertilized Ovule
Ripening Seed
Dry Seed
Developing Seed
Grown Seed
SeedDuring Hydration And Germination
DrySeed Coat
Dehydrated Endosperm
Dormant Embryo
Completed SeedCoat
ResidualEndosperm OfGrownSeed
Mature Embryo
Developing SeedCoat
EndospermOf DevelopingSeed
Developing Embryo
Developing Endosperm
Completed Endosperm
EndospermDuring CompletedEndosperm Breakdown
Hydrating Seed
Seed Undergoing Metabolic Activation
Germinating Seed
(also on Seed Parts and Stages 2)
Hydrated Seed
Metabolically ActiveSeed
Hydrated SeedCoat
Hydrated Endosperm
Hydrated Embryo
SeedCoatOf Metabolically ActiveSeed
EndospermOf Metabolically ActiveSeed
Metabolically ActiveEmbryo
Metabolically ActiveEmbryo RootSystem
RadicleOf Metabolically ActiveEmbryo
stage
hp
contains

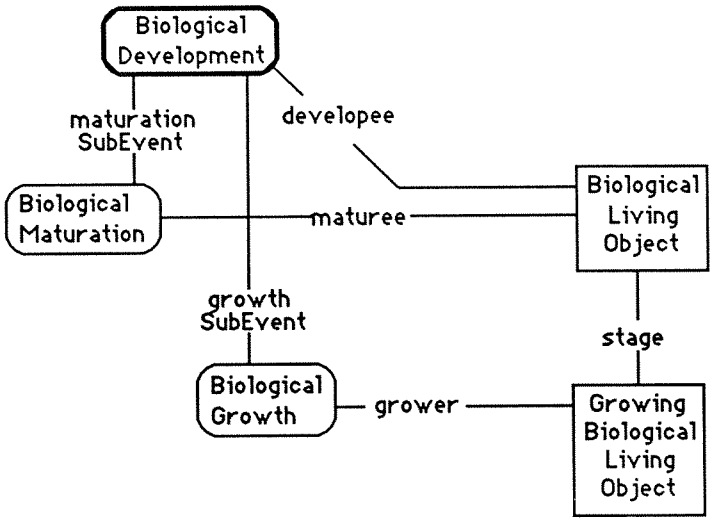
Seed Parts and Stages 2



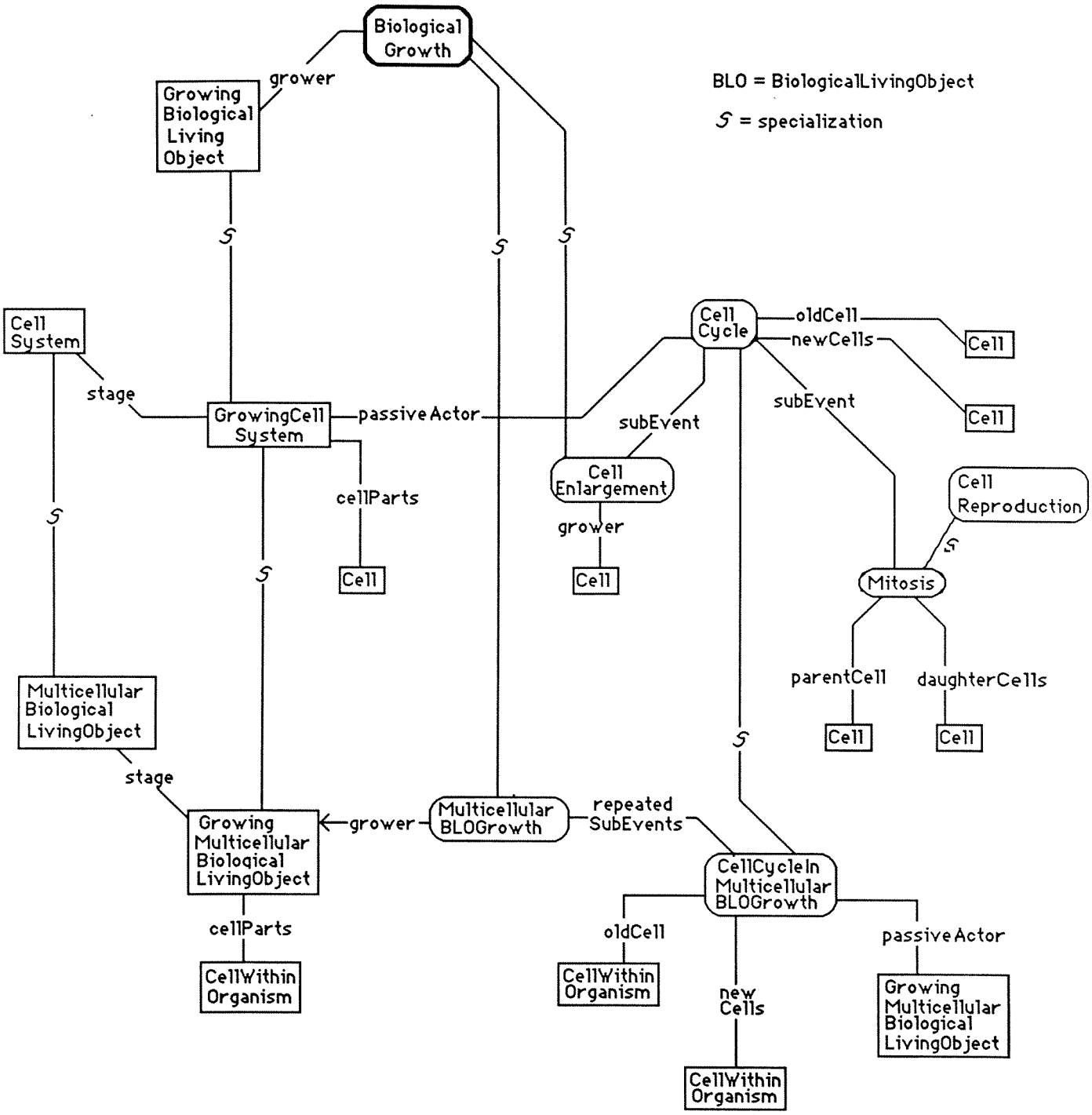
ıdosperm Stages



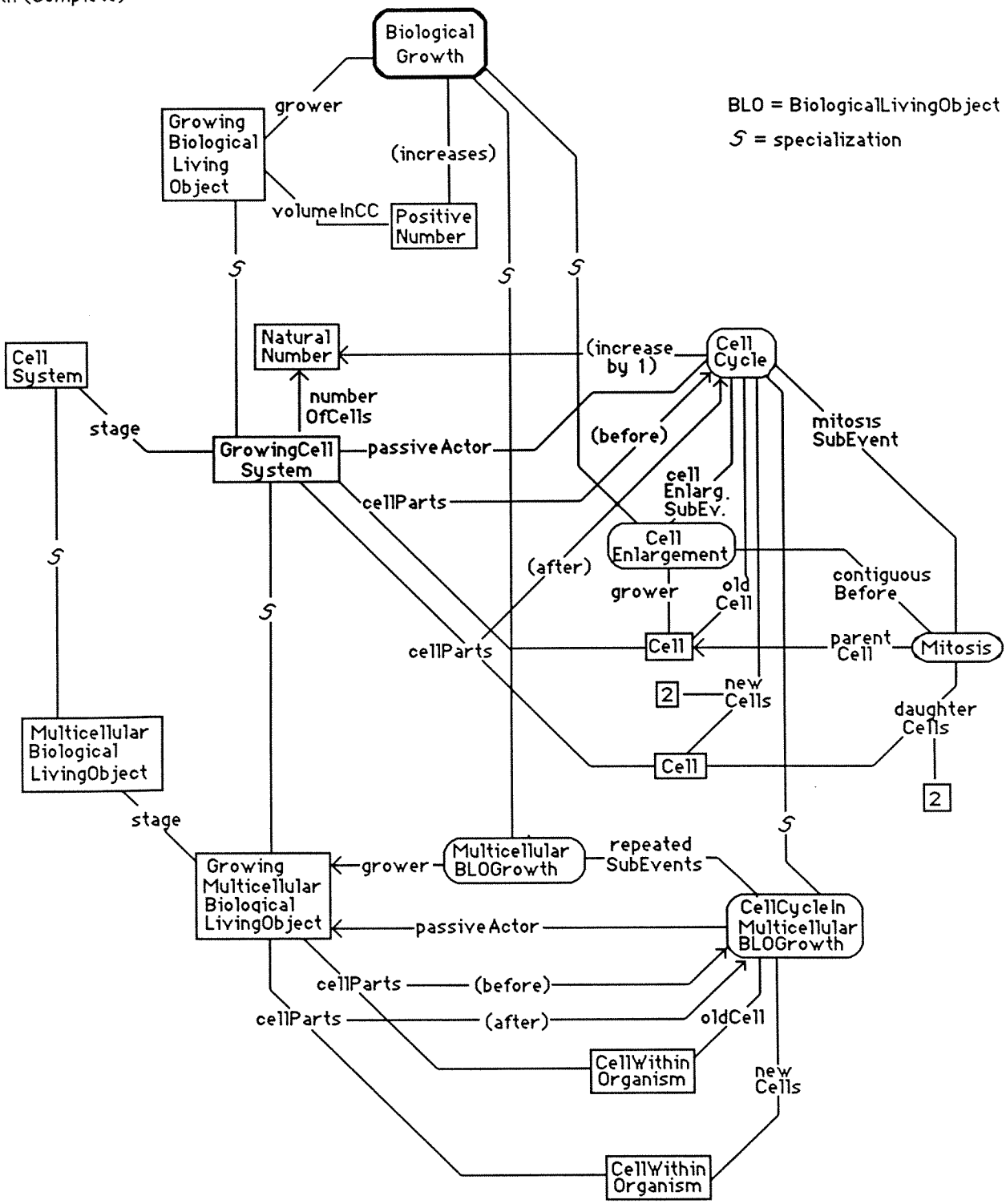
Development



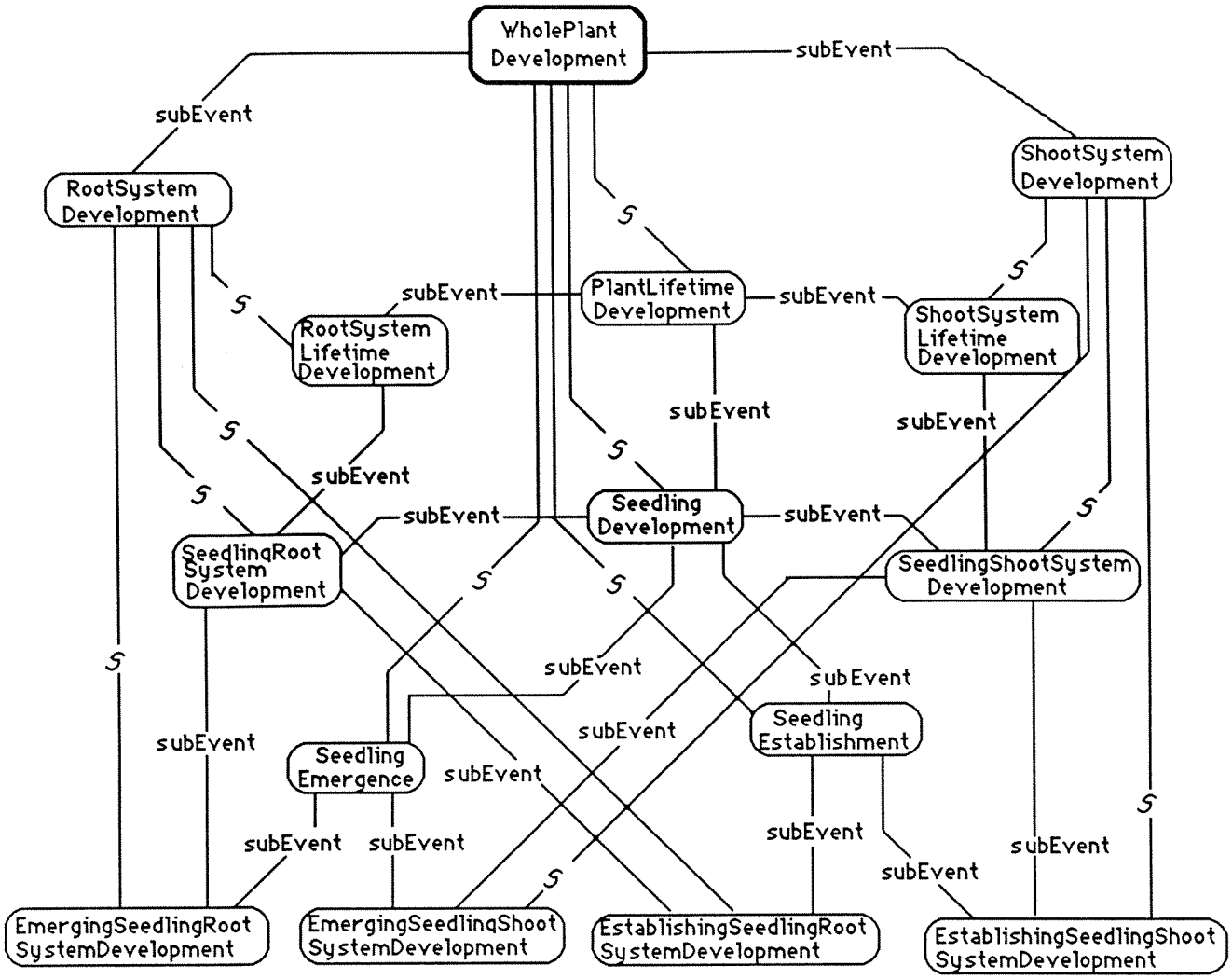
irowth


Biological Growth
grower
Growing Biological Living Object
BLO = BiologicalLivingObject
S = specialization
Cell System
stage
GrowingCell System
passiveActor
cellParts
Cell
Cell Cycle
oldCell
newCells
Cell
Cell
subEvent
subEvent
Cell Enlargement
grower
Cell
Cell Reproduction
Mitosis
parentCell
daughterCells
Cell
Cell
Multicellular Biological LivingObject
stage
Growing Multicellular Biological LivingObject
grower
Multicellular BLOGrowth
repeated SubEvents
CellCycleIn Multicellular BLOGrowth
cellParts
CellWithin Organism
oldCell
CellWithin Organism
new Cells
CellWithin Organism
passiveActor
Growing Multicellular Biological LivingObject

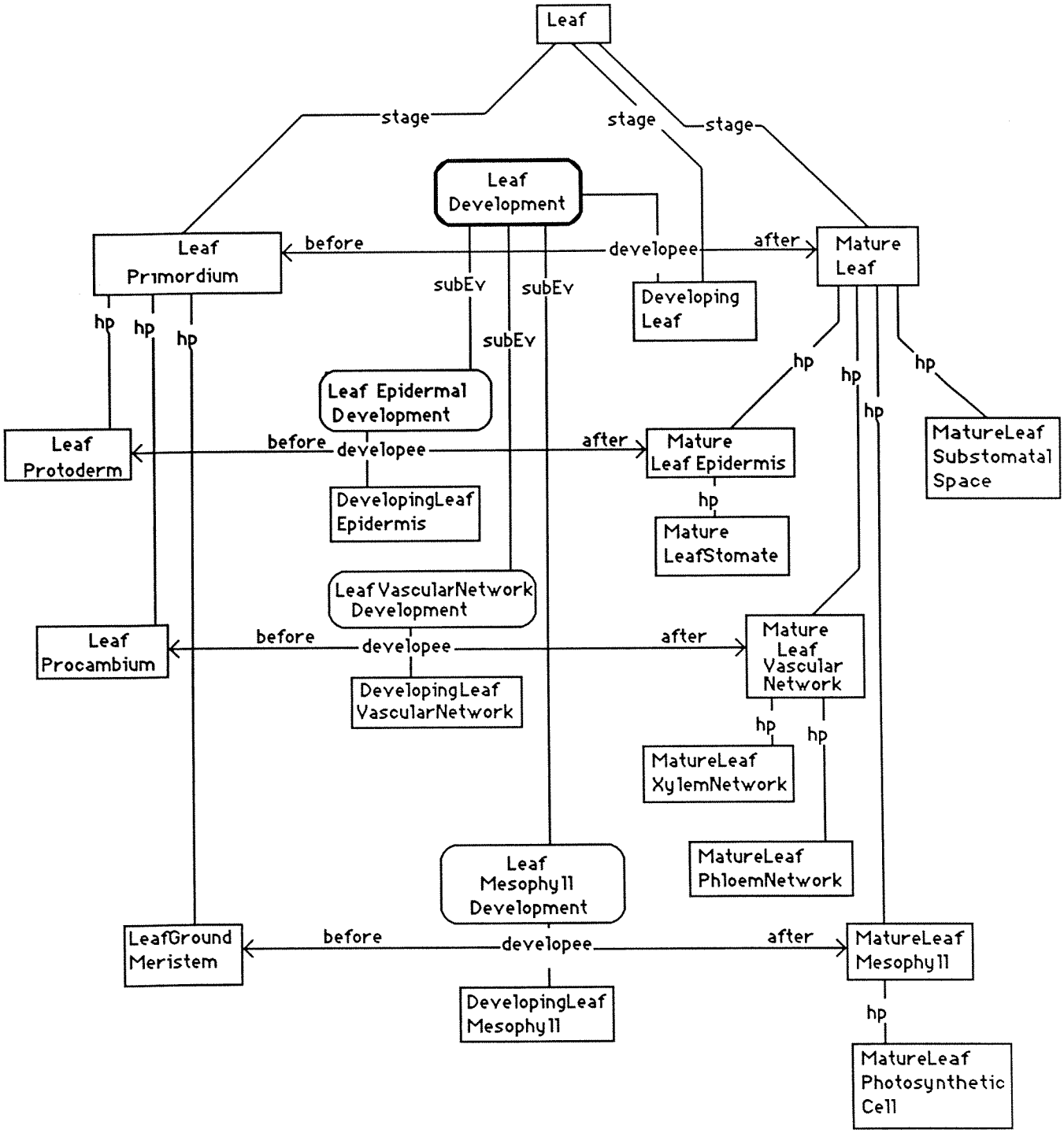
Growth (Complete)



Whole Plant Development

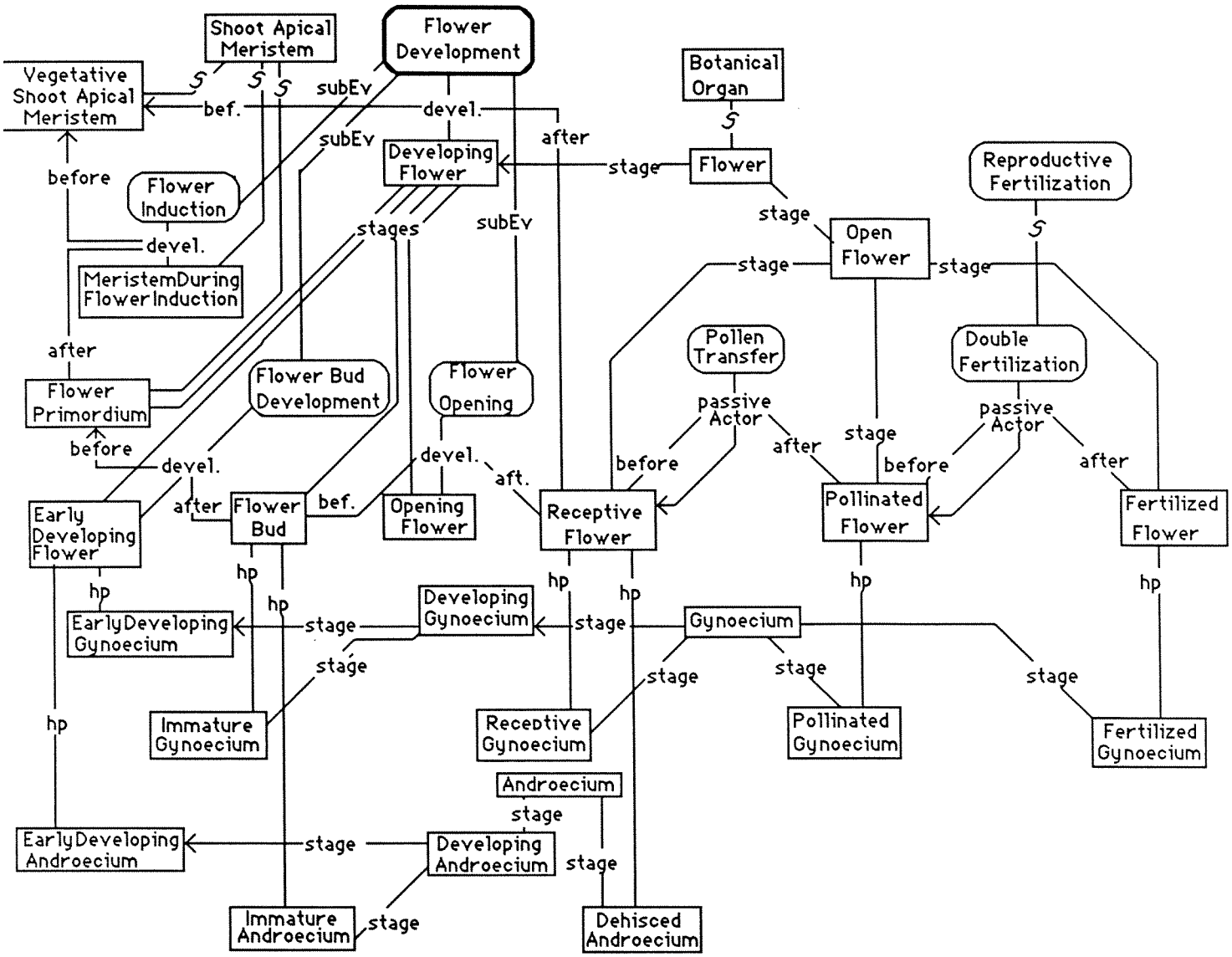


S = specialization

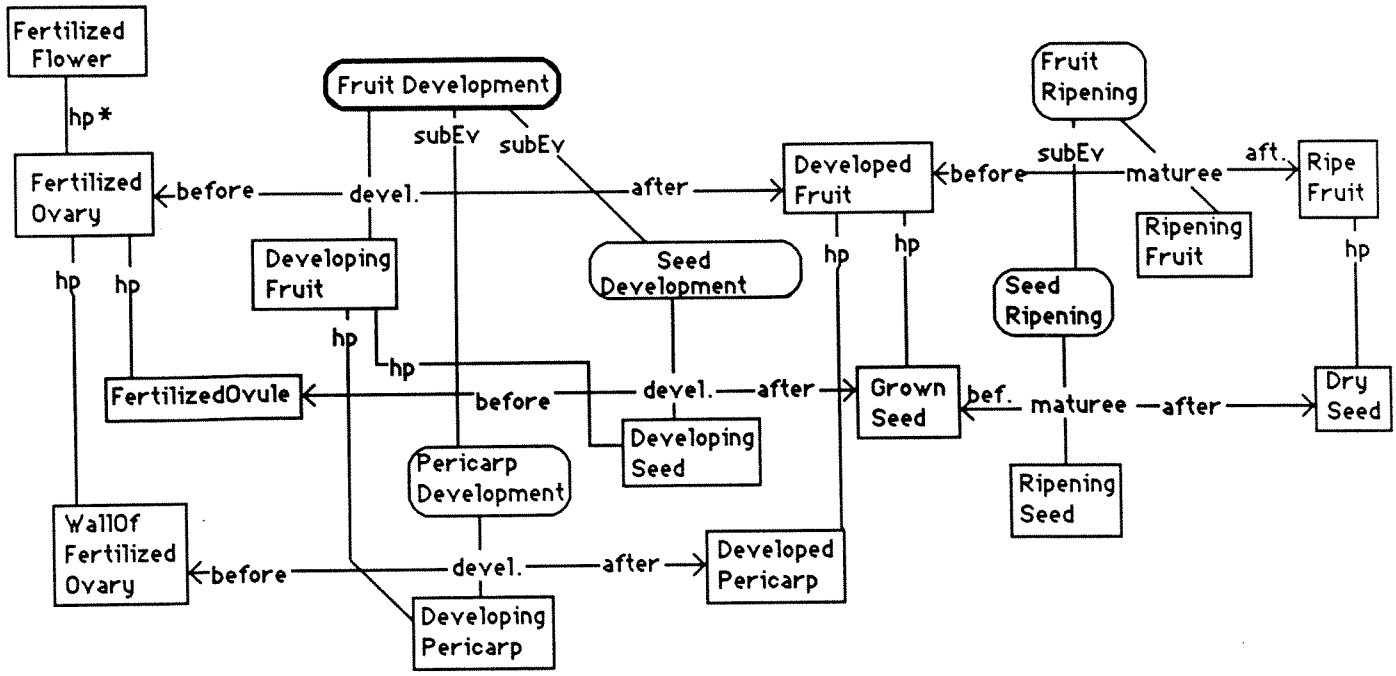

Leaf
stage
stage
stage
Leaf Development
Leaf Primordium
before
developee
after
Mature Leaf
subEv
subEv
subEv
Developing Leaf
hp
hp
hp
hp
hp
hp
Leaf Epidermal Development
Leaf Protoderm
before
developee
after
Mature Leaf Epidermis
MatureLeaf Substomatal Space
DevelopingLeaf Epidermis
hp
Mature LeafStomate
Leaf VascularNetwork Development
Leaf Procambium
before
developee
after
Mature Leaf Vascular Network
DevelopingLeaf VascularNetwork
hp
hp
MatureLeaf XylemNetwork
MatureLeaf PhloemNetwork
Leaf Mesophyll Development
LeafGround Meristem
before
developee
after
MatureLeaf Mesophyll
DevelopingLeaf Mesophyll
hp
MatureLeaf Photosynthetic Cell

Flower Development

S = specialization
hp = hasPart
subEv = subEvent
devel. = developee

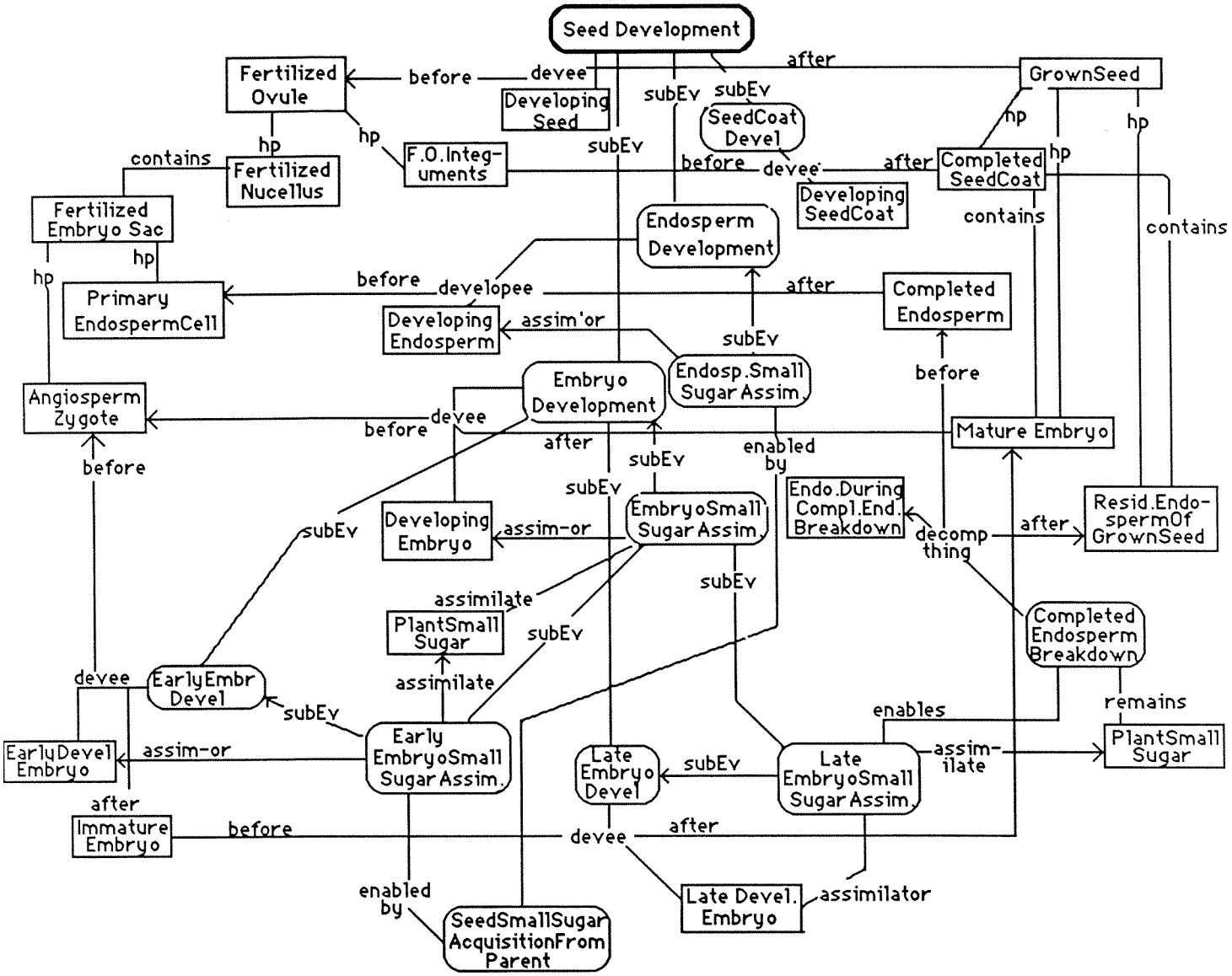


Fruit
Development



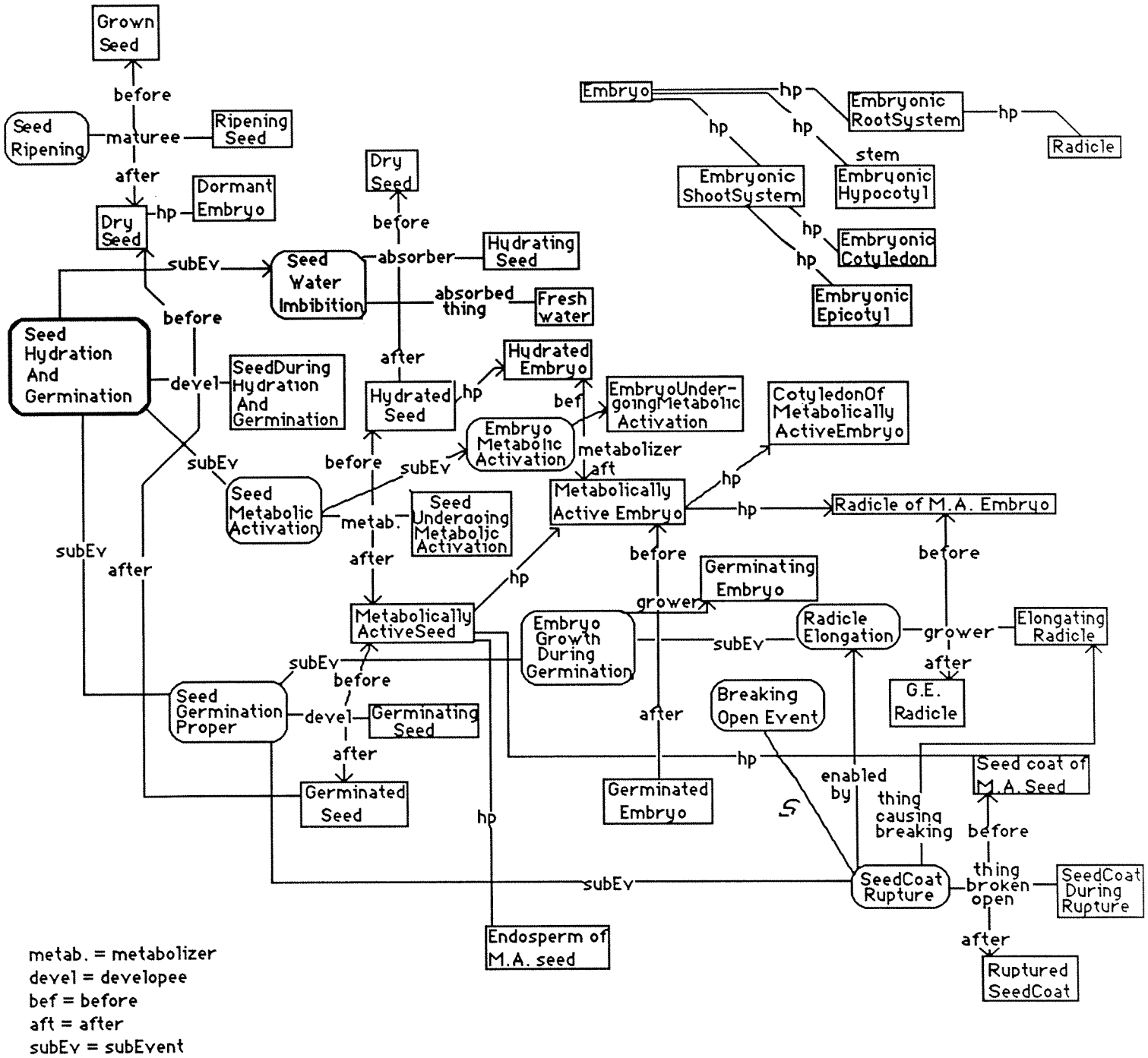
devel. = developee

Seed Development



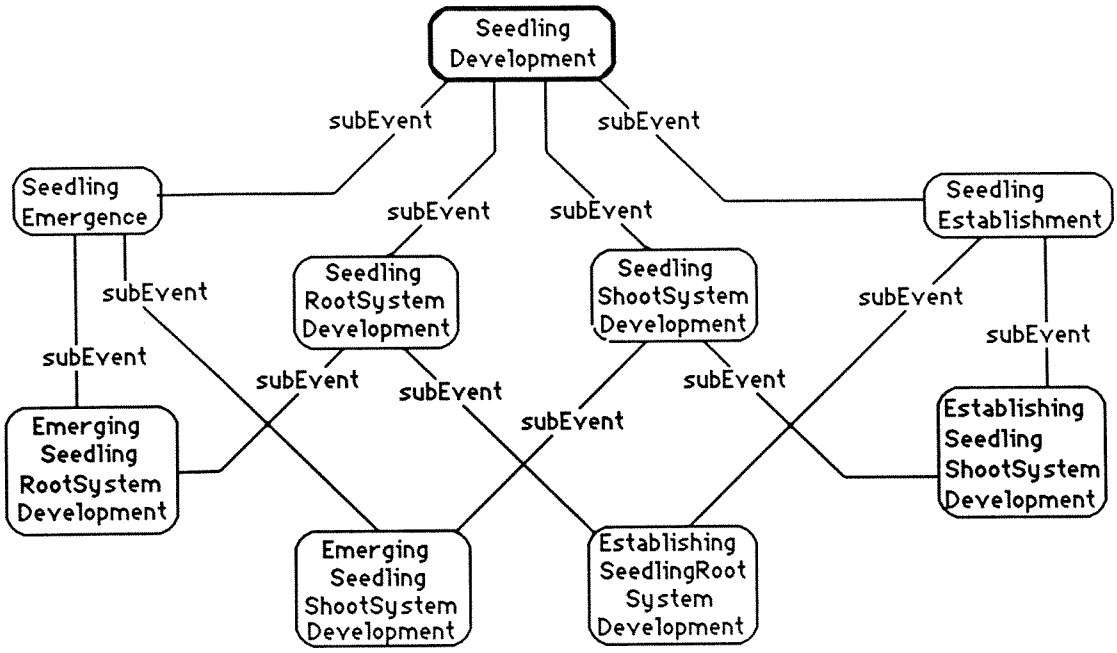
assim-or = assimilator
devee = developee
subEv = subEvent

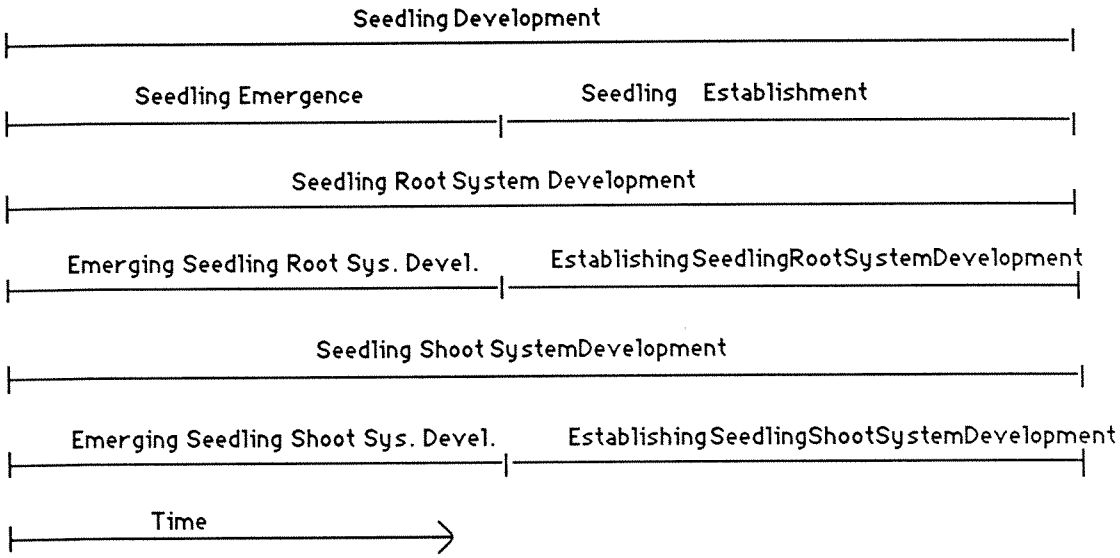
Seed Hydration and Germination



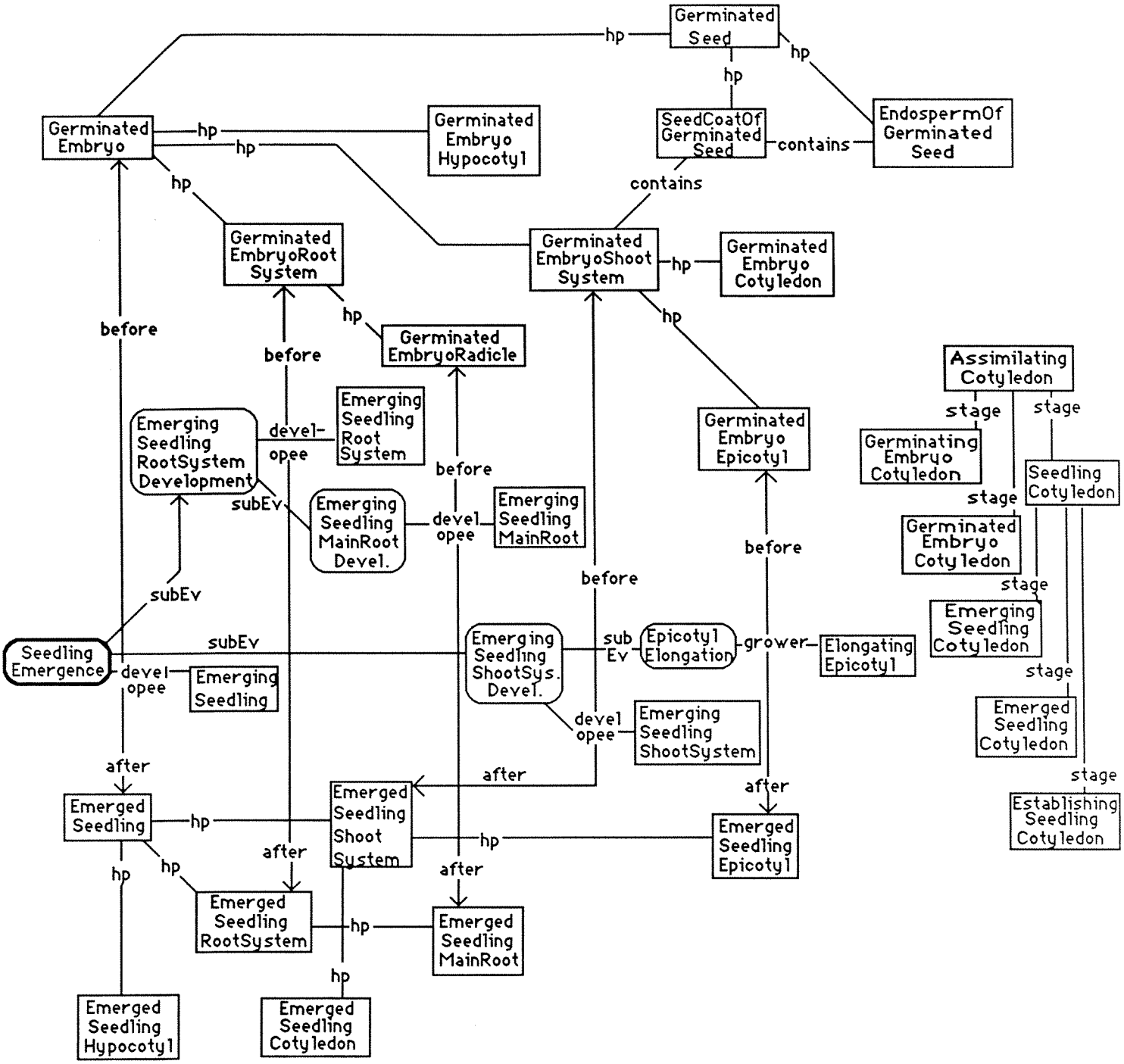
metab. = metabolizer
devel = developee
bef = before
aft = after
subEv = subEvent

Seedling Development - Overview

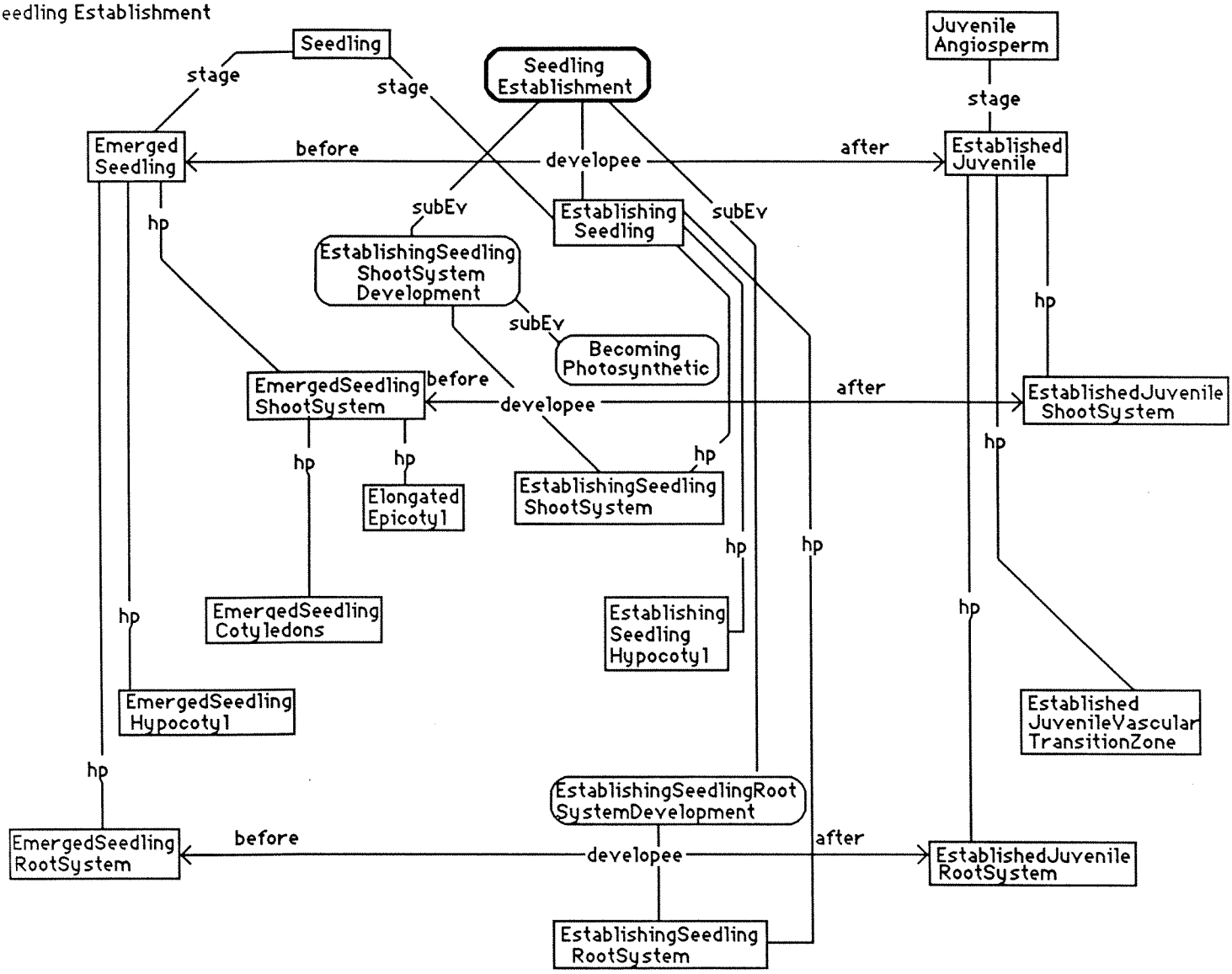


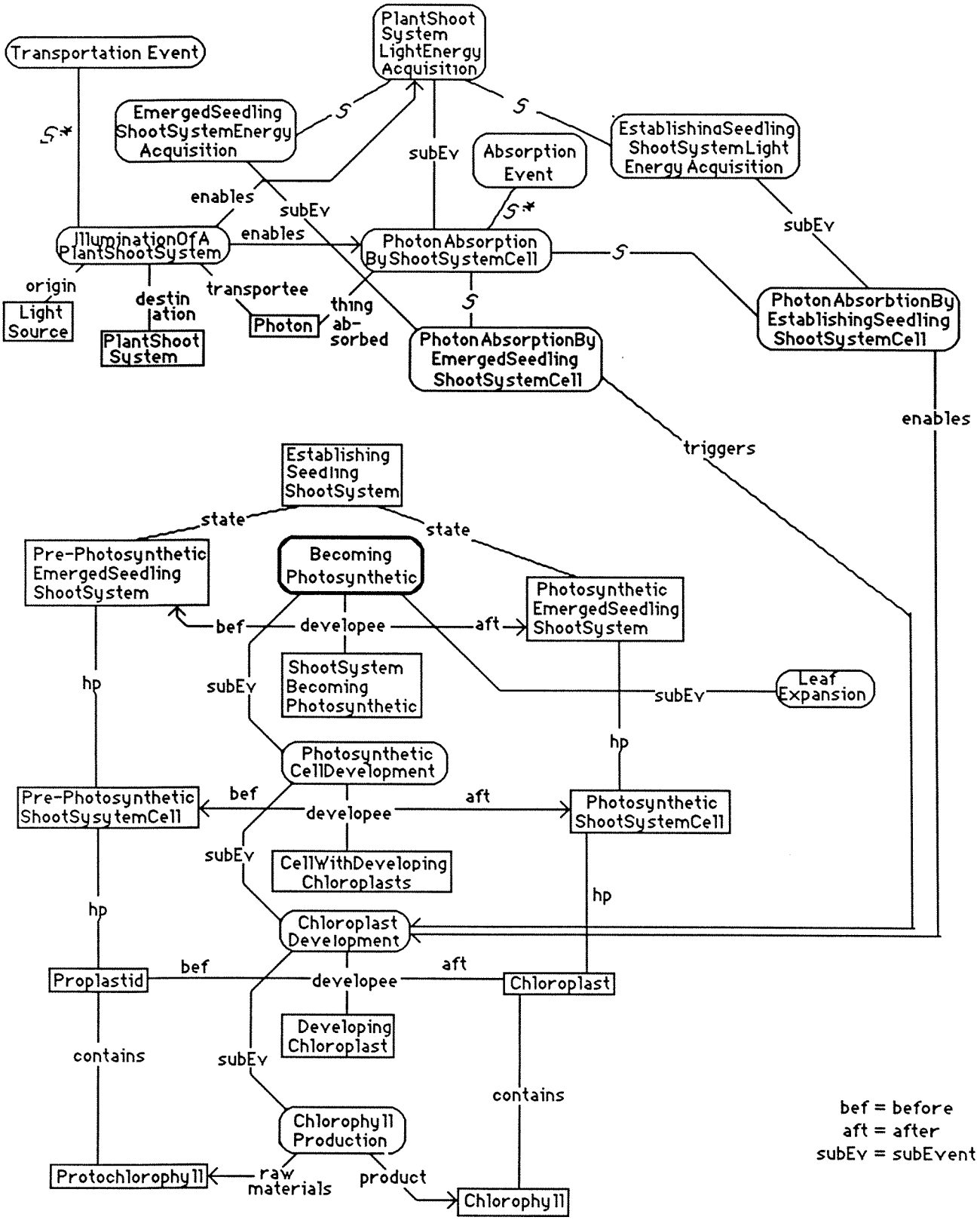


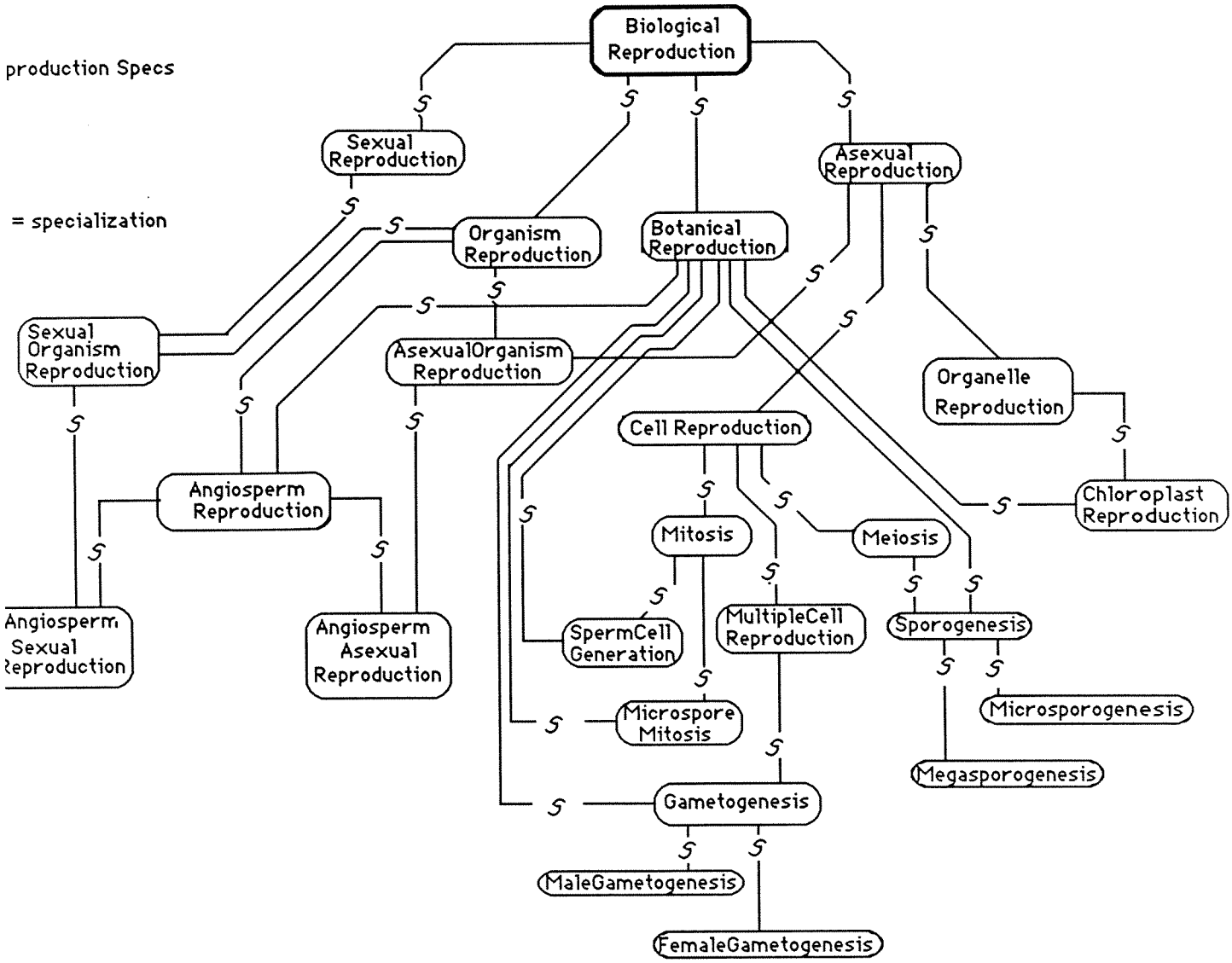
Seedling Emergence



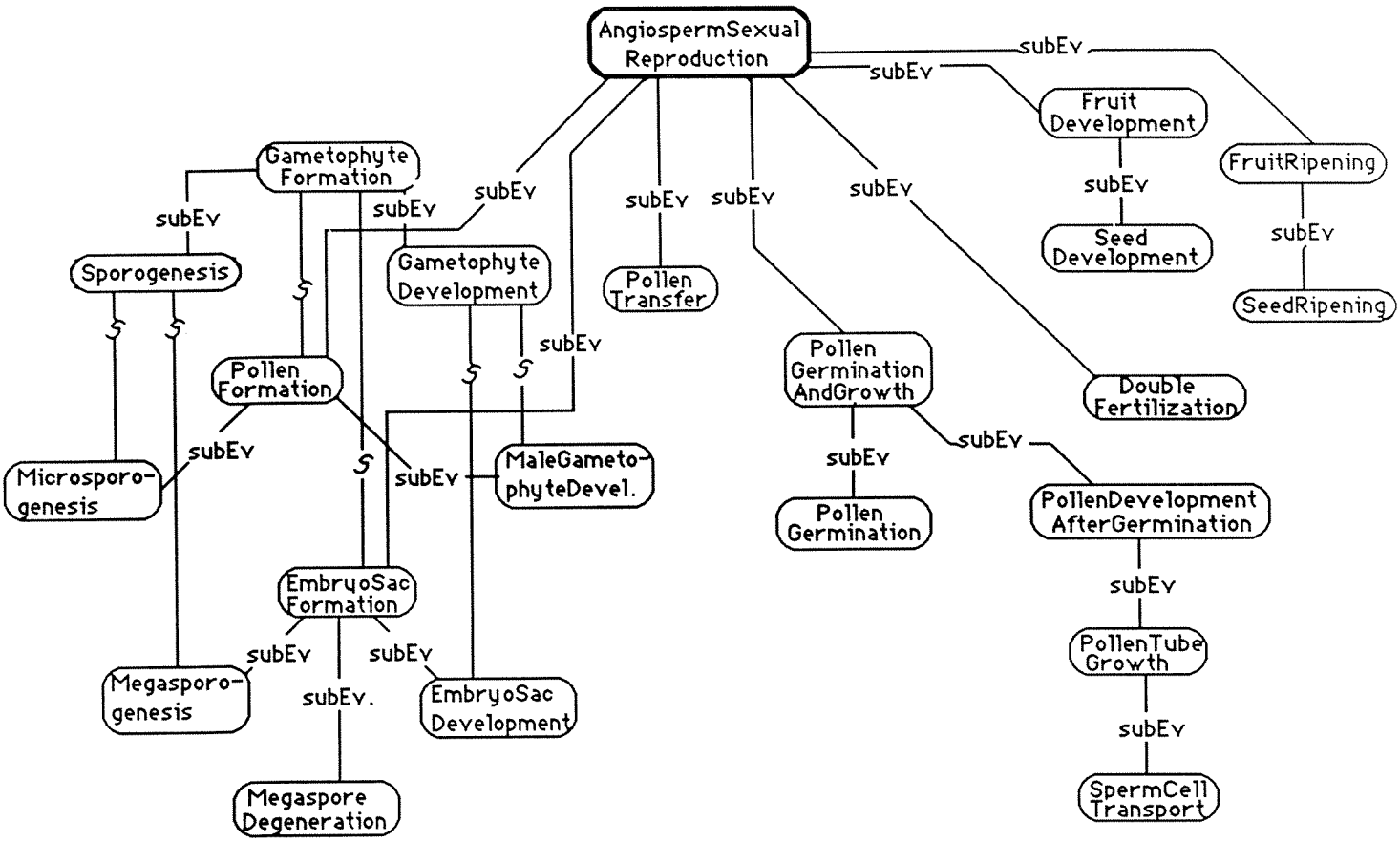
Seedling Establishment




PlantShoot System LightEnergy Acquisition
Transportation Event
EmergedSeedling ShootSystemEnergy Acquisition
EstablishingSeedling ShootSystemLight Energy Acquisition
Absorption Event
subEv
enables
IlluminationOfA PlantShootSystem
PhotonAbsorption ByShootSystemCell
origin
Light Source
destin ation
PlantShoot System
transportee
Photon
thing ab- sorbed
PhotonAbsorptionBy EmergedSeedling ShootSystemCell
PhotonAbsorbtionBy EstablishingSeedling ShootSystemCell
triggers
Establishing Seedling ShootSystem
state
Pre-Photosynthetic EmergedSeedling ShootSystem
Becoming Photosynthetic
Photosynthetic EmergedSeedling ShootSystem
bef
developee
aft
hp
ShootSystem Becoming Photosynthetic
Leaf Expansion
Photosynthetic CellDevelopment
Pre-Photosynthetic ShootSysytemCell
Photosynthetic ShootSystemCell
CellWithDeveloping Chloroplasts
Chloroplast Development
Proplastid
Chloroplast
Developing Chloroplast
contains
Chlorophyll Production
Protochlorophyll
raw materials
product
Chlorophyll
bef = before
aft = after
subEv = subEvent


production Specs
= specialization
Biological Reproduction
Sexual Reproduction
Asexual Reproduction
Organism Reproduction
Botanical Reproduction
Sexual Organism Reproduction
AsexualOrganism Reproduction
Organelle Reproduction
Cell Reproduction
Angiosperm Reproduction
Chloroplast Reproduction
Mitosis
Meiosis
Angiosperm Sexual Reproduction
Angiosperm Asexual Reproduction
SpermCell Generation
MultipleCell Reproduction
Sporogenesis
Microspore Mitosis
Microsporogenesis
Megasporogenesis
Gametogenesis
MaleGametogenesis
FemaleGametogenesis

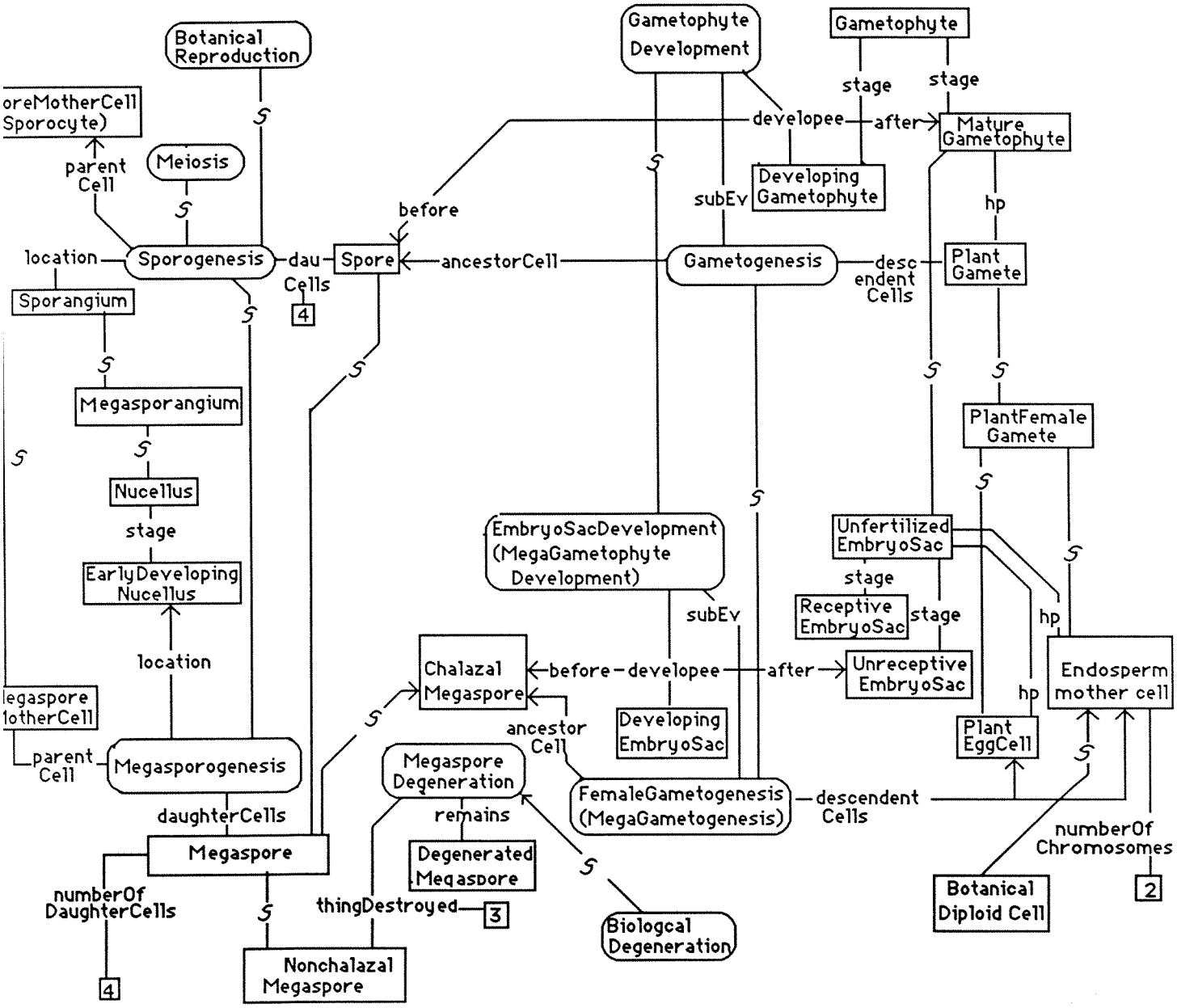
Angiosperm Sexual Reproduction- Overview



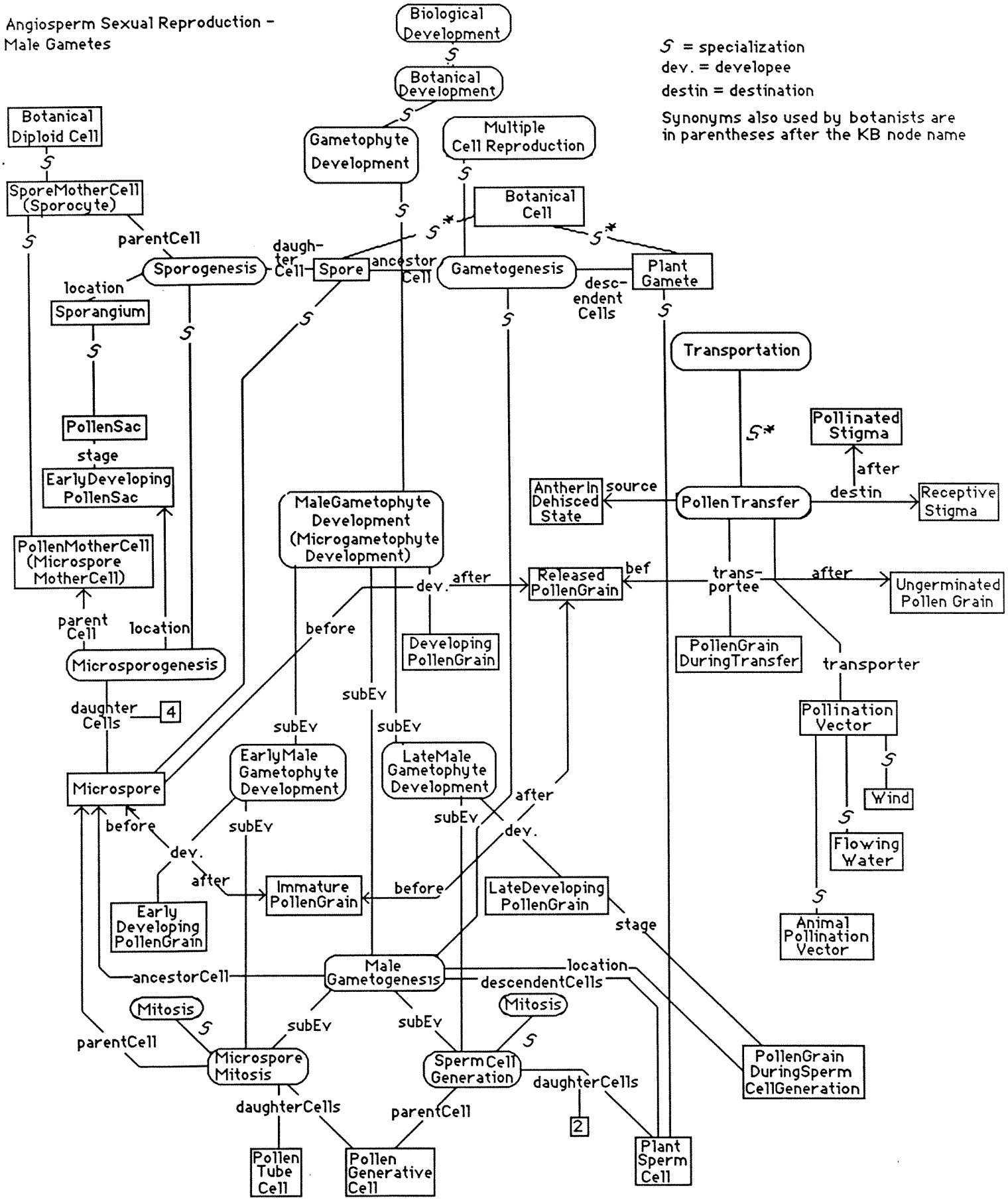
S = specialization
subEv = subEvent

S = specialization

Synonyms also used by botanists are
in parentheses after the KB node name



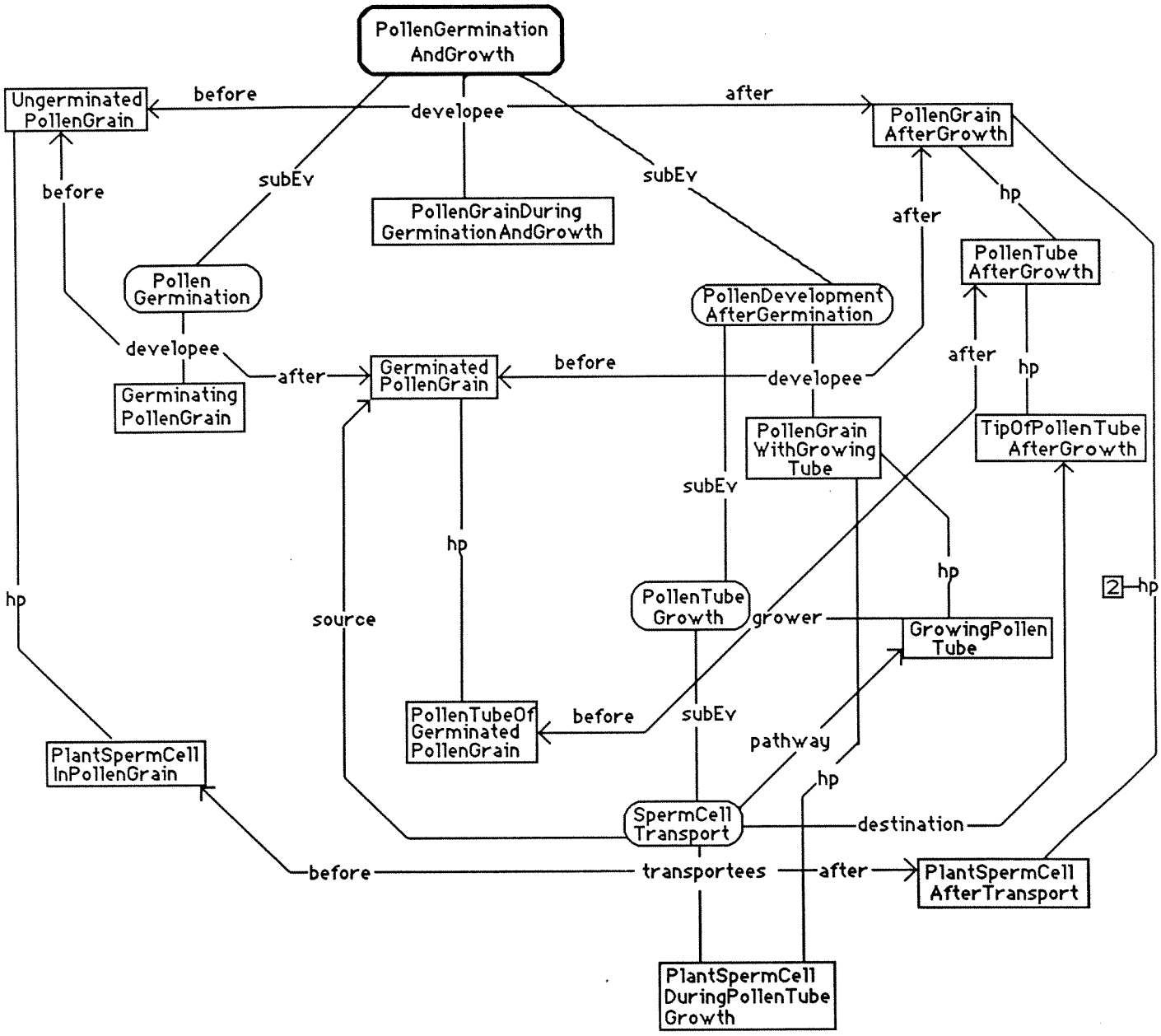
Angiosperm Sexual Reproduction - Male Gametes



S = specialization
dev. = developee
destin = destination

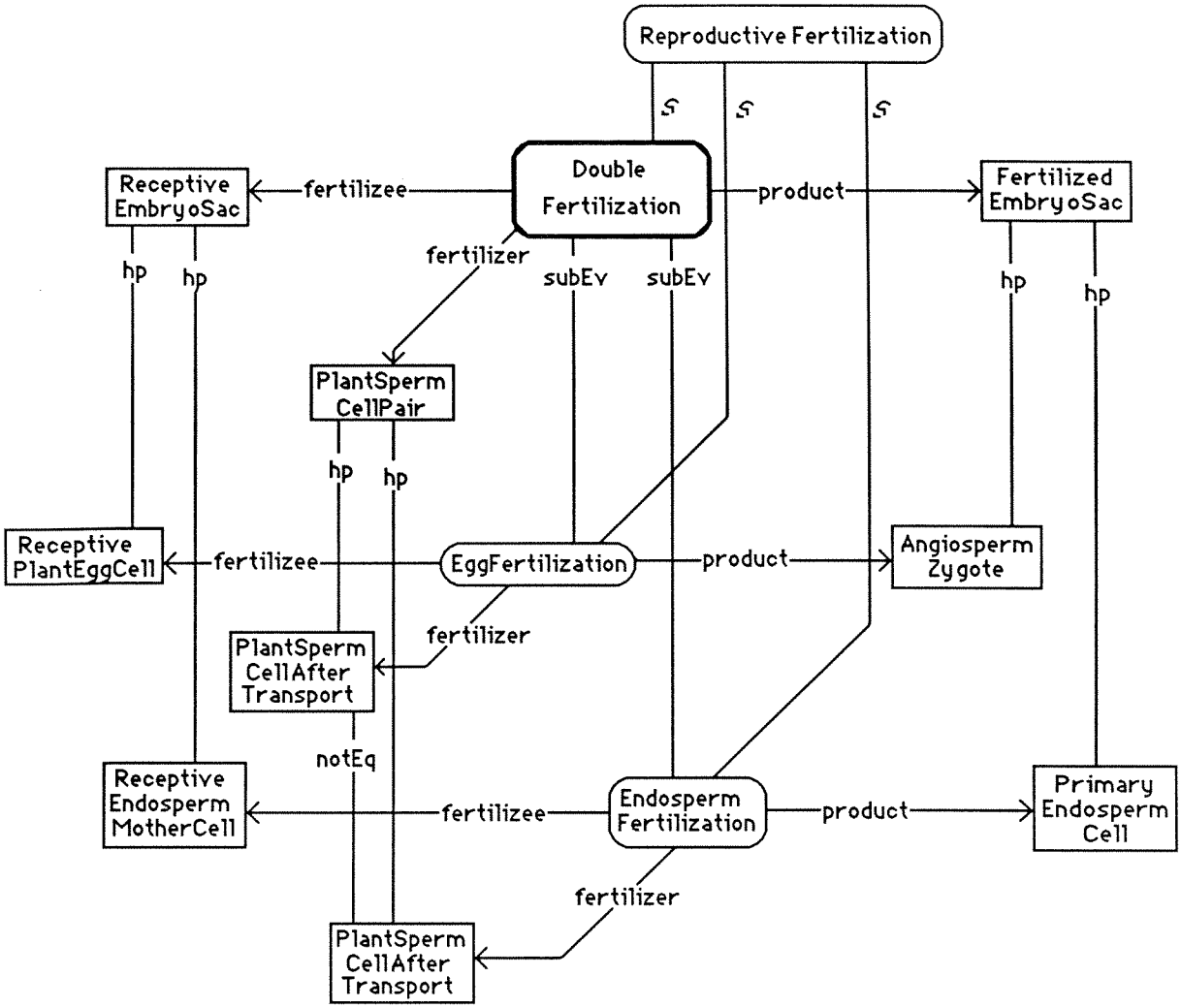
Synonyms also used by botanists are in parentheses after the KB node name

ollen Germination and Growth



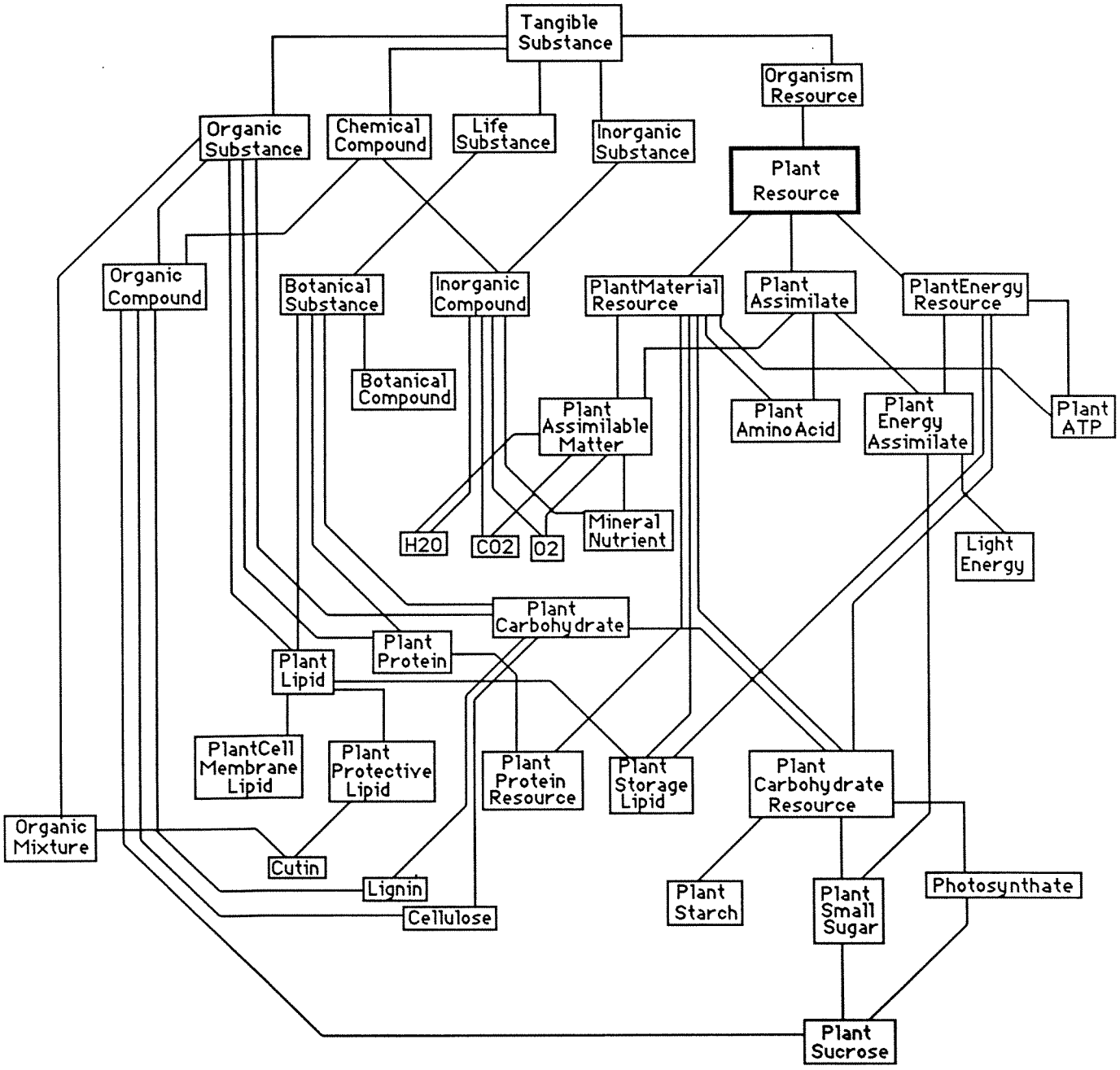
hp = hasPart
subEv = subEvent

DoubleFertilization

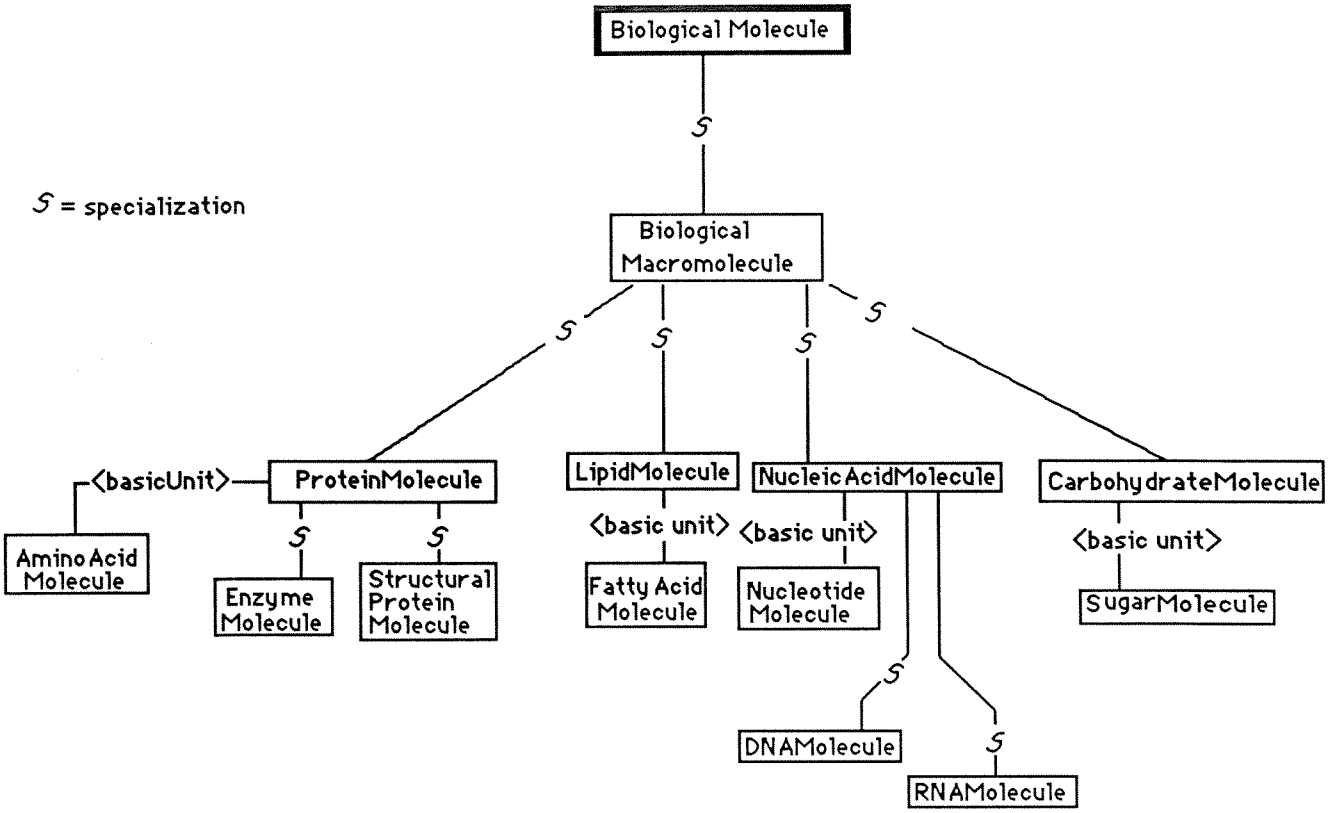


Plant Resources

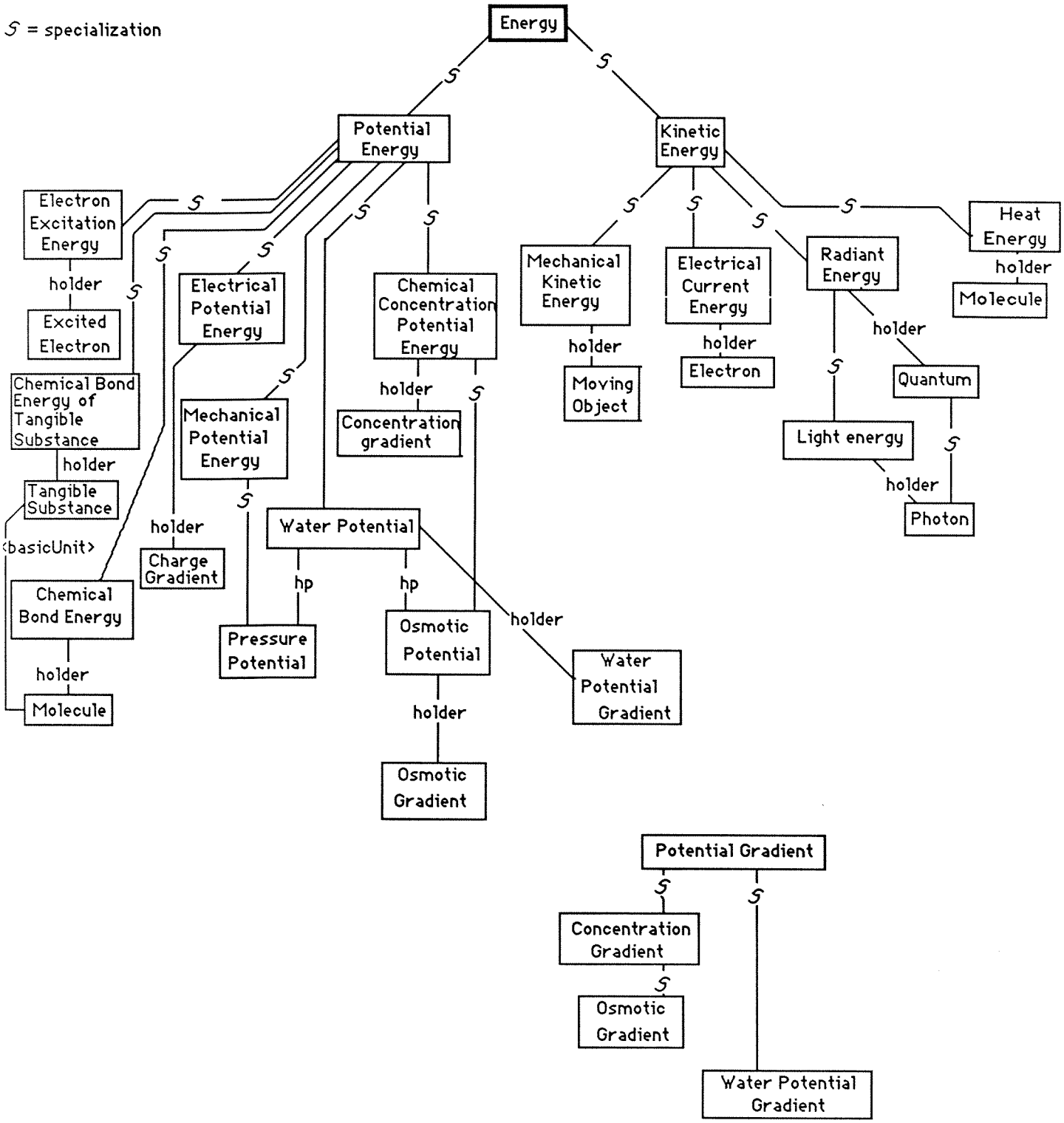
all relations are specialization

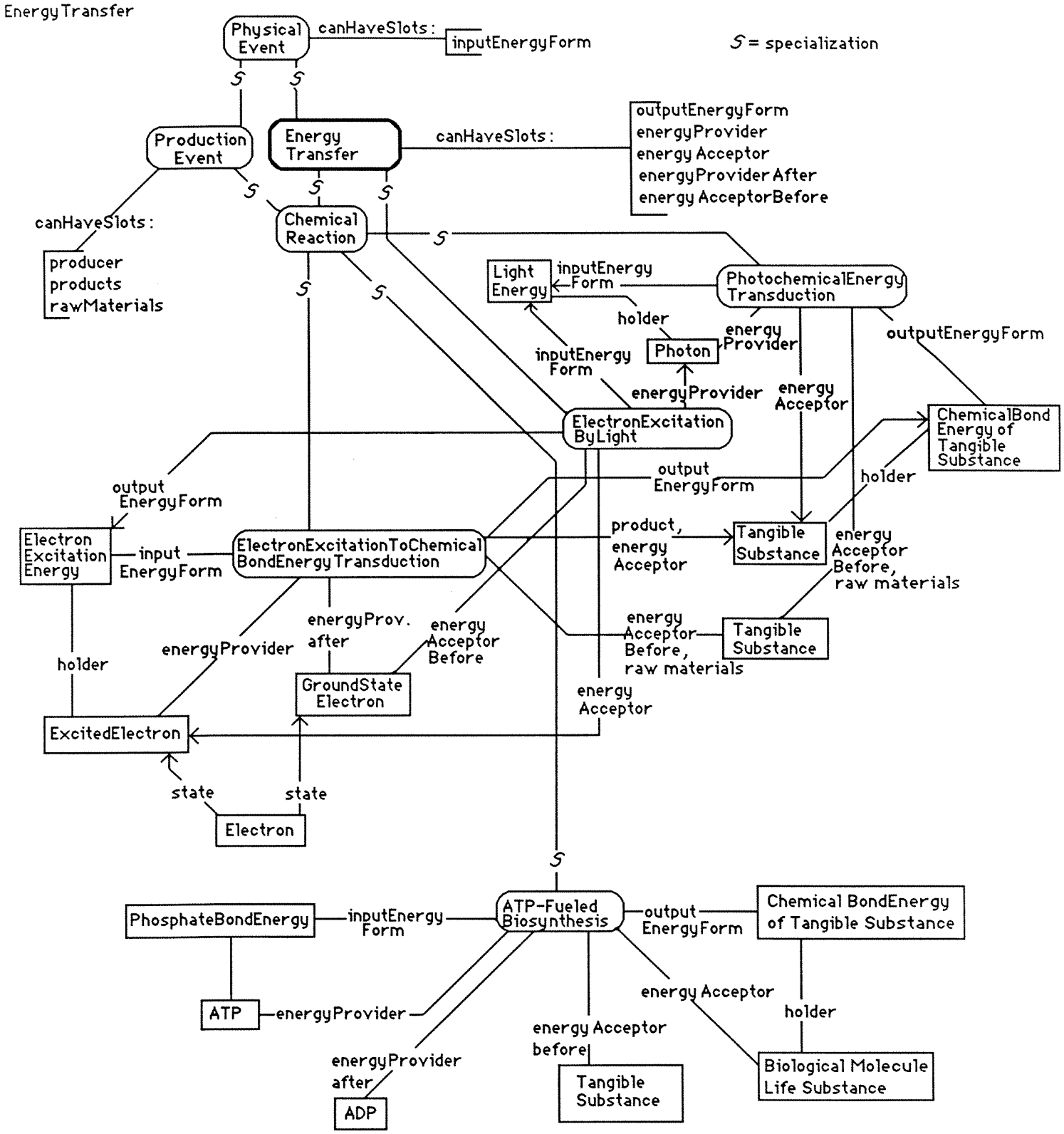


Biological Molecules



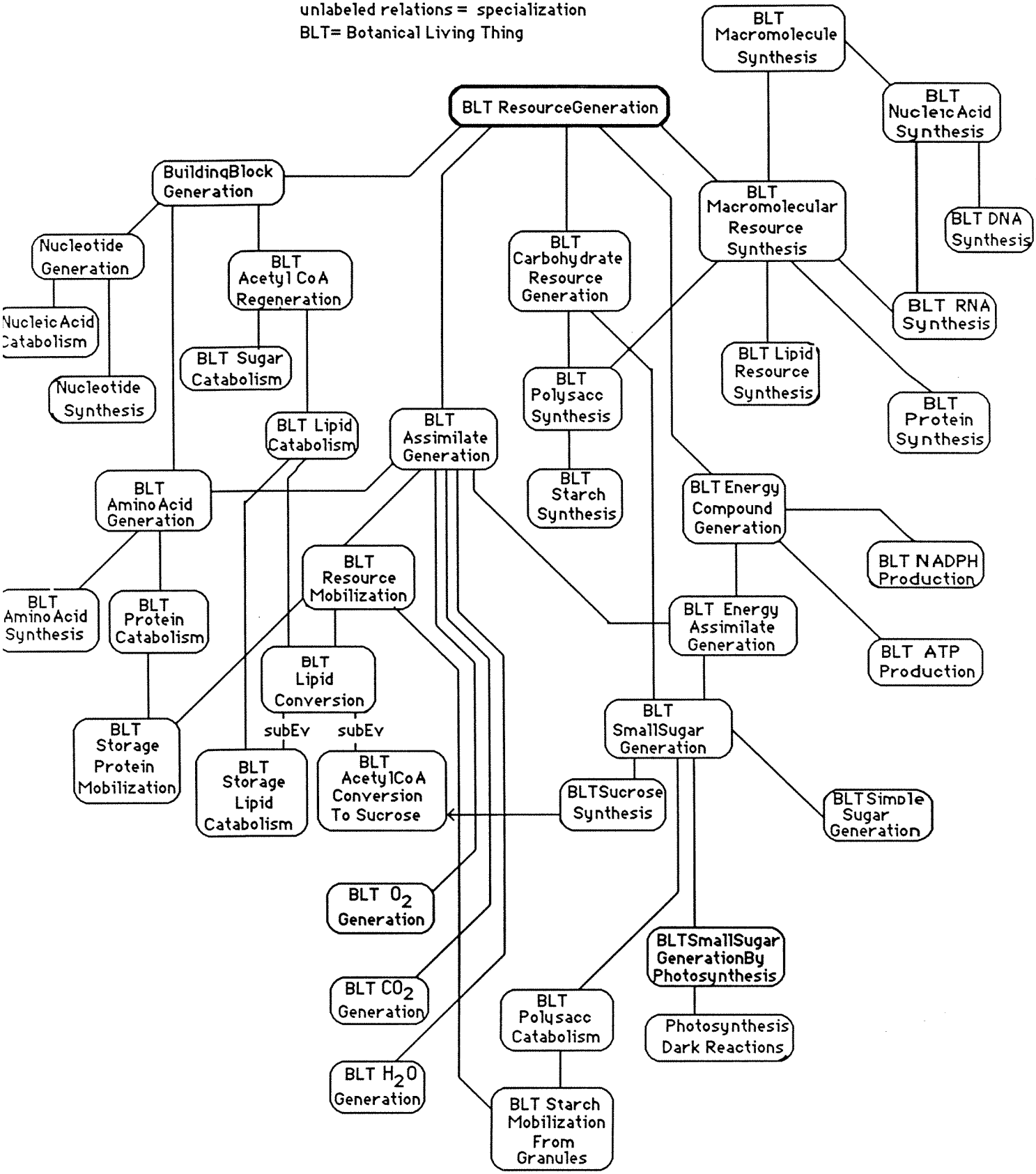
Energy Specs



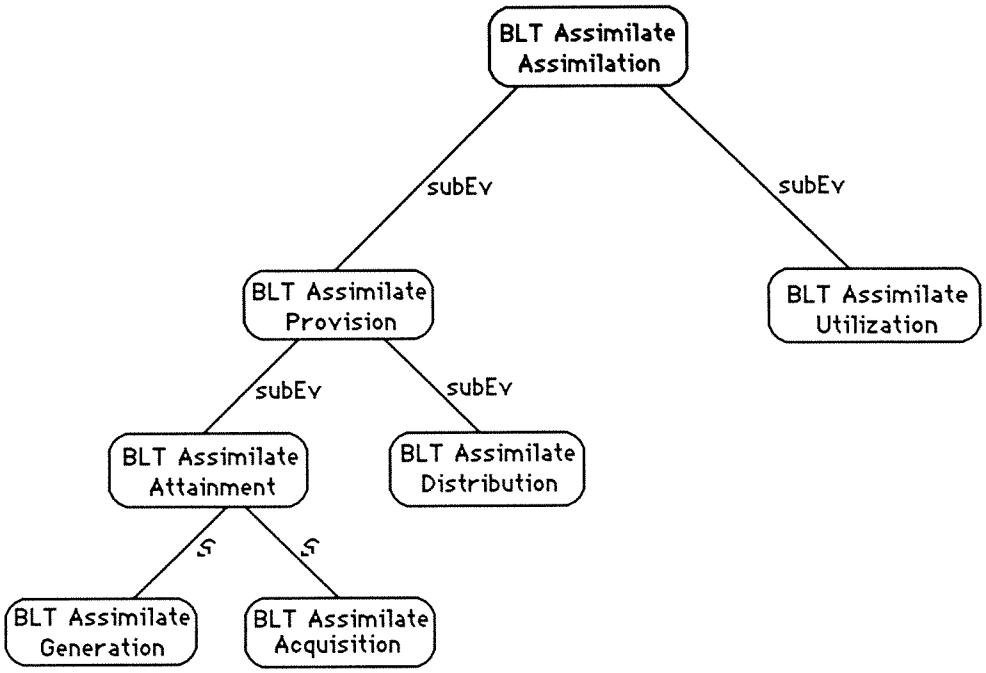

Energy Transfer
Physical Event
canHaveSlots:
inputEnergyForm
S = specialization
Production Event
Energy Transfer
canHaveSlots:
outputEnergyForm
energyProvider
energy Acceptor
energyProvider After
energy AcceptorBefore
canHaveSlots:
producer
products
rawMaterials
Chemical Reaction
Light Energy
inputEnergy Form
PhotochemicalEnergy Transduction
holder
Photon
energy Provider
outputEnergyForm
inputEnergy Form
energyProvider
energy Acceptor
ElectronExcitation ByLight
ChemicalBond Energy of Tangible Substance
output EnergyForm
holder
output EnergyForm
Electron Excitation Energy
input EnergyForm
ElectronExcitationToChemical BondEnergyTransduction
product, energy Acceptor
Tangible Substance
energy Acceptor Before, raw materials
energyProv. after
energy Acceptor Before
energy Acceptor Before, raw materials
Tangible Substance
holder
energyProvider
GroundState Electron
energy Acceptor
ExcitedElectron
state
state
Electron
PhosphateBondEnergy
inputEnergy Form
ATP-Fueled Biosynthesis
output EnergyForm
Chemical BondEnergy of Tangible Substance
ATP
energyProvider
energy Acceptor
holder
energy Acceptor before
energyProvider after
ADP
Tangible Substance
Biological Molecule Life Substance

BLT Resource Generation

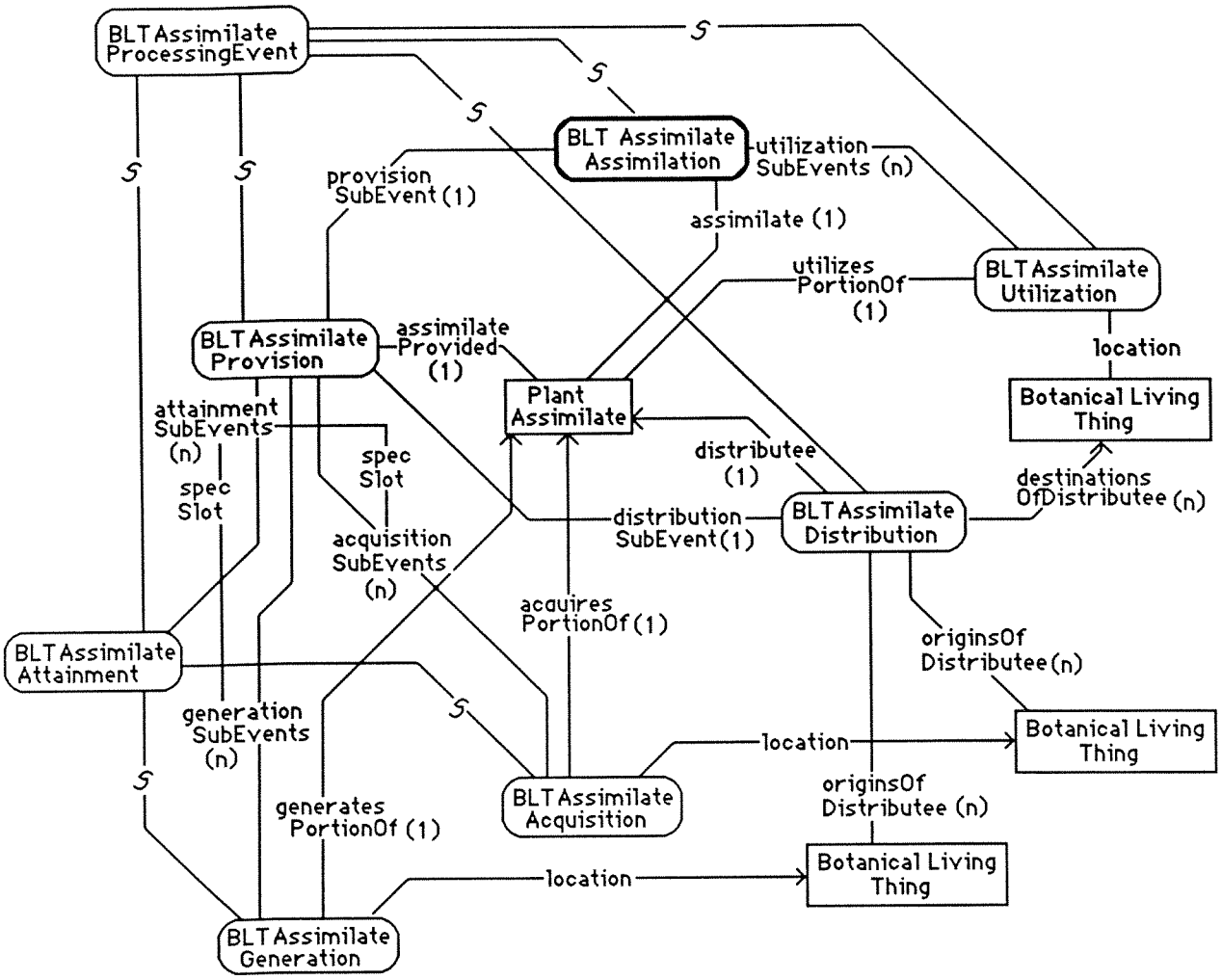
unlabeled relations = specialization
BLT= Botanical Living Thing



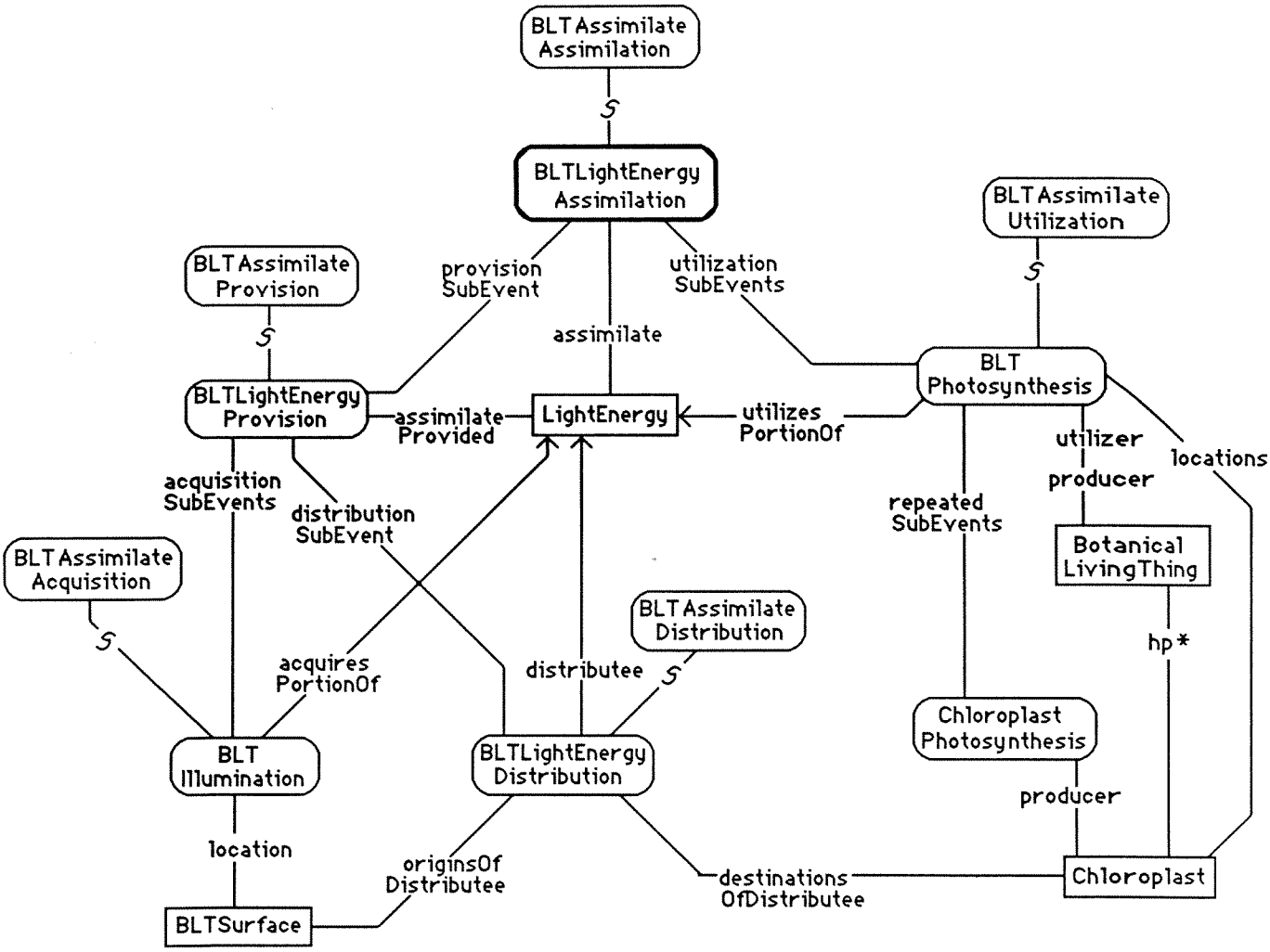
BLT Assimilate Assimilation SubEvents



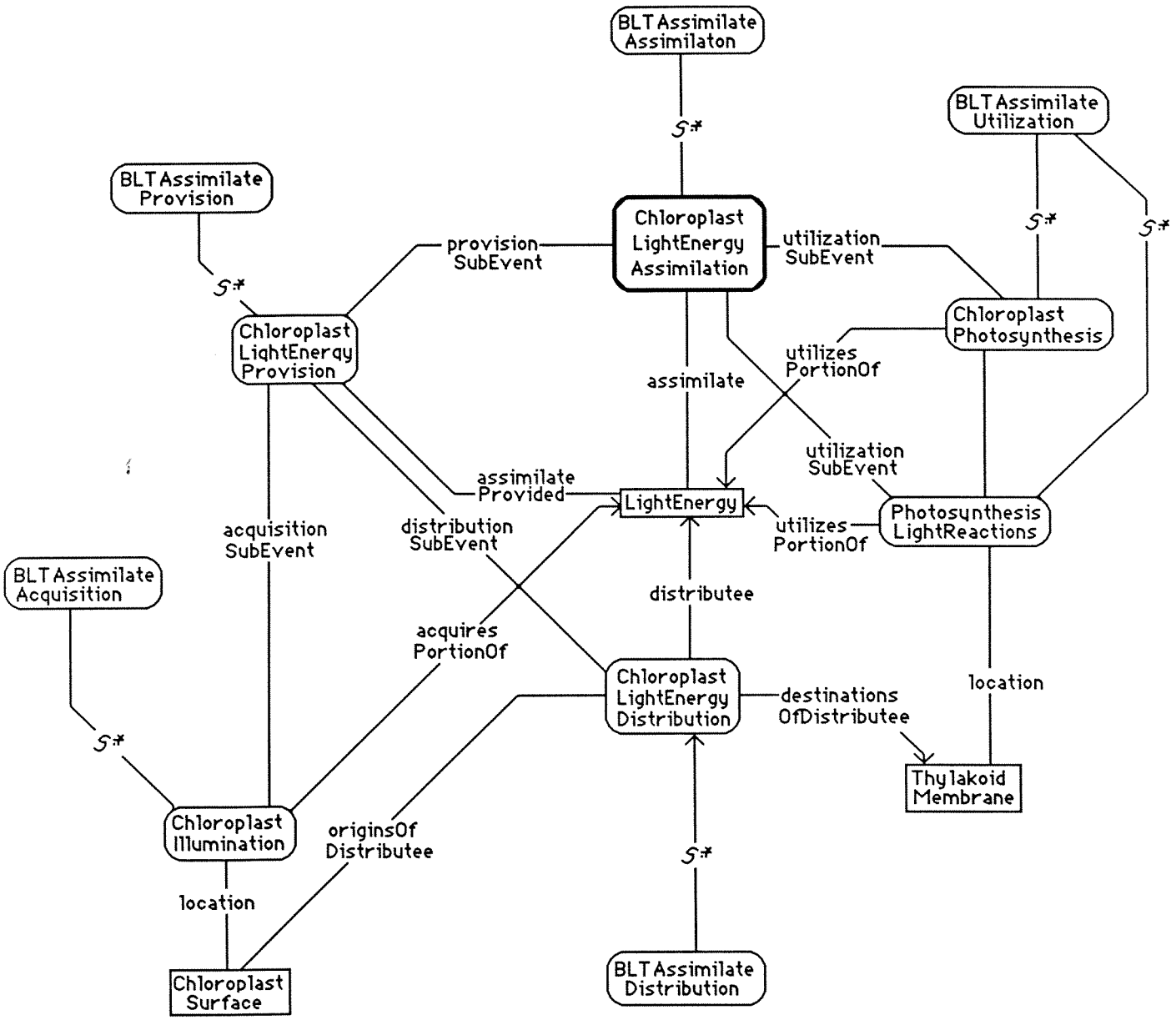
BLT Assimilate Assimilation (Complete)



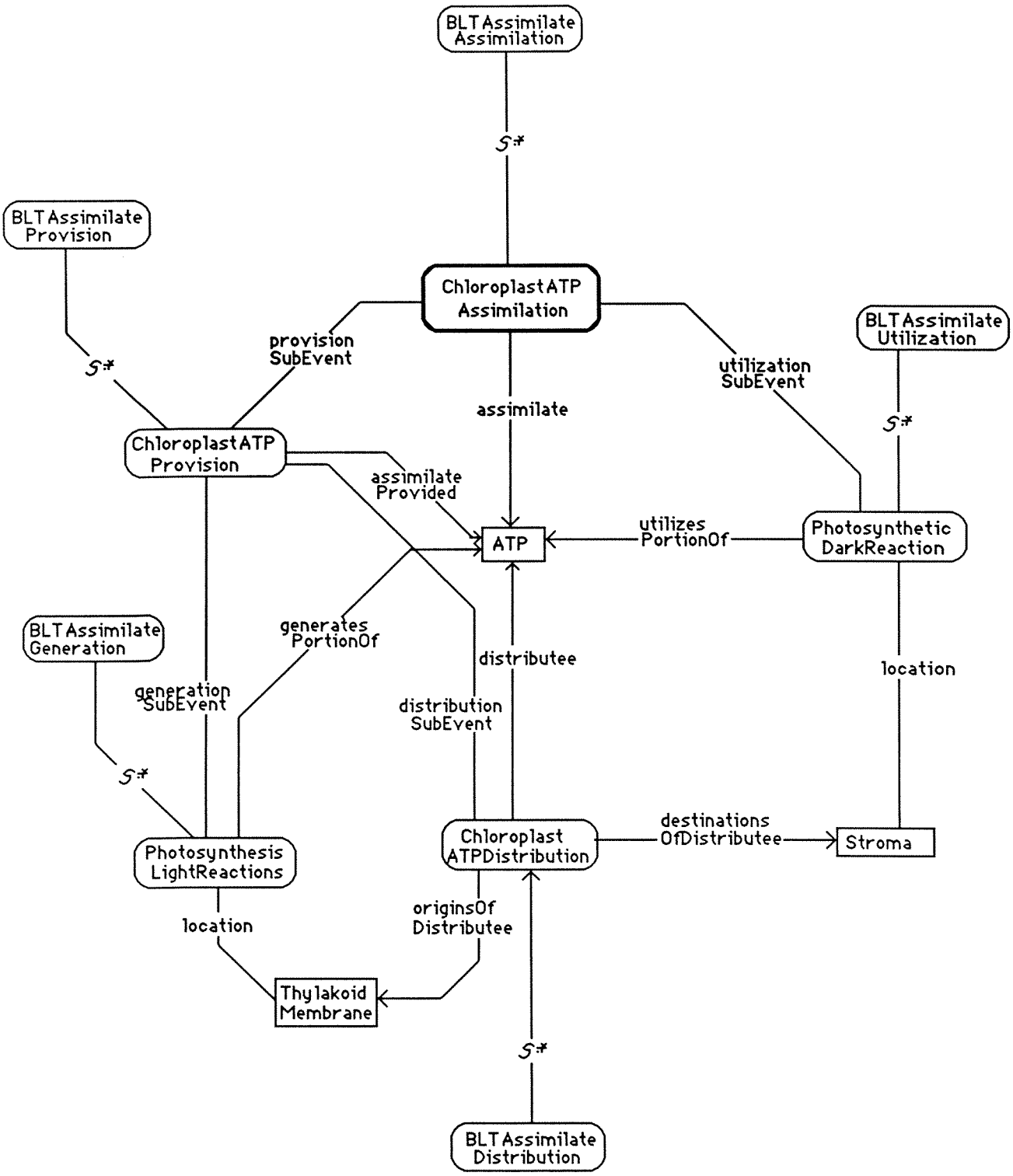
BLT Light Energy Assimilation



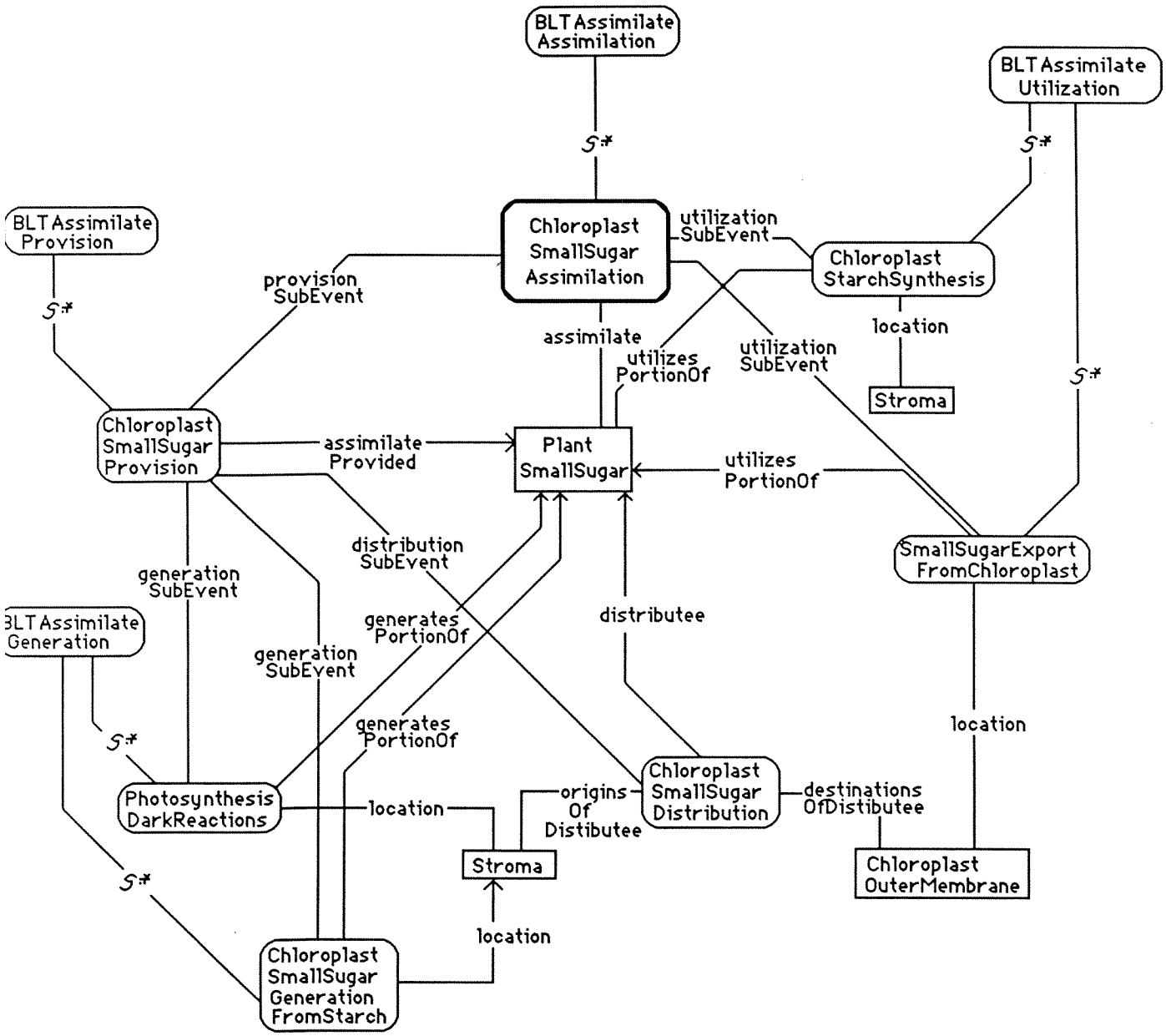
ɔroplast Light Energy Assimilation



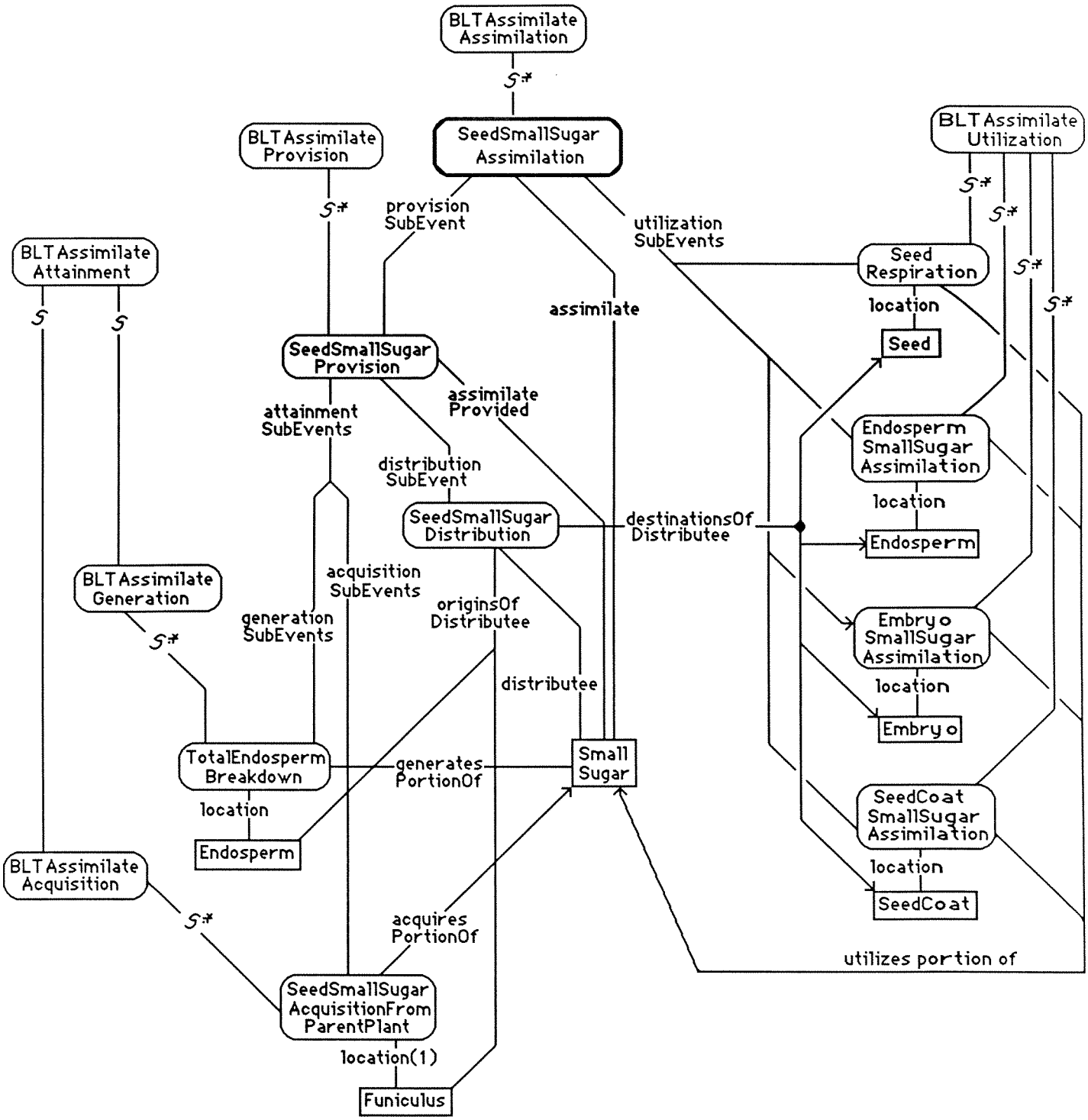
Chloroplast ATP Assimilation



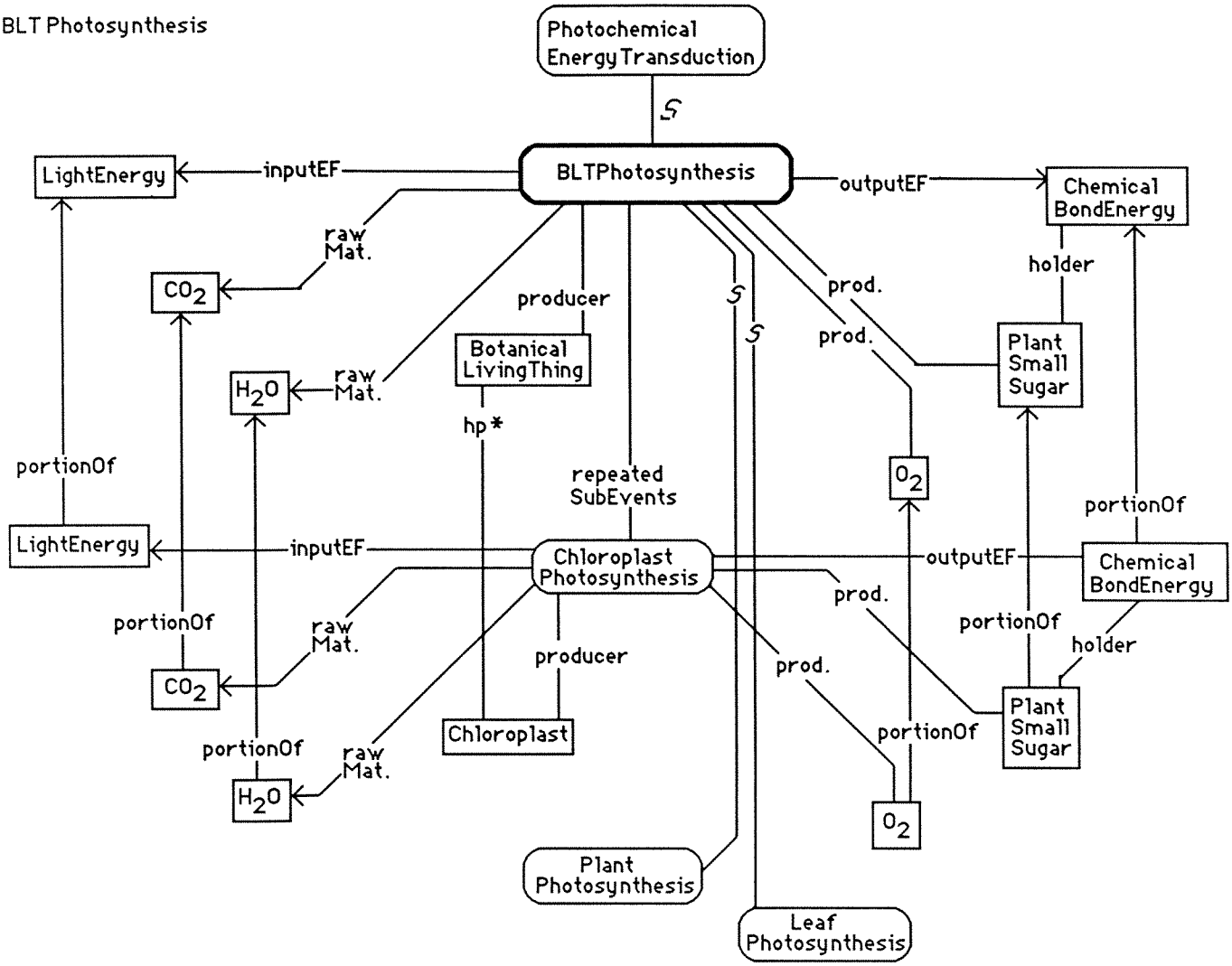
hloroplast Small Sugar Assimilation



Seed Small Sugar Assimilation

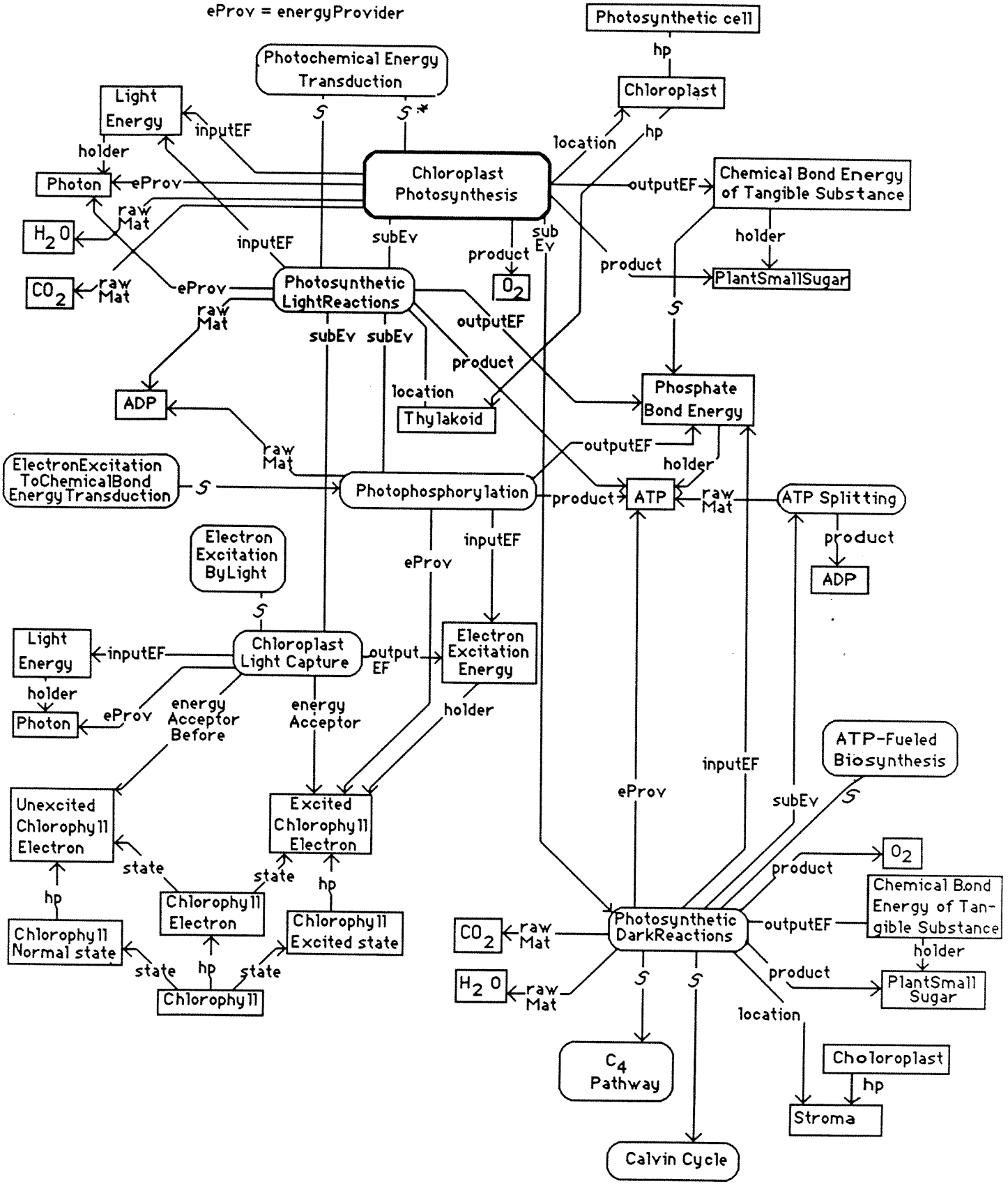


BLT Photosynthesis



S = specialization
inputEF = inputEnergyForm
outputEF = outputEnergyForm
prod. = products
rawMat. = rawMaterials

Chloroplast Photosynthesis

subEv=subEvent
inputEF = inputEnergyuForm
outputEF = outputEnergyForm
eProv = energyProvider

rawMat = rawMaterial
S = specialization