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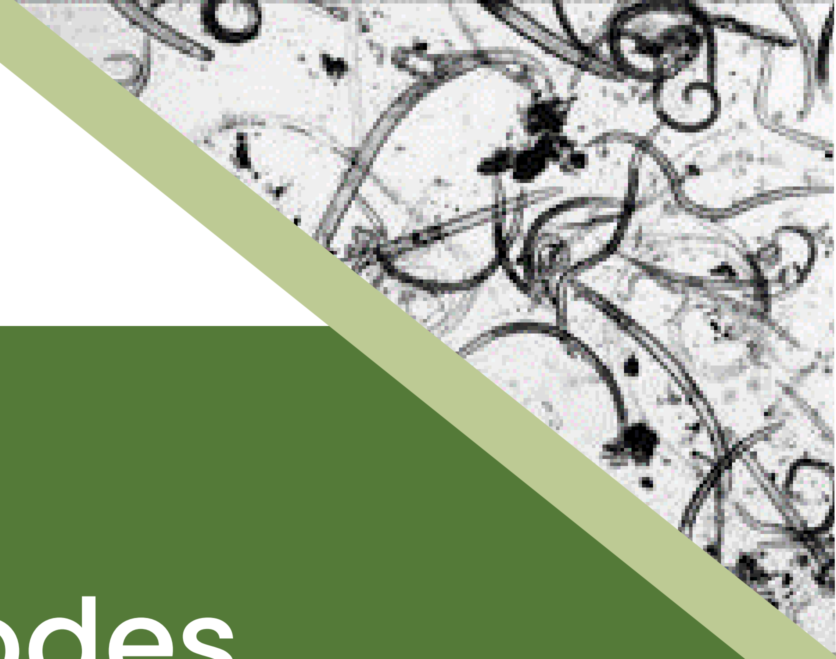

Plant Parasitic Nematodes in Horticulture

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SARDI
SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

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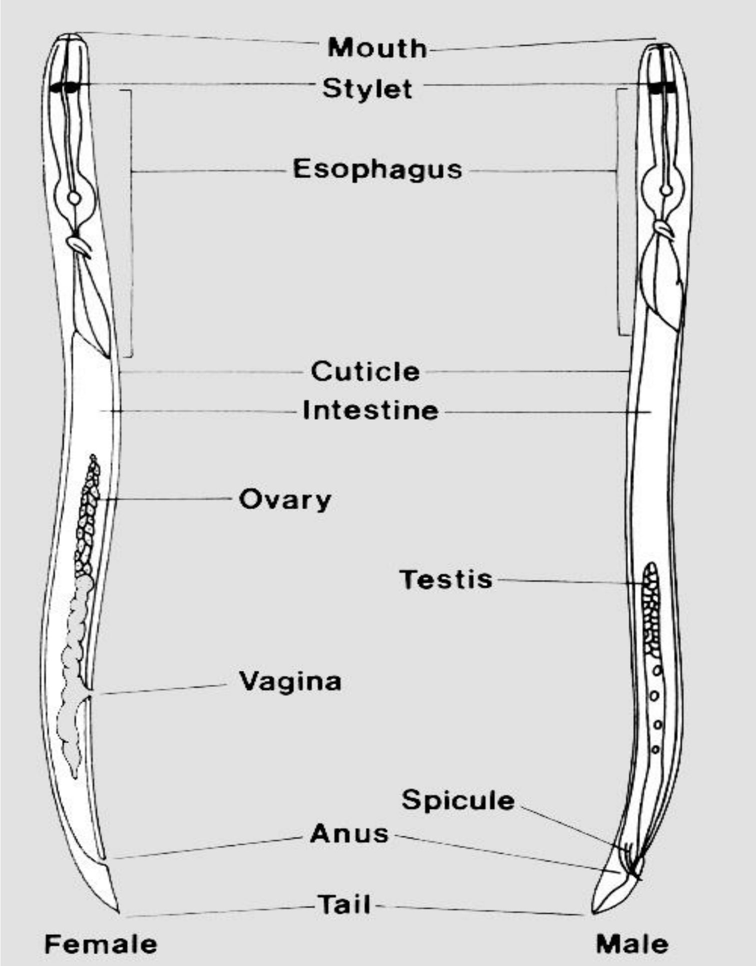
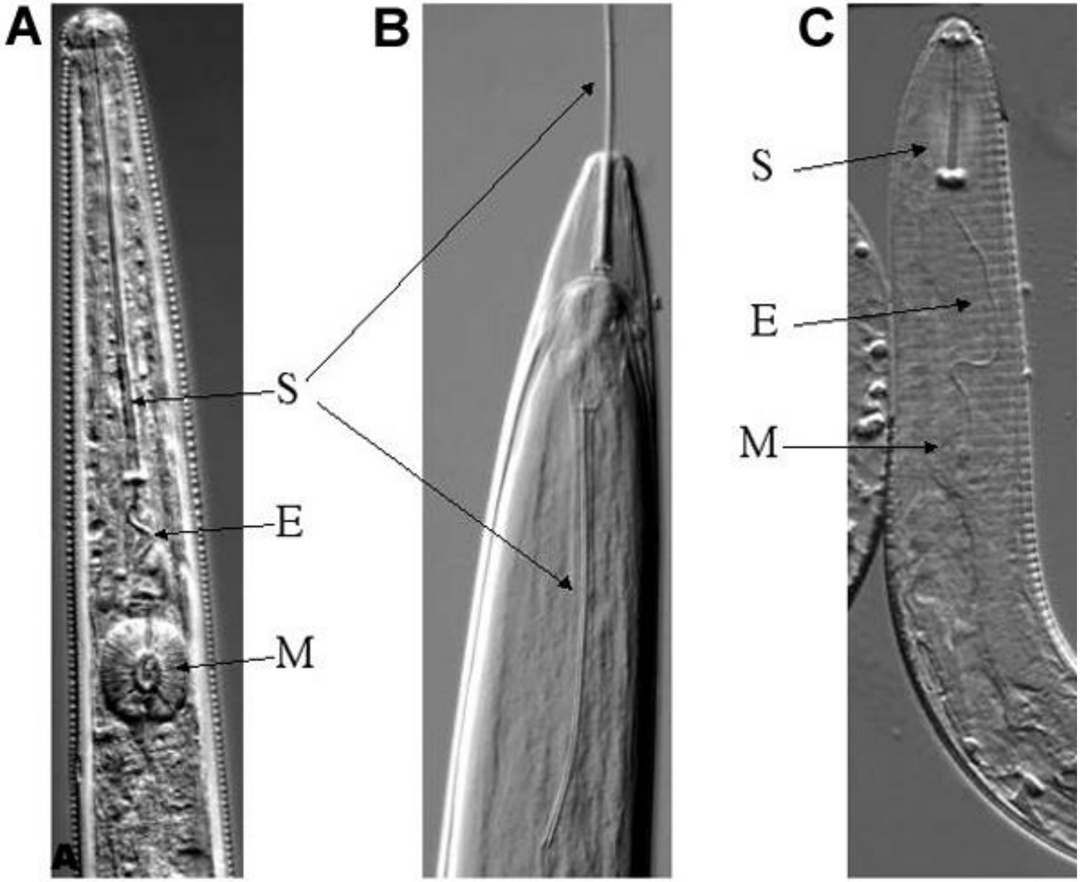
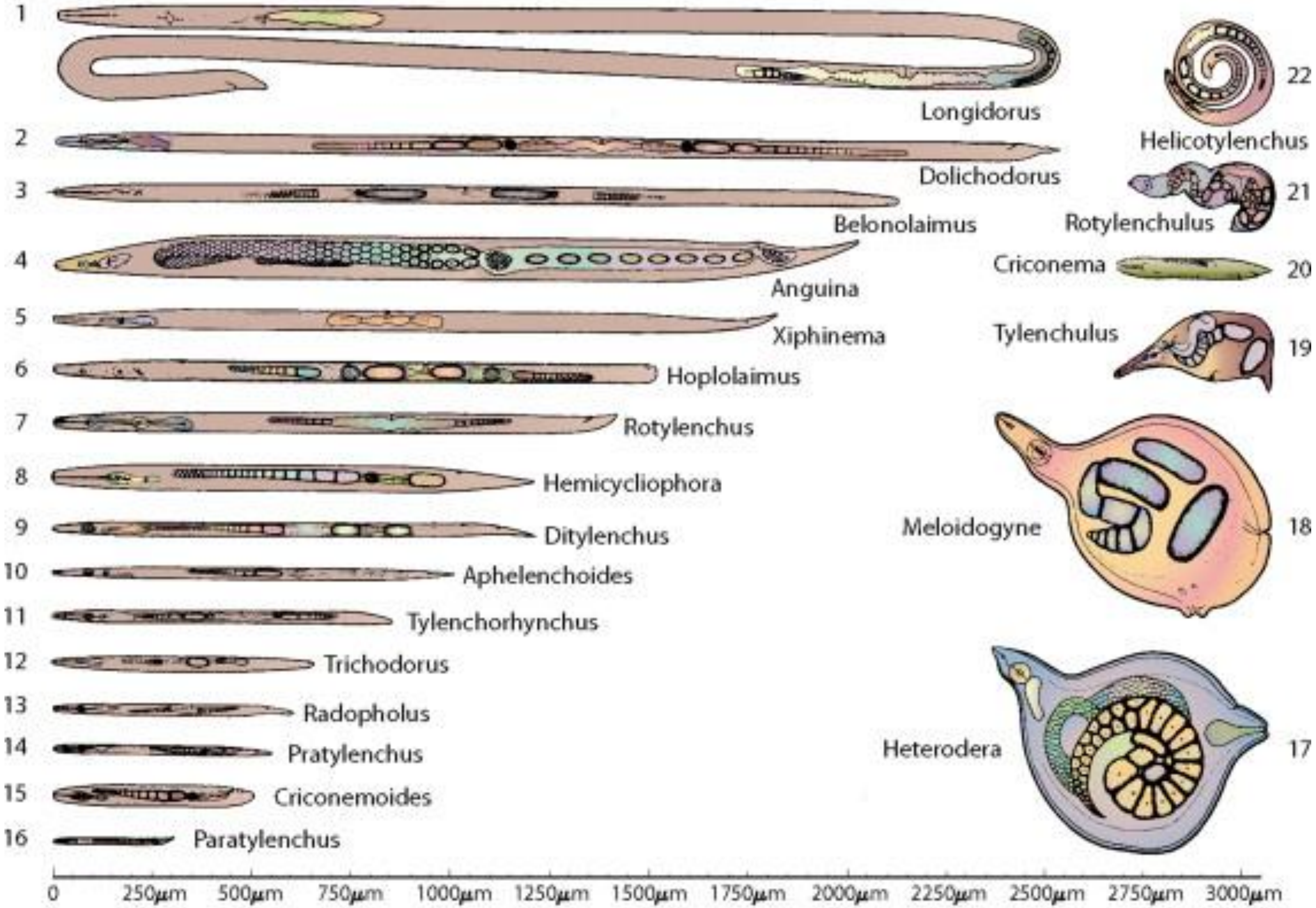
Plant Parasitic Nematodes






1 Longidorus
2 Dolichodorus
3 Belonolaimus
4 Anguina
5 Xiphinema
6 Hoplolaimus
7 Rotylenchus
8 Hemicycliophora
9 Ditylenchus
10 Aphelenchoides
11 Tylenchorhynchus
12 Trichodorus
13 Radopholus
14 Pratylenchus
15 Criconemoides
16 Paratylenchus
17 Heterodera
18 Meloidogyne
19 Tylenchulus
20 Criconema
21 Rotylenchulus
22 Helicotylenchus
0
250µm
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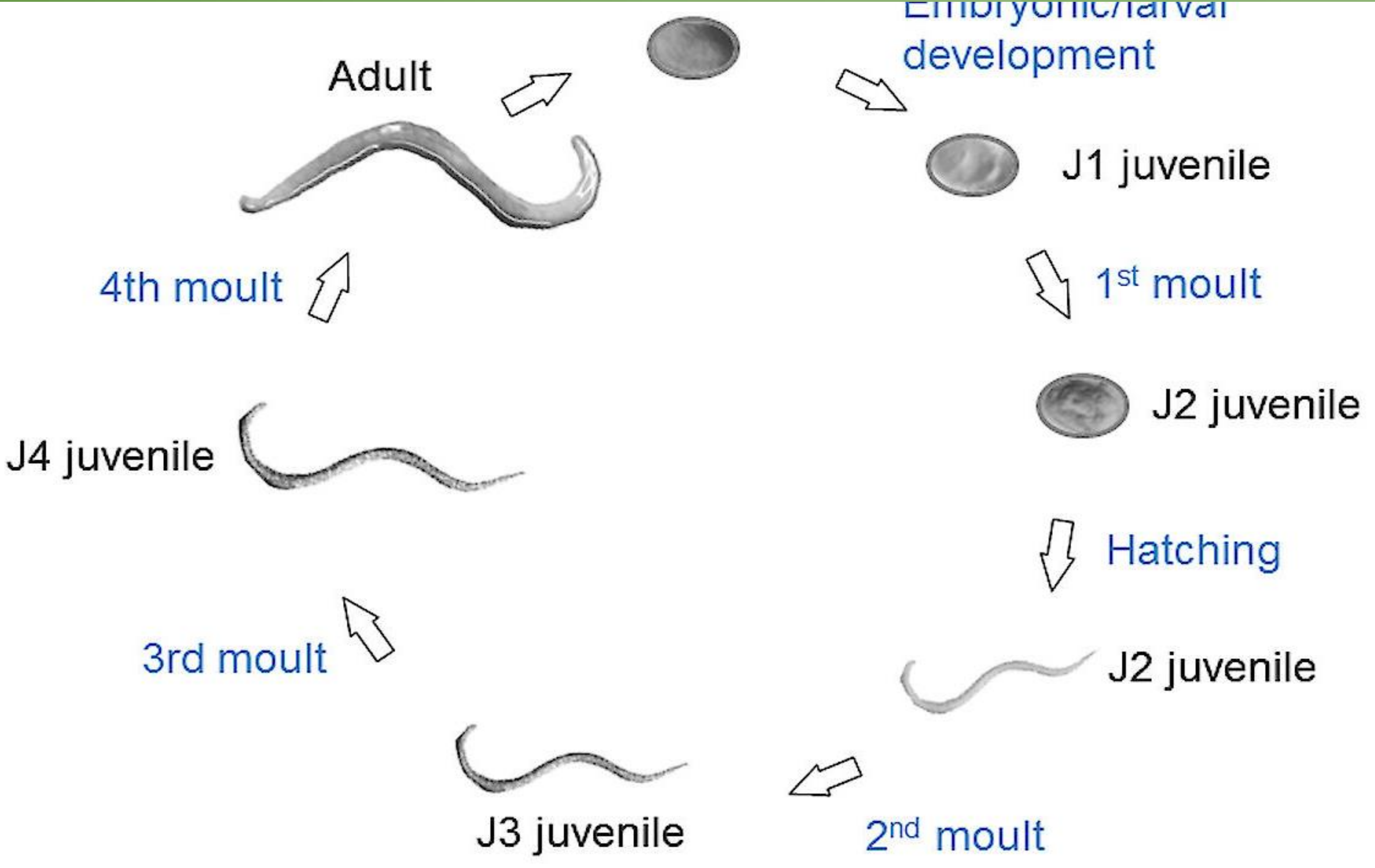
Plant Parasitic Nematodes



ABOVE GROUND

BELOW GROUND

Plant Parasitic Nematodes

- Nematodes require at least a film of water to move
- Some genera die within dry soils but others can survive in a anhydrobiotic state between crops or for many years
- Soil structure is important as pore size affects nematode movement
- Sandy soils generally are the most favourable
- Most genera have broad host range
- Most genera of eggs will hatch irrespective of the presence of a host

Plant Parasitic Nematodes

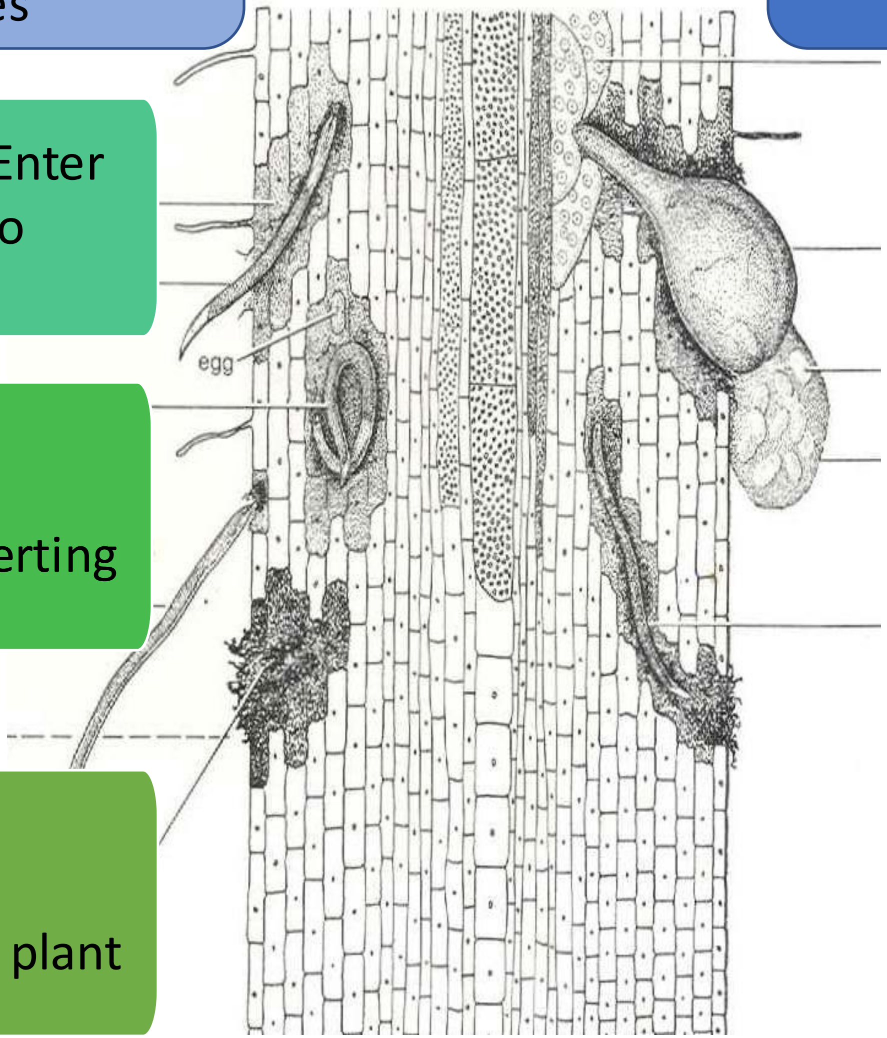
Migratory
Migrate to new feeding sites

Sedentary
Feed from a fixed feeding site

Endoparasitic – Enter the root/plant tissue to feed

Ectoparasitic – Remain outside the root/plant feed by inserting stylet

Semi Endoparasitic – Partially penetrate the plant and feed





ROOT KNOT NEMATODE
Meliodogyne

ROOT KNOT NEMATODE - *Meliodogyne*

- ***M. javanica*** – Javanese root knot nematode
- ***M. incognita*** – Southern root knot nematode
- ***M. arenaria*** – Peanut root knot nematode

warm climate species most active at soil temps 20 – 30°C

- ***M. hapla*** – Northern root knot nematode
  - Temperate climates
  - Southern Aust and elevated tropics

restricted to areas max summer temps <27°C, with an optimum of 15-25°C

- ***M. fallax*** – False Columbia root knot nematode
  - relatively widespread in southern Aust

most active in warm soils (15-25°C)
survives cold soil temps <10°C

- ***M. enterolobii*** - Guava root knot nematode
  - found in NT & QLD (2022)

Quarantine pest

Guava Root Knot Nematode - *M. enterolobii*

- Despite its common name, broad host range including many vegetables

- Sweet Potato
- Tomato
- Capsicum
- Chilli
- Potato
- Pumpkin
- Broccoli
- Eggplant
- Celery
- Zucchini
- Cucumber
- Onions
- Ginger
- Grapes
- Melon
- Guava

- Significant concern
  - increased virulence - has a higher infection rate and induces more severe root galling than other species
  - reproduce on crops that are resistant to other species

- Mainly subtropical to tropical climate

ROOT KNOT NEMATODE – Biology

- Sedentary endoparasite

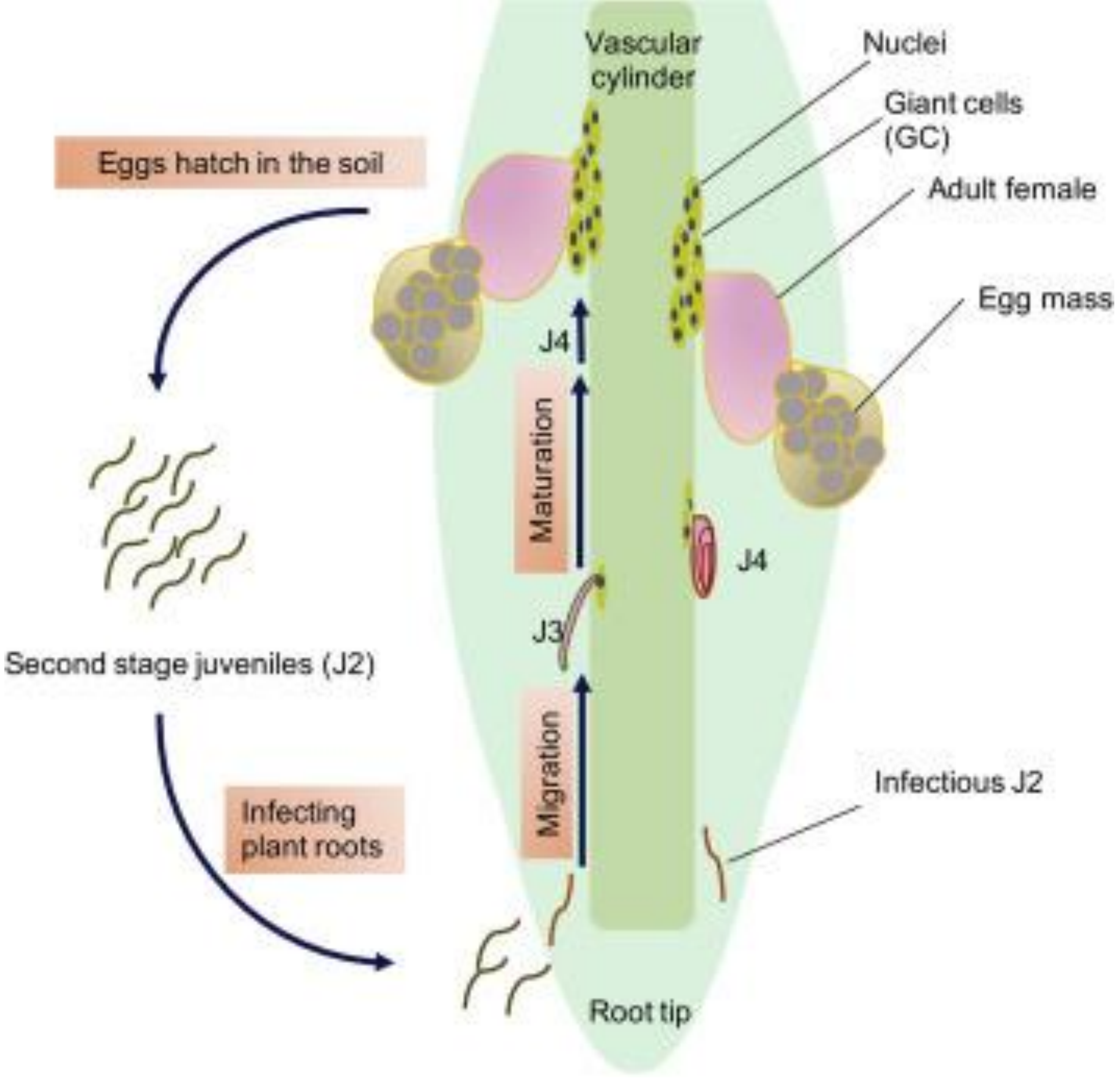
- J2 hatch from egg
- hatching dependent on temperature and moisture, with no stimulus from host plants required

- J2 move through the soil guided by root exudates
- enter roots by puncturing behind root tip
- enter developing tubers through lenticels

- establish a permanent feeding site – giant cells

- plant responds to feeding by producing gall tissue

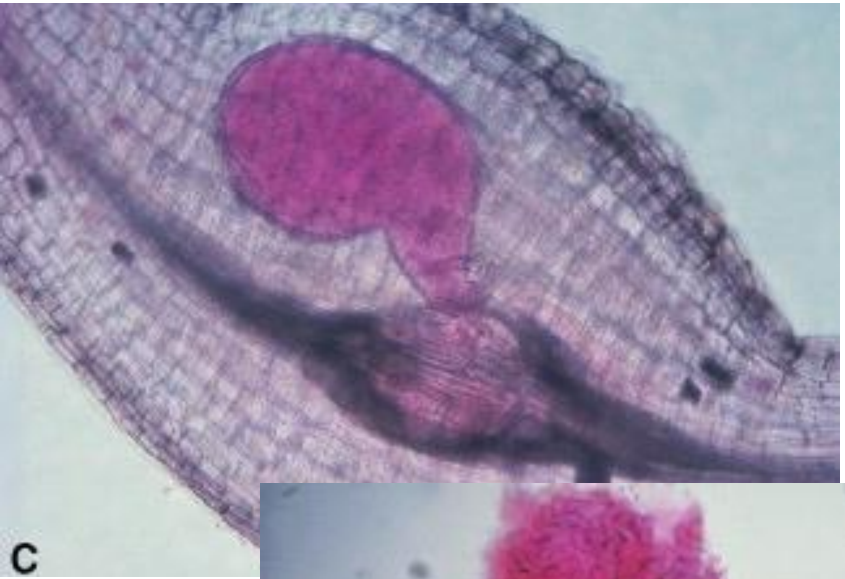
- Over 20-30 days feed and develop to mature females
- So enlarged split root – visible as pear shape

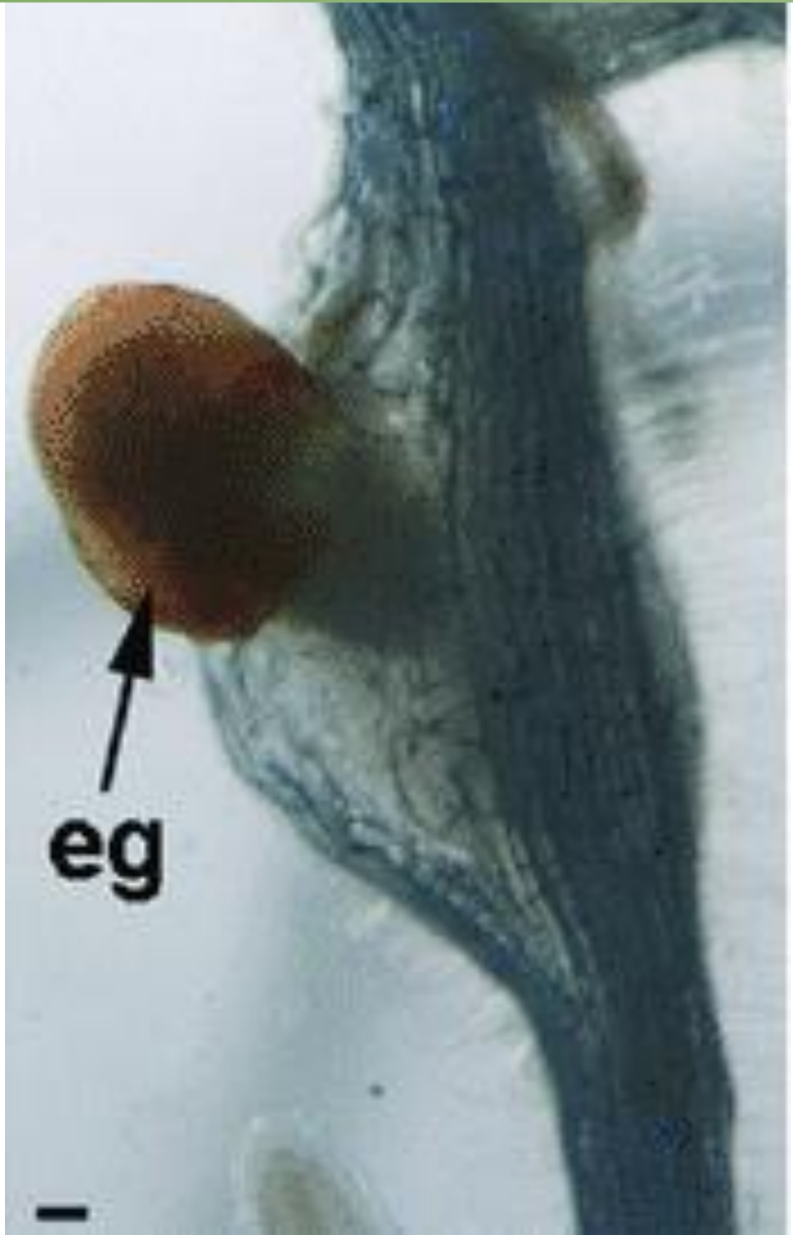


ROOT KNOT NEMATODE – Biology

- Enormous capacity to reproduce
- Female is able to produce up to about 1000 eggs

- 2nd gen hatch to re infect gall or new tissue





ROOT KNOT NEMATODE – Population Dynamics

- Depending on the
  - species
  - length of time the crop is in the ground
  - soil temperature

- Generally complete their life cycle between 4-10 weeks - 3 or more generations can occur

Nematode	Developmental temperature range[a] (°C)	No. degree-days for completion of lifecycle[b]	Approximate number of days between invasion of J2, development to egg-laying adult females and hatch of new J2 at the following **constant** temperatures (°C)					
			10°C	13°C	16°C	20°C	24°C	28°C
M. javanica	13 and 32 °C	371	-	-	124	53	34	25
M. incognita	10 and 28 °C	413	-	138	69	41	30	-
M. hapla[c]	8.5 and 28 °C	499	333	111	67	43	32	-



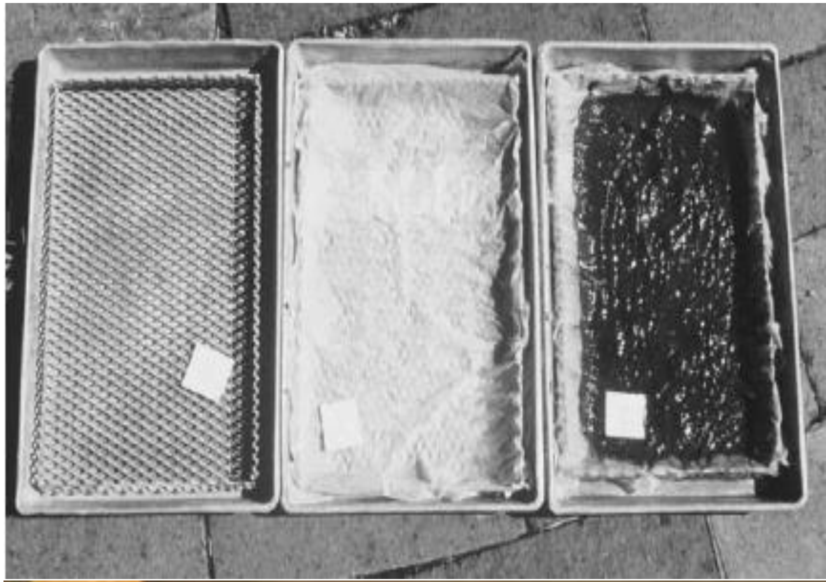

knot nematodes: severe symptoms caused by *Meloidogyne fallax*.

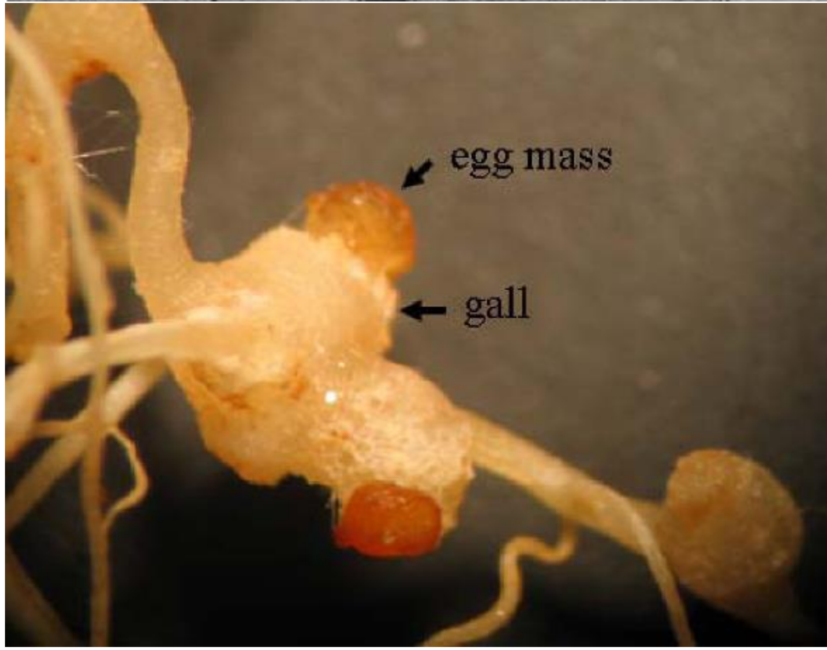
Root-knot nematodes: knotted spots on the skin surface.

GO BACK

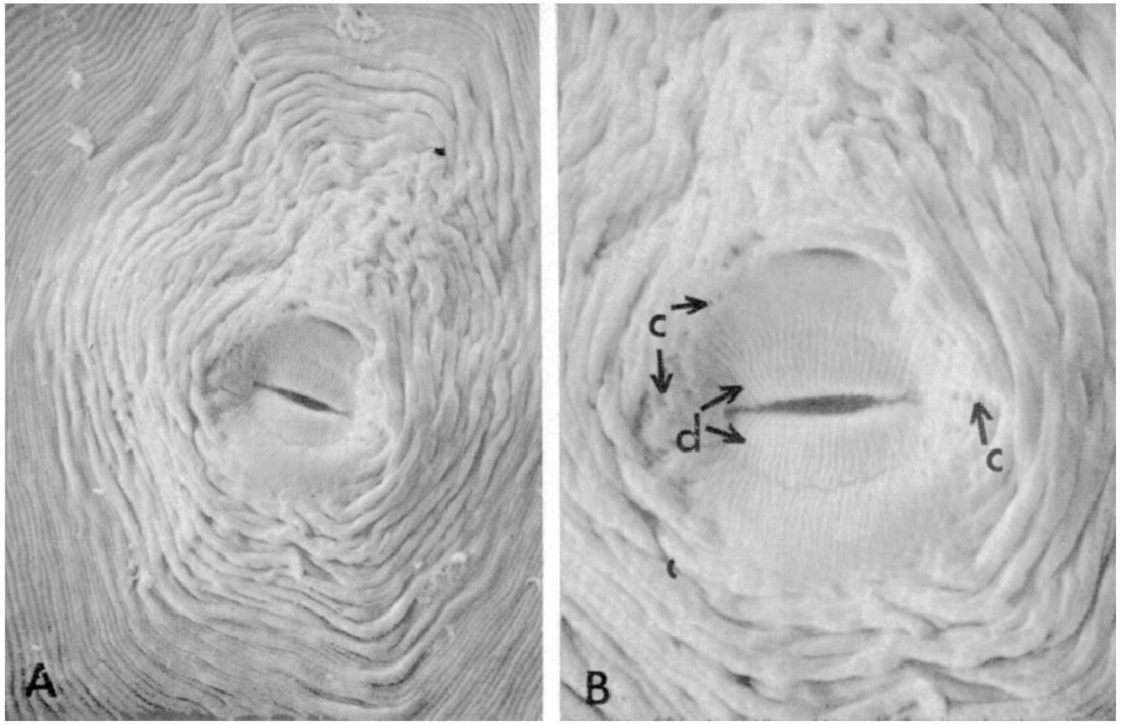
ROOT KNOT NEMATODE – Population Dynamics

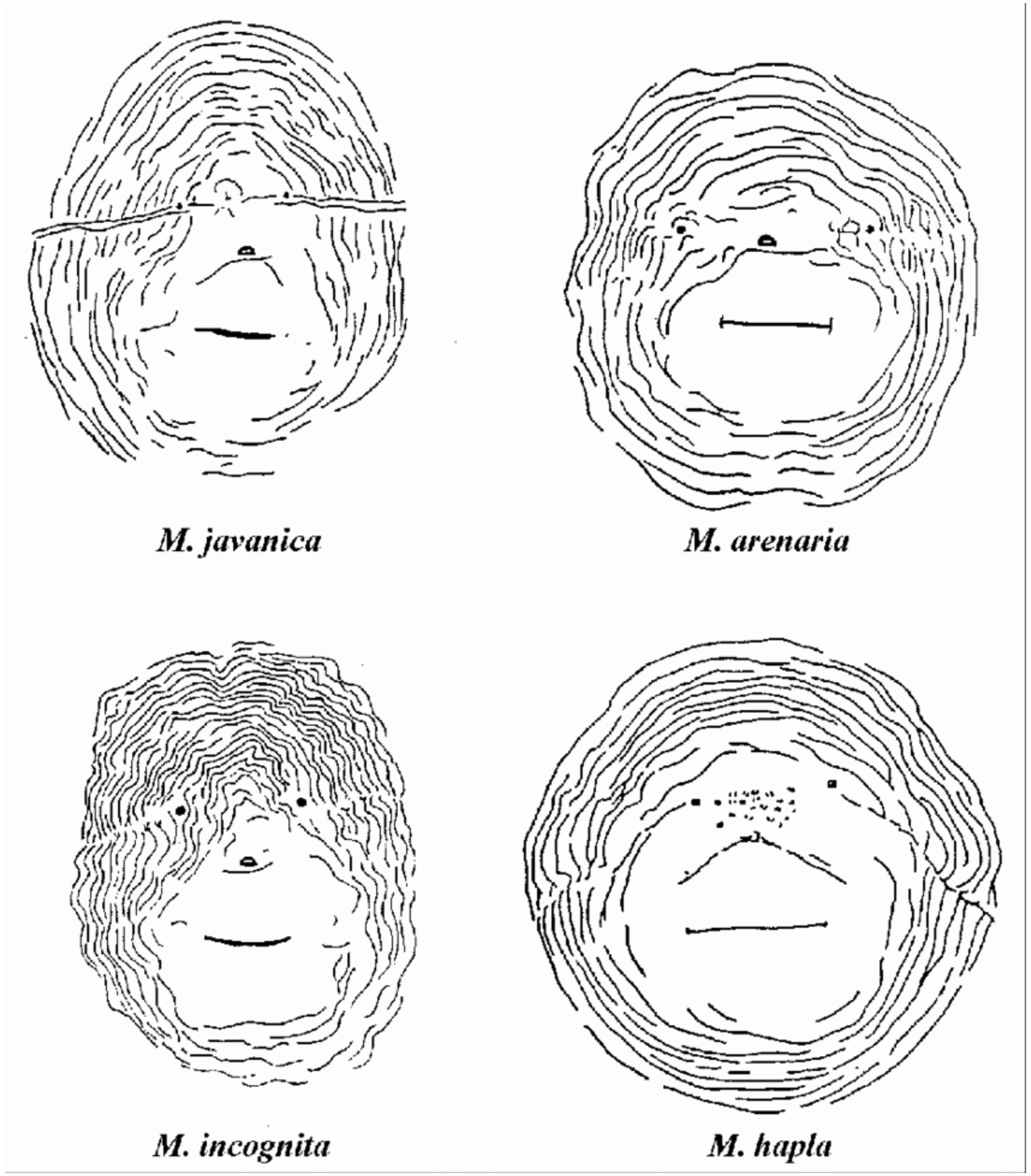
- J2 only motile stage so they can be extracted from soil
- All other stages extracted from roots and tubers by dissecting from galled tissue.
- Morphological ID to
  - genus from motile stage and
  - species using perineal pattern





ROOT KNOT NEMATODE – Population Dynamics





ROOT KNOT NEMATODE – Population Dynamics

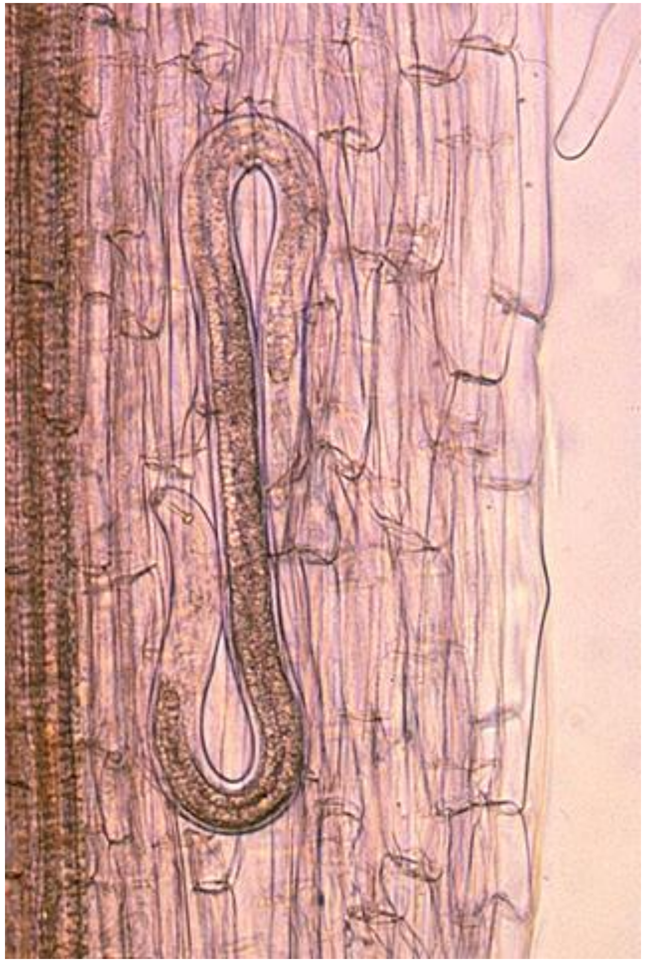
- Metabolically inactive and do not move/hatch when the soil is dry
- Prefer porous sandy and sandy loam soils <15% clay content
- Have not evolved specialised survival mechanisms in the absence of host plants
  - Numbers decline after crop is harvested thus can control with weeds and volunteer free fallows
- Instead, it has a very wide host range (>2000 plant species)
  - Thus control through crop rotation can be difficult (Winter cereals)
- Repeated cultivation kills RKN -mechanical abrasion and drying
- Form disease complexes with other fungal and bacterial pathogens which can exacerbate crop damage

ROOT LESION NEMATODE
Pratylenchus

ROOT LESION NEMATODE - *Pratylenchus*

The widespread species in Australia

- ***P. penetrans*** — Carrot, Potato, Beetroot, Strawberry
- ***P. crenatus*** — Most vegetables, Strawberry, Apple
- ***P. neglectus*** — Potato, Onion, Brassicas
- ***P. thornei***
- ***P. zeae***



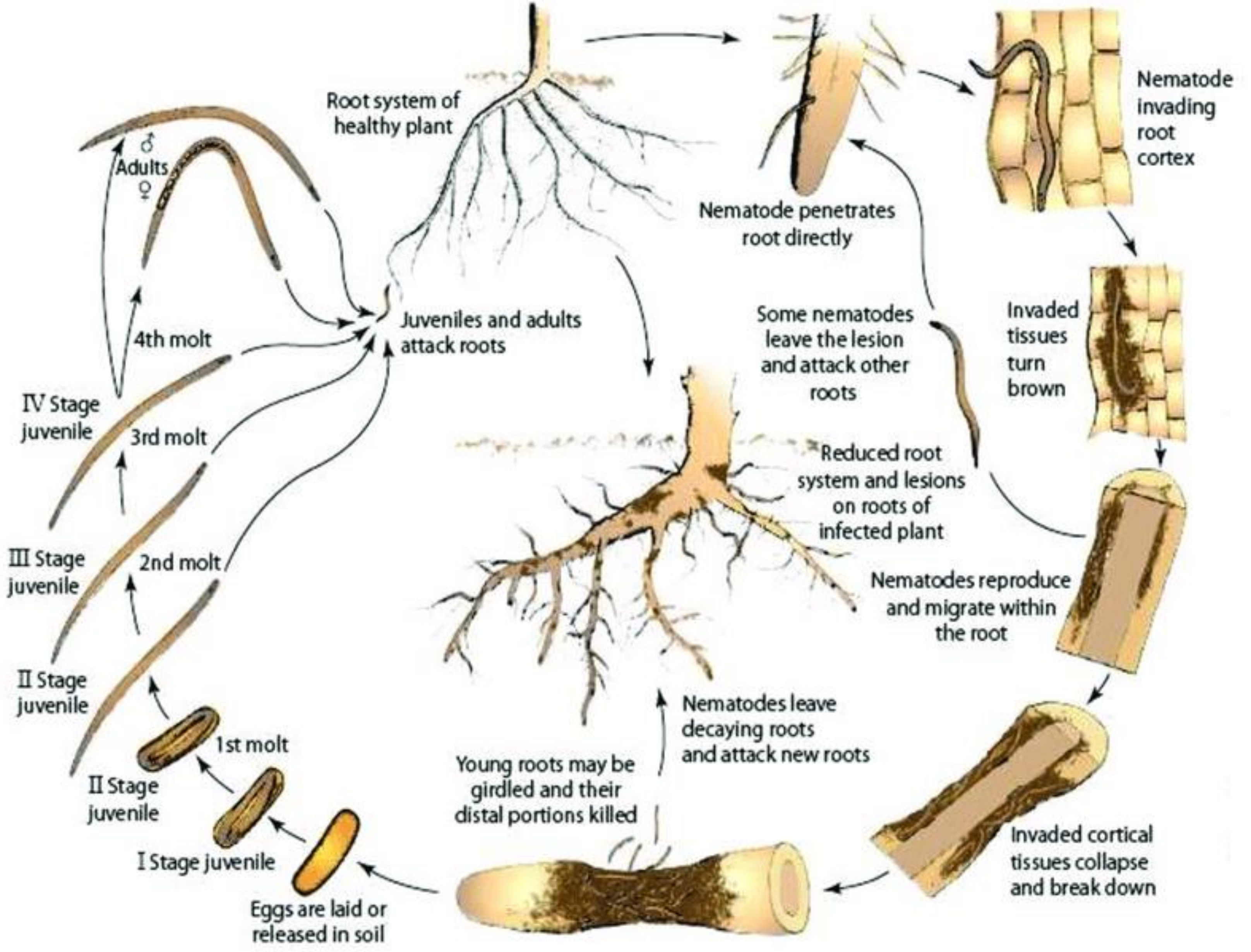
Present but not widespread

- *P. brachyurus*
- *P. coffeae*
- *P. jordanensis*
- *P. vulnus* — Grapes, Apple
- *P. pratensis*

- We don’t have ***P. scribneri*** – major problem in potatoes worldwide

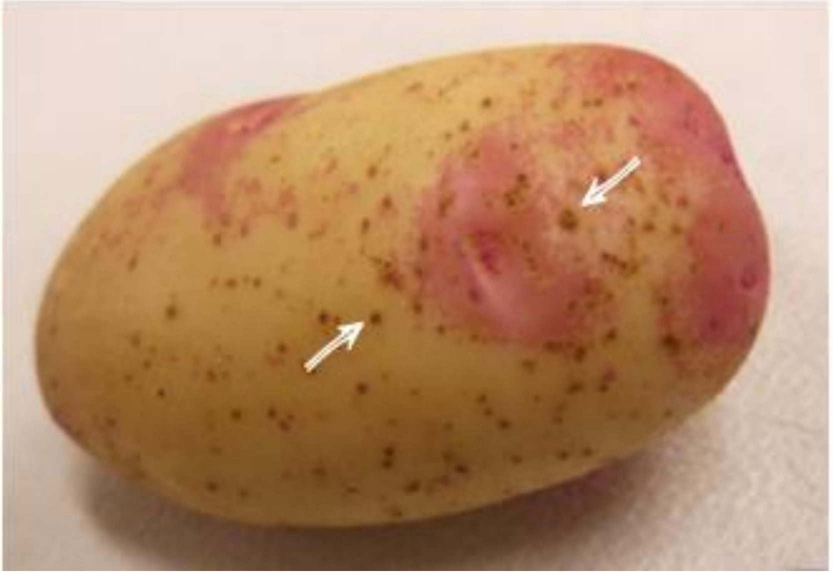
ROOT LESION NEMATODE - *Pratylenchus*

- Migratory endoparasite
- Nematodes move, feed and reproduce within the cortex and don’t enter the vascular tissues
- Feeding causes cells to collapse and break down and lesions occurs
- All life stages (except eggs) can infect roots
- Life cycle 40-65 days so if a host is present 2-3 generations per year.
- Reproduce asexually
- Females lays eggs singly – (1-2 eggs/ day)



Damage to potato root system caused by *Pratylenchus penetrans.*
IMAGE: MARIA VIKETOFT, SWEDISH UNIVERSITY OF AGRICULTURAL SCIENCES

ROOT LESION NEMATODE - *Pratylenchus*



- Mostly feed in roots but will infest tubers and underground stems
- Small, light brown, depressed lesions on tubers are similar to symptoms caused by other pathogens and abiotic stresses.
- May only be noticed when heavy infestation

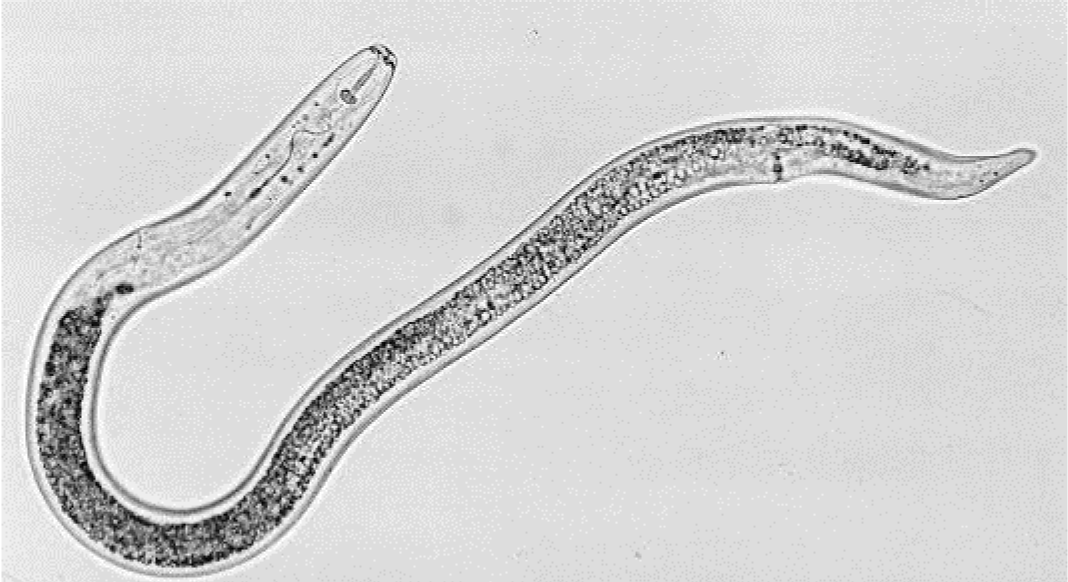
ROOT LESION NEMATODE - *Pratylenchus*

- Above ground symptoms not diagnostic – moisture stress
- Control with crop rotations is difficult due to the wide host range

- Oversummer as eggs or as adults in a dehydrated state (anhydrobiotic)
  - can survive in dry soil for years
- Also survive in tubers

ROOT LESION NEMATODE - *Pratylenchus*

- Damage caused by feeding increases the susceptibility of roots to infection by fungal pathogens, particularly *Verticillium dahliae* and *Fusarium* spp.
- The lesions also known to be initial invasion and establishment of other fungi such as *Pythium*, *Rhizoctonia* and also some bacteria
-
- Correct species ID important – selection non host rotations and resistant varieties
- Morphologically similar thus difficult to ID.



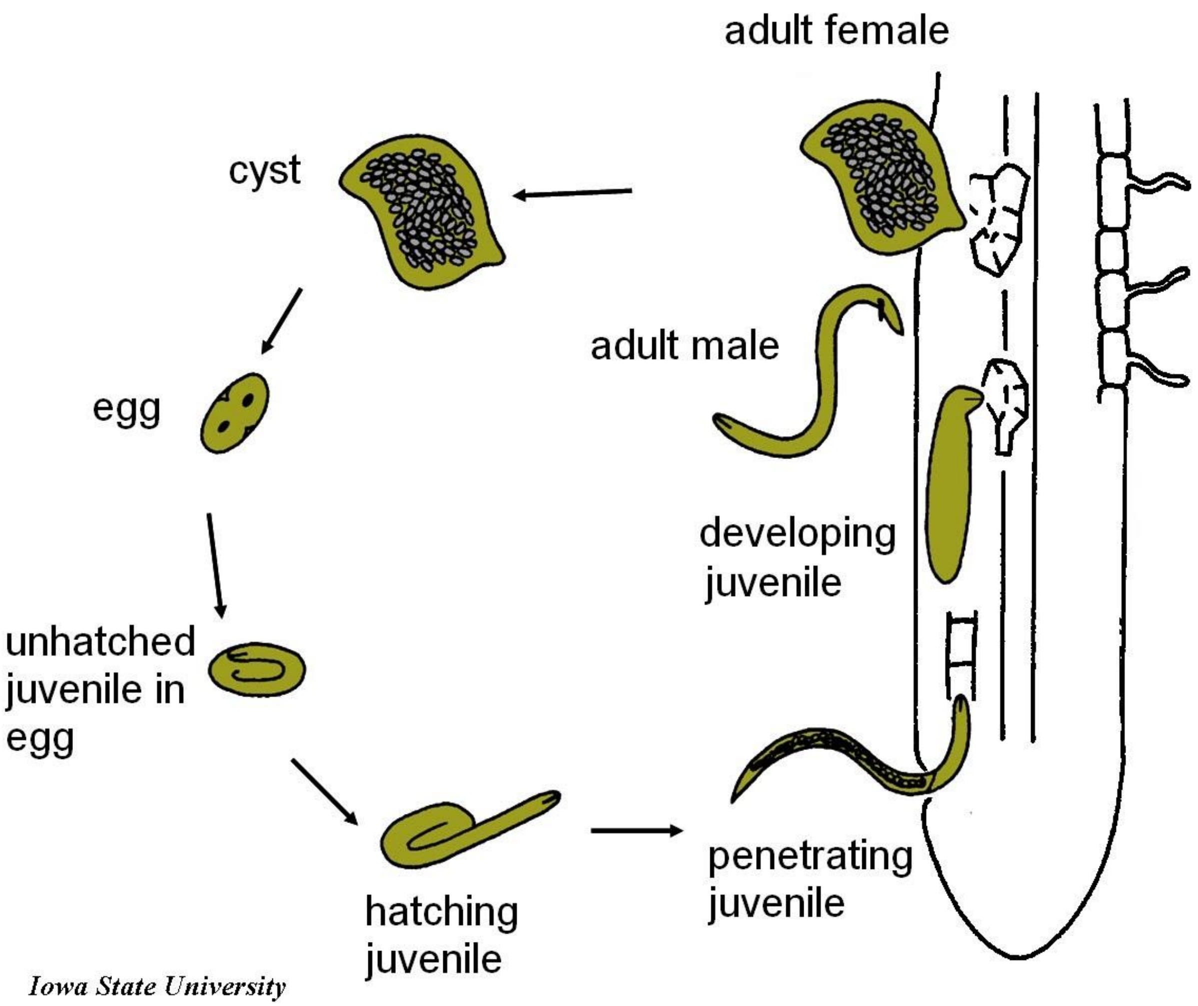
CYST NEMATODE
Heterodera

CYST NEMATODE - *Heterodera*

- 57 species described - In Australia 2 important parasites of vegetable crops
- ***H. schachtii*** - Sugar Beet Cyst Nematode
- ***H. cruciferae*** - Cabbage Cyst Nematode (WA Declared pest) SA on Cabbage
- parasitise cruciferous crops (cabbage, cauliflower, Brussels sprouts, broccoli, turnip, radish and Swede) *H. schachtii* also on beets (red and silver), rhubarb and spinach
- Also present
- *H. humuli* – Hop Cyst Nematode (Tas and Vic) (peas, beans, vetch, mustard, clover)
- *H. trifolii* – Clover Cyst Nematode (Clover, Lucerne, Soybean, Spinach, Tumeric, Solanum, Pea and Bean)
- *H. australis* – Cereal cyst nematode (formally *H. avenae*)
- *H. mani* – Ryegrass cyst nematode

CYST NEMATODE - *Heterodera*

- Most species require root exudate and moisture to stimulate egg hatch
- Hatched J2 invade near the tips
- Establish specialised feeding sites just outside the vascular tissue - syncytia.
  No root galls are induced
- Juveniles moult to adults and swell and rupture root
- Lemon shaped females die and harden to form a cyst



CYST NEMATODE - *Heterodera*

- lemon shaped females die and harden to form a cyst
- 100-300 eggs per cyst

- Life cycle 4-8 weeks, depending on temperature.
- Thus up to 5 generations per season possible in warm climates, when plants are re-invaded by hatched juveniles

CYST NEMATODE - *Heterodera*

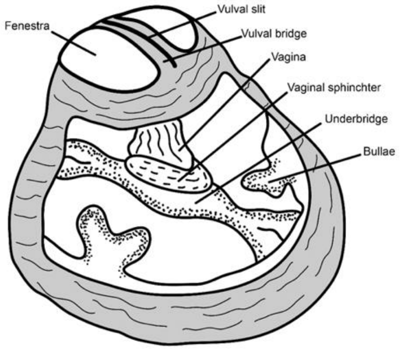
CYST NEMATODE - *Heterodera*

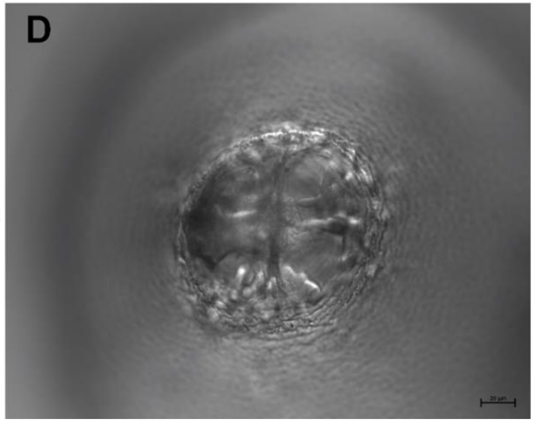
- Cysts can remain viable in the soil for several years, even in the absence of a host plant

- Not all eggs in a cyst will hatch at the same time, thus hatching can continue over several years
  - 3-4 years of crop rotation with non host crops are required
  - Rotation is more useful for preventing build-up than for reducing high populations

- Males are worm-like and usually exist the root to mate with females
  Juveniles and males can be found in the soil along with cysts
- Cysts can be extracted from soil by flotation.

- ID of species can be done from males/J2 motile stage or from cyst (difficult)



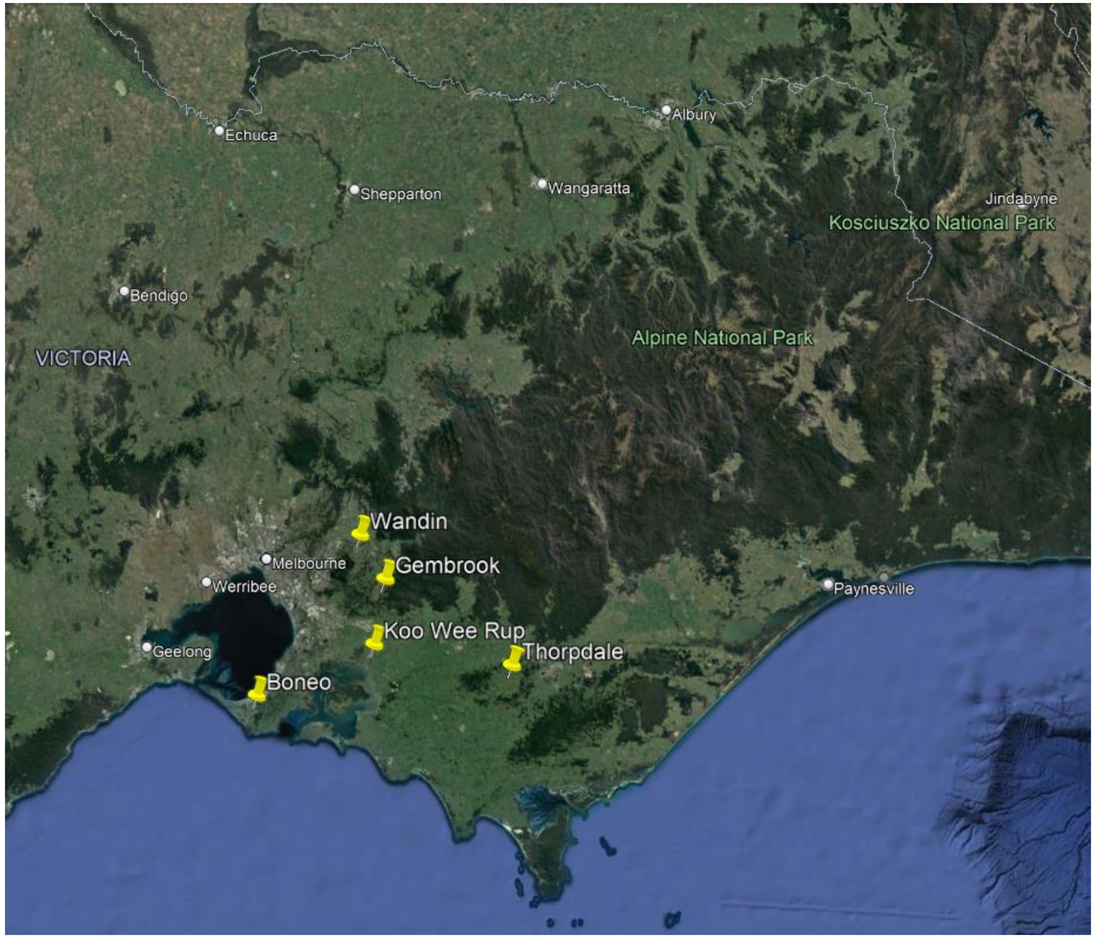


CYST NEMATODE - *Heterodera*

- **Not present in Australia**
- ***H. carotae*** – Carrot cyst nematode (an exotic plant pest - notifiable pest)
- ***H. glycines*** – Soybean cyst nematode (an exotic plant pest - notifiable pest)
- ***H. goettingiana*** – Pea cyst nematode

POTATO CYST NEMATODE - *Globodera*

- ***G. rostochiensis*** was previously detected in WA in 1986 but eradicated since 1989 from the state
- Notifiable pest
- At present, in parts of Victoria
  - all PCN-affected parcels of land are Control Areas to prevent spread
  - Potatoes imported into WA not allowed into Gin Gin and South-west



Not present in Australia

- ***G. pallida*** - Pale potato cyst nematode

POTATO CYST NEMATODE - *Globodera*

STEM & BULB NEMATODE

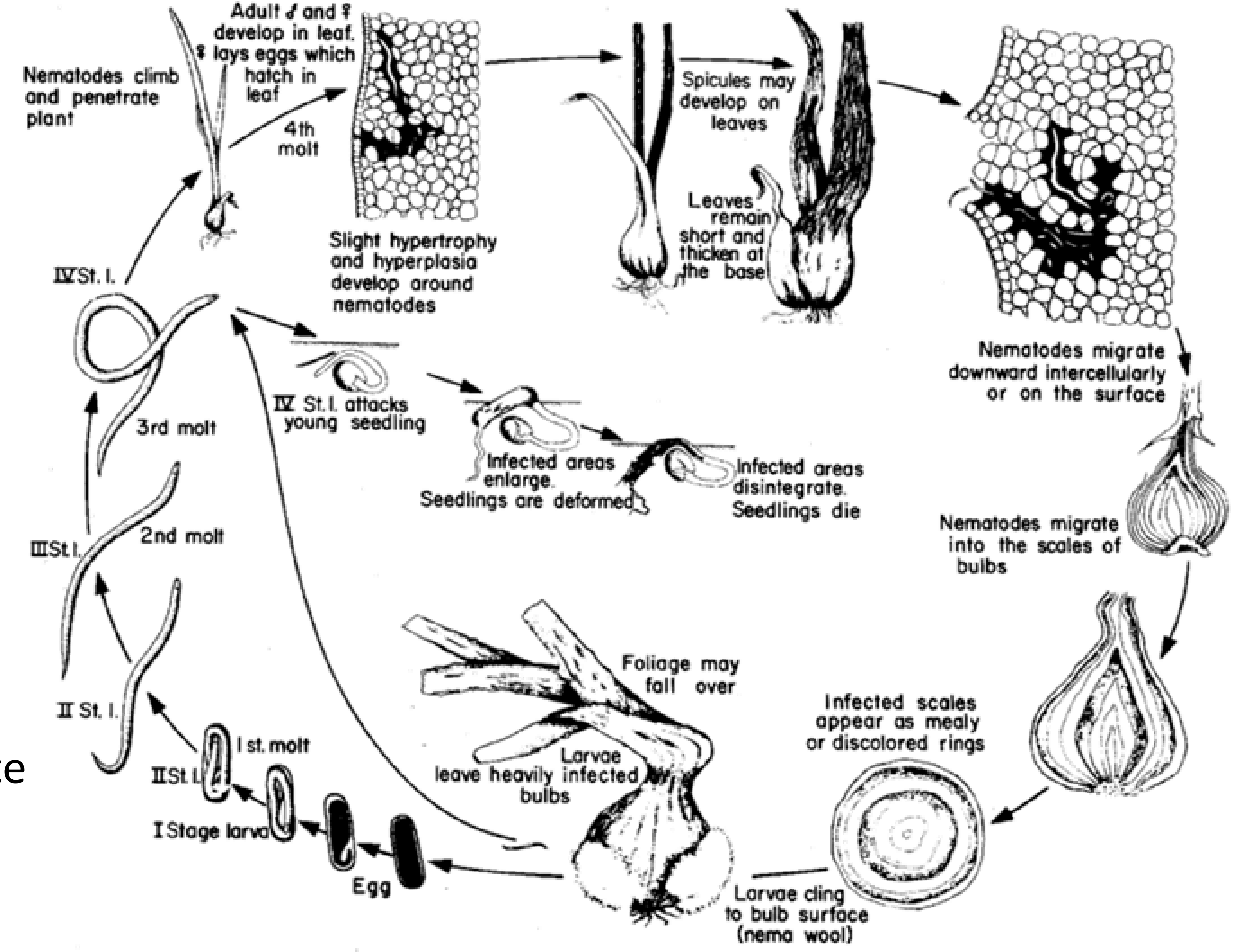
Ditylenchus dipsaci

STEM & BULB NEMATODE – *Ditylenchus dipsaci*

- ***Ditylenchus dipsaci*** - few nematode species that invade above ground parts
- Migratory endoparasites that infect
  - roots
  - bulbs (onion and garlic),
  - tubers (potato and carrot) and
  - stems and leaves (onion, garlic, potato, lucerne, clover, oat, beans & strawberry)
- Large host range of > 500 plant species and >30 of 'biological races'
- In Australia Oat race and Lucerne race
  Oat race polyphagous oats, onion, broad bean, common bean, faba bean, field pea, Beta vulgaris and many weeds
- Present in all states except WA
- Quarantine pest in many countries
- Don't have ***D. destructor*** (Potato rot nematode) wide spread in Europe in tubers

STEM & BULB NEMATODE – *Ditylenchus dipsaci*

- All life stages vermiform and are infective
- Nematodes can invade
  - roots
  - stomata on leaves
  - epidermis at leaf bases
- Feed on parenchyma tissues of the middle lamella, cause extensive tissue destruction
- cells around them divide and enlarge to form the swellings and distortions
- It has a short life cycle and a high multiplication rate
- Eggs are laid in the plant tissue
- Each female lays 200-500 egg
- Life cycle is **FAST** - 19-25 days in good conditions



STEM & BULB NEMATODE - Symptoms

- Invade young tissues while still below the soil surface
- Prefers
  - heavier soils,
  - cool temperatures and moist conditions
- Nematodes move upwards to the new leaves and stems on films of water

- Stems are often swollen, stunted and distorted with malformed leaves.
- Necrosis of stem bases, bulbs, tubers is also common

STEM & BULB NEMATODE - Symptoms

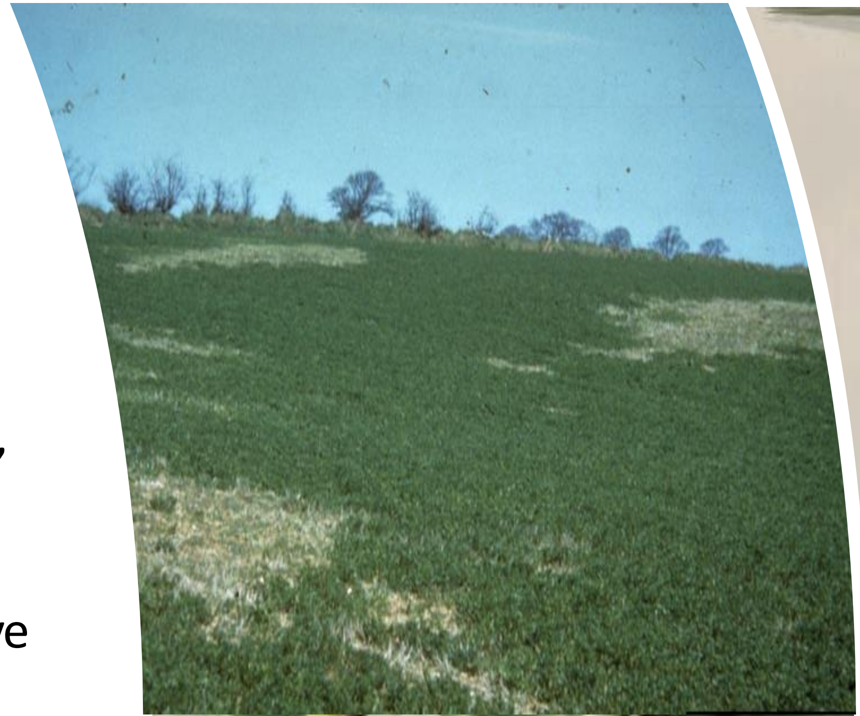
- The feeding causes deformed growth and swelling of bulbs and leaves ‘bloat’ and twisting of leaves.
- Onion seedlings are pale and twisted with puffy cotyledons with a cracked appearance
- Damage to growing point of young plants results in development of more than one crown.

- Rotting of bulbs - inner scales become necrotic and brown (rings in cross section) and rot
- Cause substantial post-harvest losses in stored onions

STEM & BULB NEMATODE - Symptoms

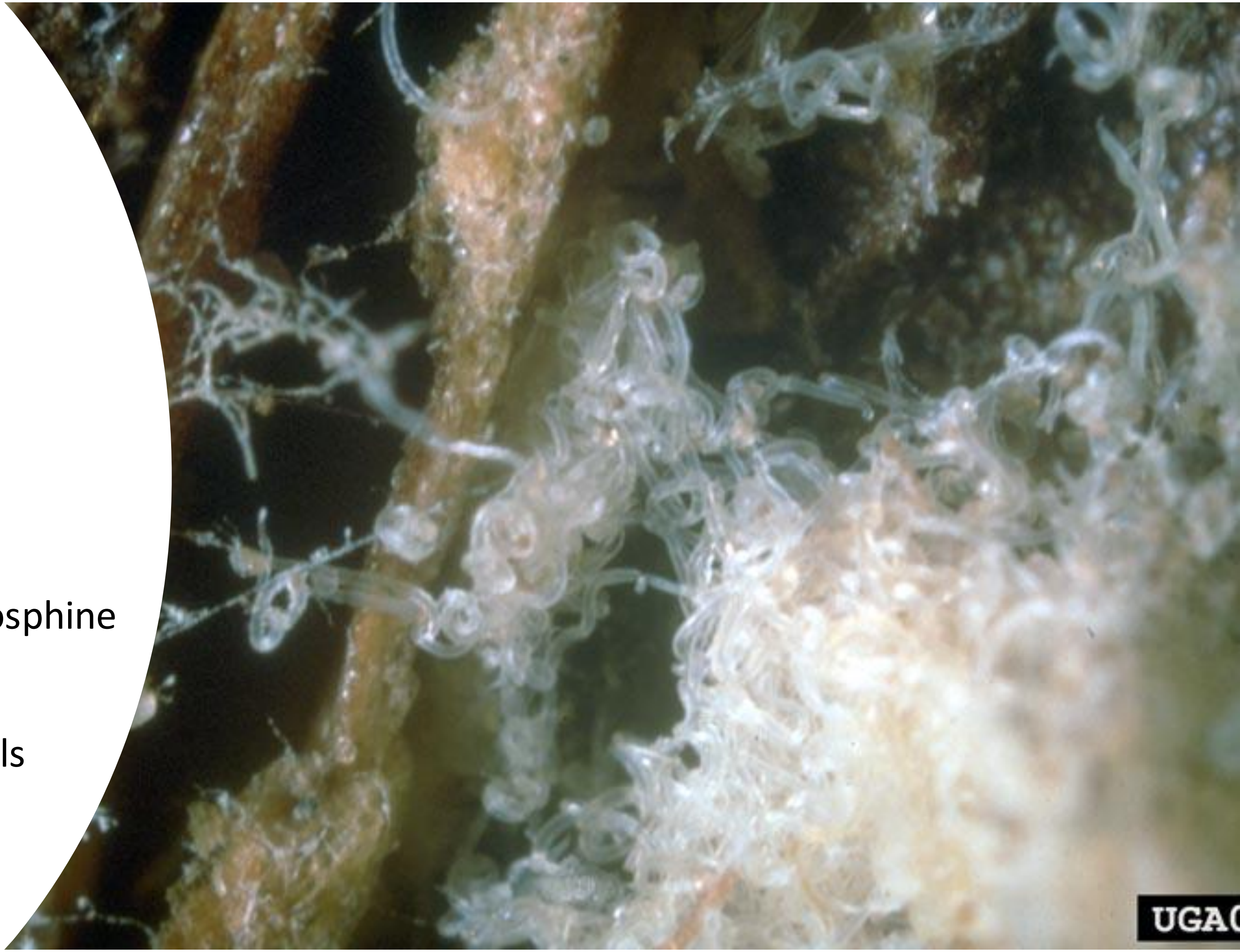
STEM & BULB NEMATODE - Symptoms

- In beans and peas swollen, distorted stems with brown to black lesions
- In lucerne thickened and shortened stems, new shots stunted and close to the ground yellow leaves and may show white flagging, rapid defoliation
- In oats usually produce extra tillers and have ‘tulip root’ appearance



STEM & BULB NEMATODE - Survival

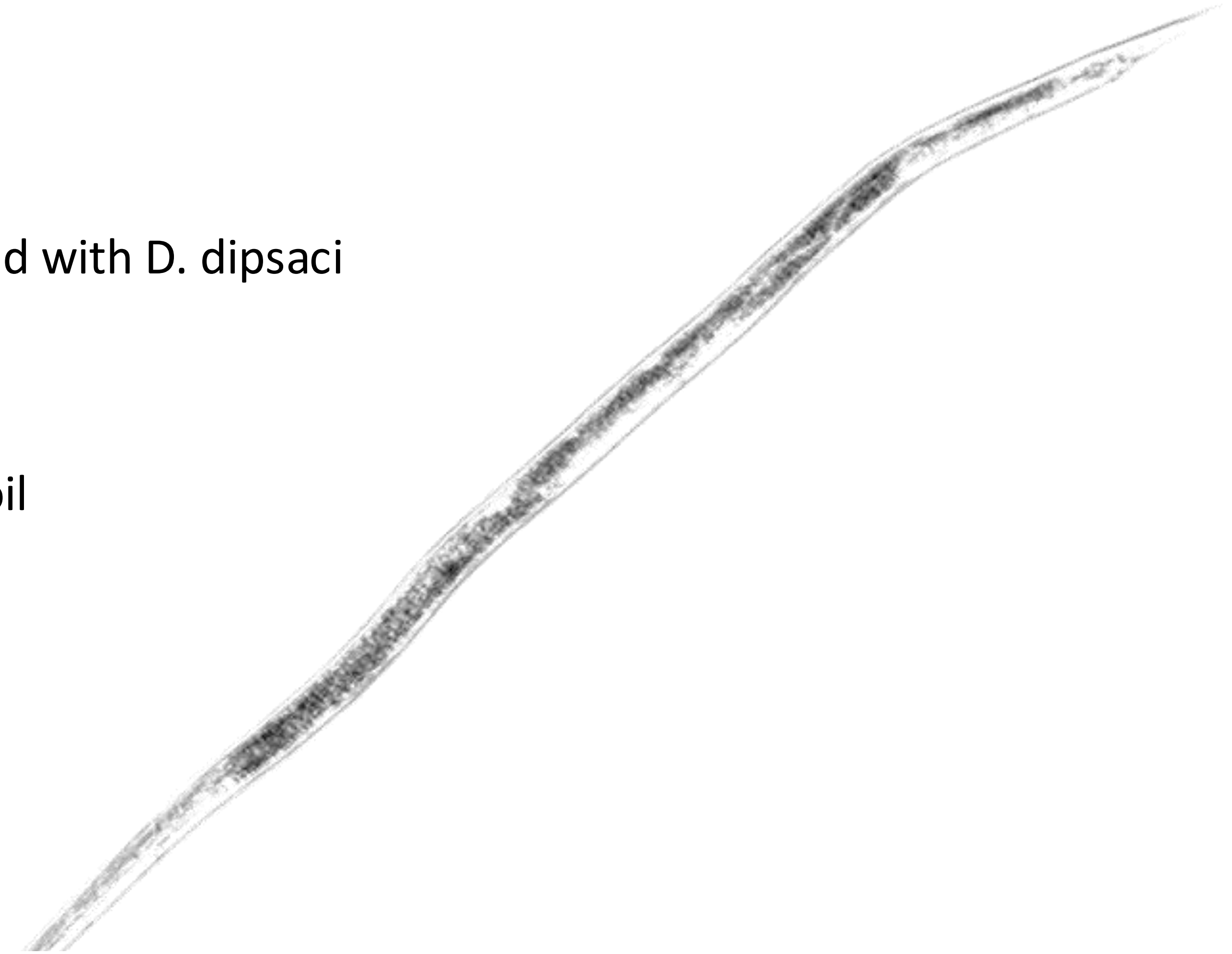
- In the later stages nematodes aggregate into mass often called ‘nematode wool’.
- slowly dry out into a anhydrobiotic state enables survival for many years >20yrs
- Can survive in root, bulbs and soil
- Seedborne on about 15 plant species
- If in the dehydrated state can survive fumigation with methyl bromide and phosphine
- Survival and damage greater in heavy soils



STEM & BULB NEMATODE - Identification

- Not easy to ID morphologically
  small delicate stylet & few distinguishing features
- There are several native species which may be confused with D. dipsaci

- Can be easily extracted from the infected tissue and soil
  - Cut infected tissue in a dish of water



STEM & BULB NEMATODE - Control

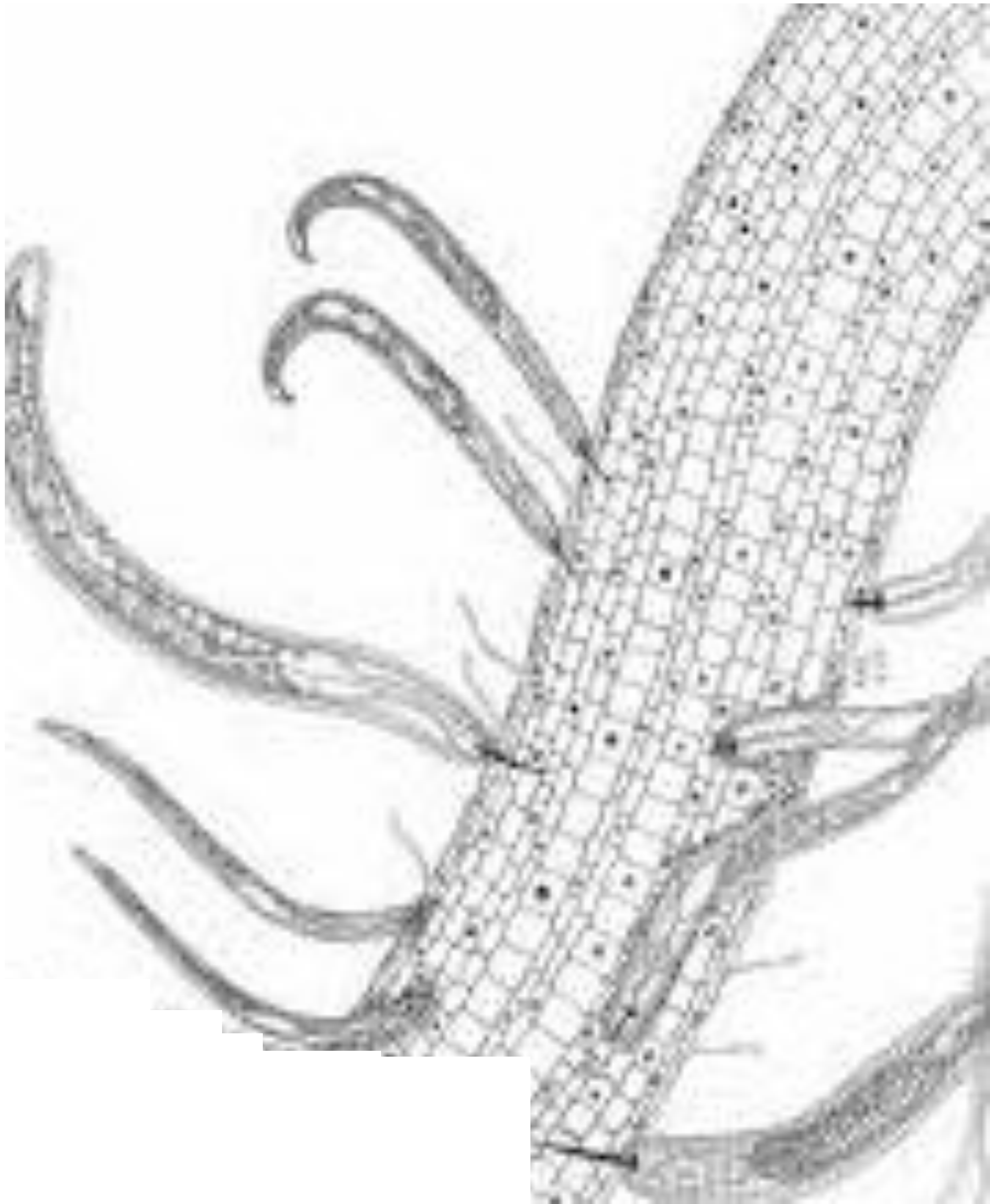
- Spread is generally
  - via water (irrigation, natural water courses in paddocks)
  - infected seed material and hay

- The survival potential and large host range enables long term persistence thus prevention is better than control

- Certified nematode free seed
- Despite large host range effective crop rotation systems can be developed.
  - Most require 4 years between plantings of susceptible crops control
  - Remove of volunteers to reduce carry over

ECTOPARASITIC NEMATODES of Vegetables

- Stubby root Nematodes - *Paratrichodorus*
- Awl Nematode – *Neodolichodorus*
- Needle Nematode – Longidorus and *Paralongidorus*
- Stunt Nematodes – *Tylenchorhynchus* and *Merlinus*
- Spiral Nematodes – *Rotylenchus*, *Scutellonema* and *Helicotylenchus*
- Pin Nematodes- *Paratylenchus*
- Sheath Nematode - *Hemicycliophora*
- Ring Nematode – *Criconemoides*
- **Large host range but don't cause economic damage**



STUBBY ROOT NEMATODE

- ***Paratricodorus minor***
- ***Paratricodorus porosus***
- ***Paratrichodorus lobatus***

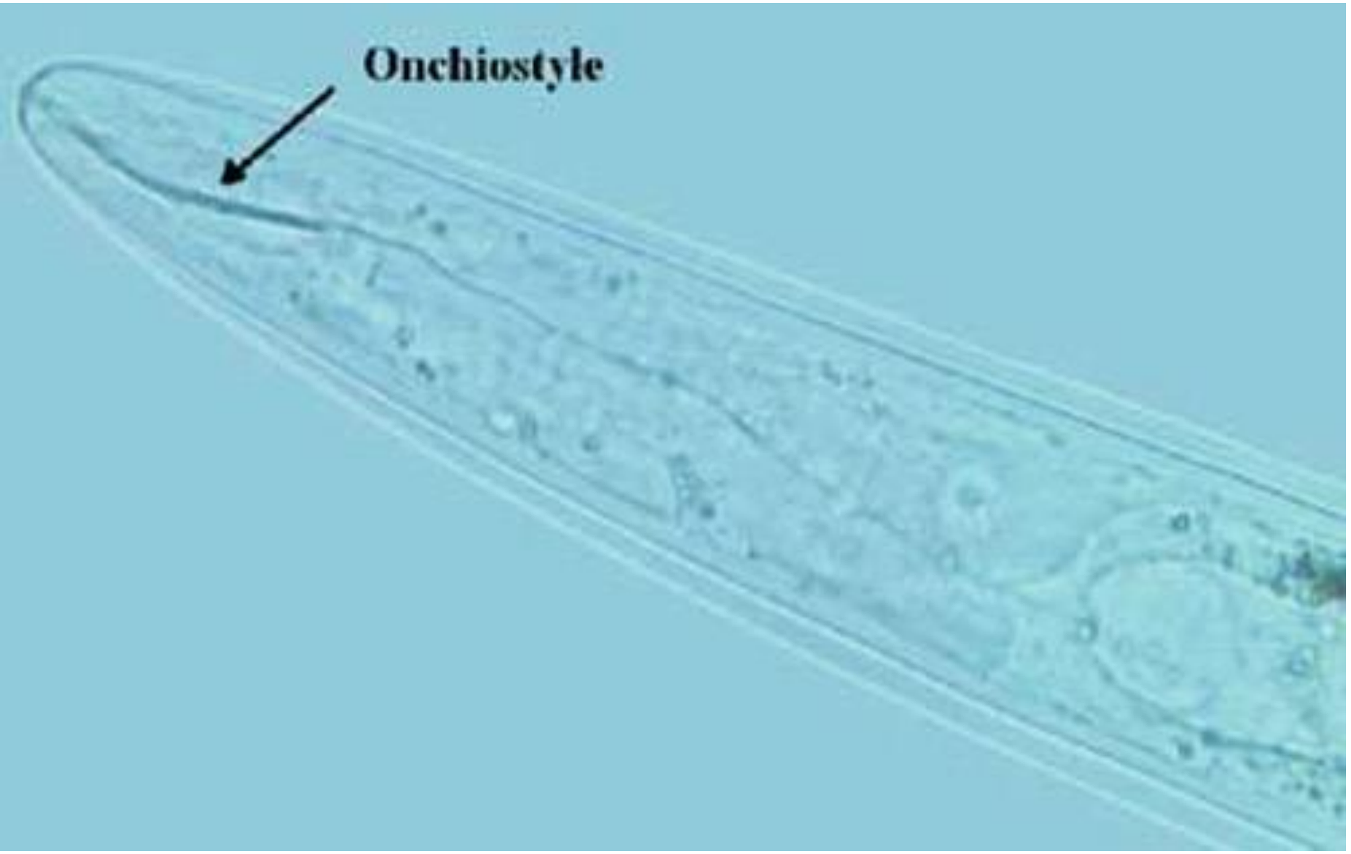
- feeds over whole root surface, but mainly at root tips, leading to typical 'stubby root' symptoms and root proliferation
- *P. minor* at high numbers cause crop losses to many vegetable crops
- Most prevalent in coarse-textured soils

- In carrots stops normal growth of the storage root by feeding on the root tip

STUBBY ROOT NEMATODE

- Stunted growth of onion seedlings
  leaves become yellow with necrotic leaf tips, and variable sizes of onion plants across the field
- Reduced root growth, excessive lateral root growth, branched and “stubby”-appearing root systems

STUBBY ROOT NEMATODE



- Morphologically unique – curved stylet and short (0.6-0.9mm) and sausage shaped
- Very mobile in the soil and can migrate vertically
    - difficult to quantify
    - and control through soil solarization and fumigation
- Some species are also vector tobacco rattle virus (TMV)

STUNT NEMATODE

- Over 100 species

- ***Tylenchorhynchus annulatus***
- ***Tylenchorhynchus clarus***
- ***Tylenchorhynchus claytoni***
- ***Tylenchorhynchus dubius***
- ***Tylenchorhynchus mashoodi***
- ***Merlinius brevidens*** Cereals

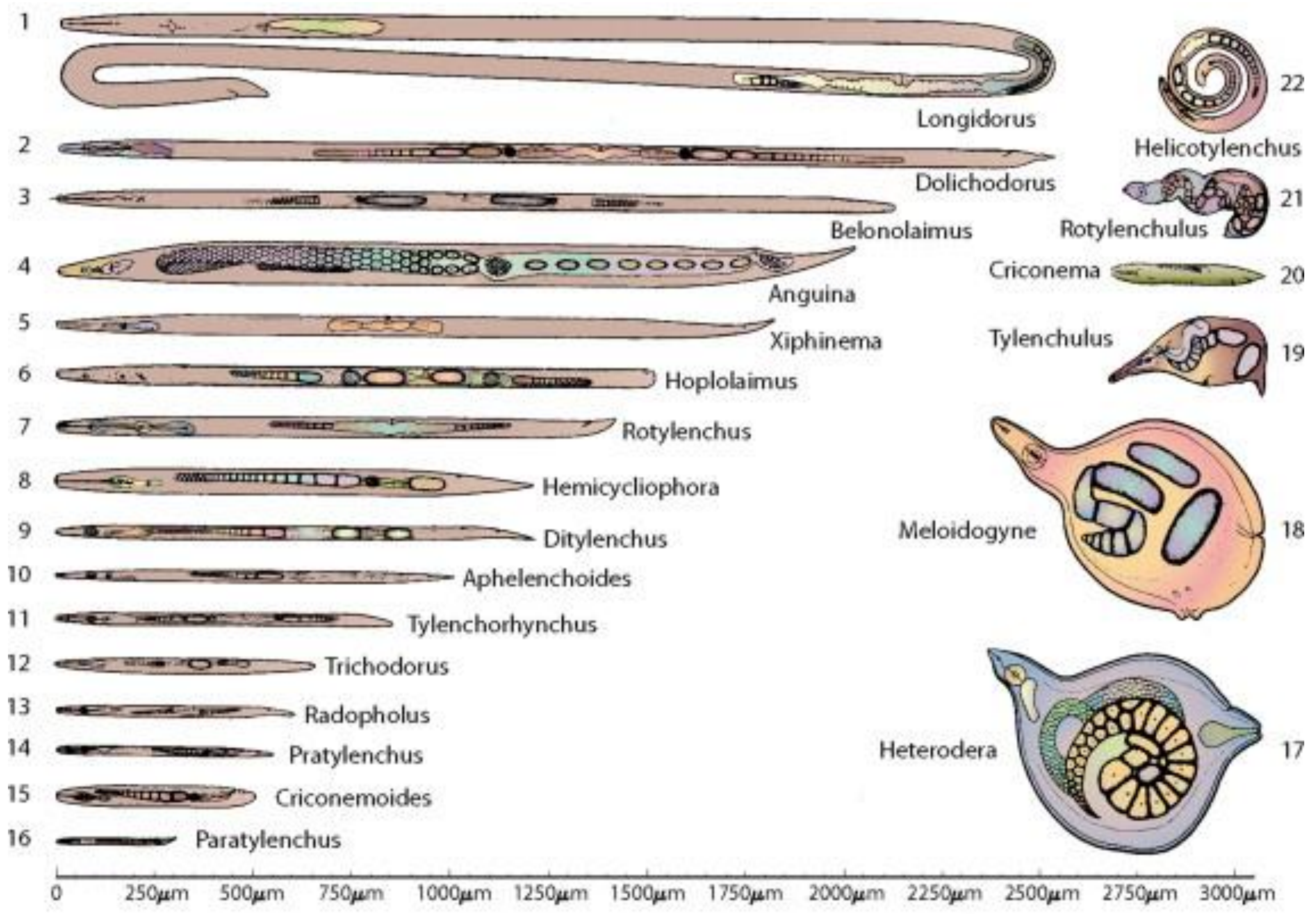
- Feed on epidermal cells and root hairs, but capable of endoparasitic feeding on some hosts

- Commonly associated with areas of poor growth in cabbage and cauliflower

PIN NEMATODE

- ***Paratylenchus* spp.**

- Smallest PPN
- Wide host range which includes several major vegetables
- *P. hamatus* causes a 'rat-tail' appearance to carrot taproots



NEEDLE NEMATODE

- Largest PPN - up to 10mm in length and very stylets often > 1mm
- ***Longidorus elongatus*** Strawberry and Carrot
- ***Paralongidorus* spp.** Potato

- Feed on root tips causing cell death and loss of the growing point sometimes confused with galls produced by RKN
- The plant responds by developing new growing points - forking

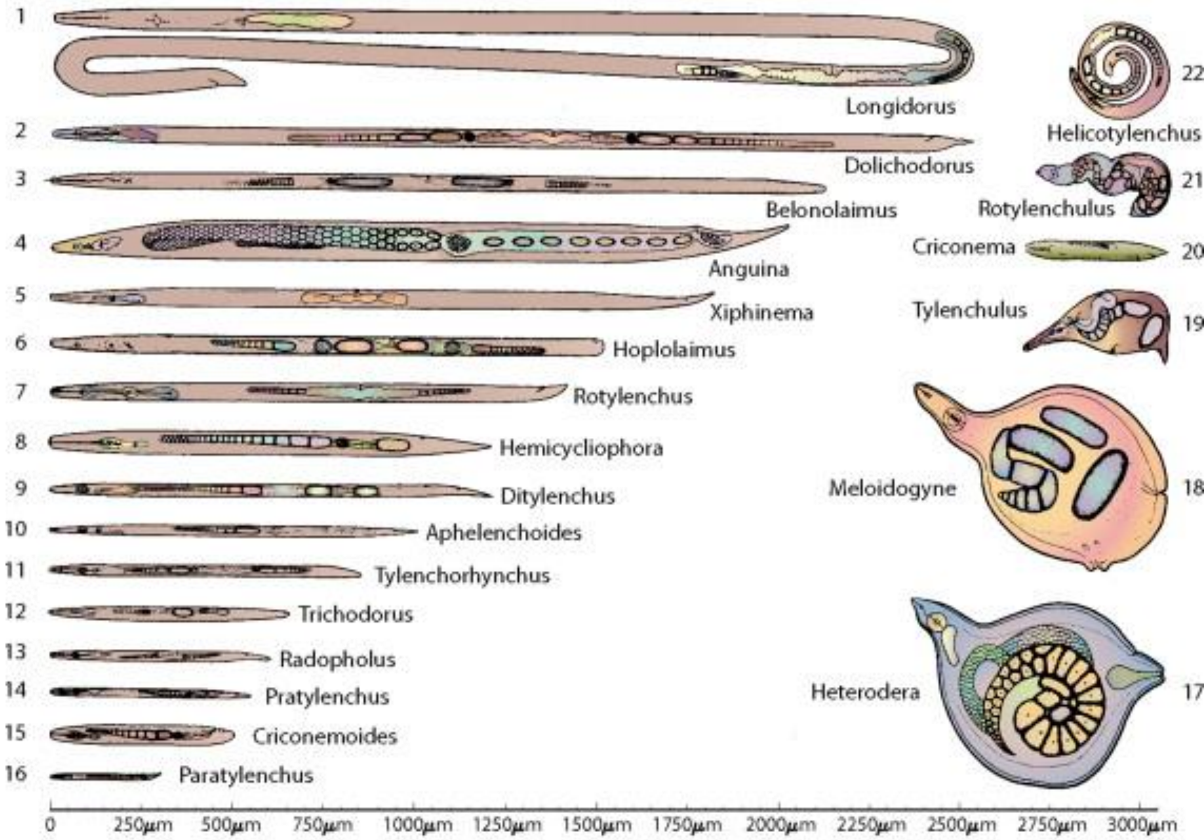
- Have extremely long life cycles 1-2 years

AWL NEMATODE - *Neodolichodorus*

- ***Neodolichodorus spp.***

- Moist to wet soil, low areas and near irrigation
- Large PPN - 1.5 mm to 3 mm,
- All stages feed on roots, sometimes remaining in one spot for up to a week.
- Feeds on small or large roots, root tips and the hypocotyl
- Brown lesions form causing dead or dying root tips leads to severe stunting
- Roots often coarse with stubby tips

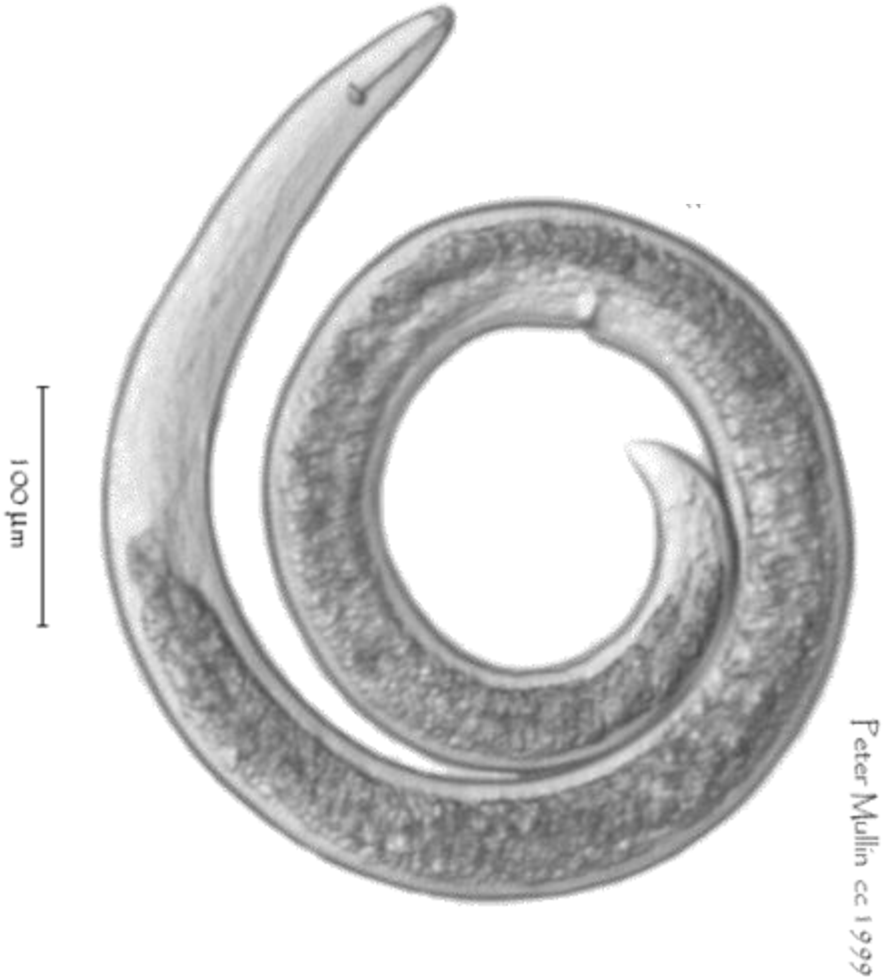
- Celery, bean, tomato, capsicum, cabbage, potato, carrot



SPIRAL NEMATODE

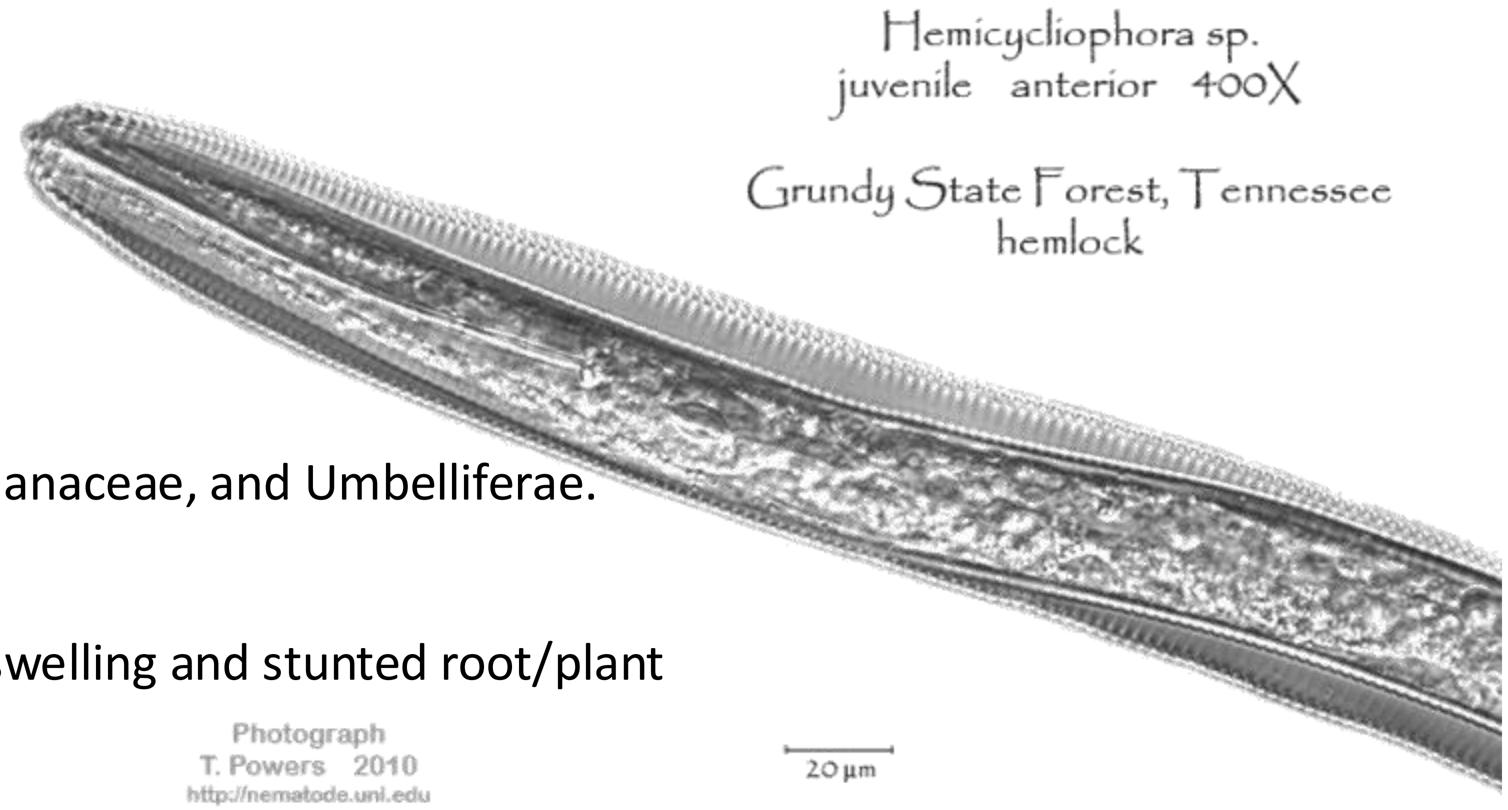
- ***Rotylenchus robustus***
- ***Scutellonema* spp.**
- ***Helicotylenchus dihystera*** Potatoes
- ***Helicotylenchus multicinctus*** Bannana

- Upon relaxation, female body usually forms a single spiral, sometimes C-shaped.
- *R. robustus* causes severe reduction in roots and stunting of top growth in carrots. Also infects lettuce, cabbage, red beet, parsnip, spinach, celery, cauliflower, pea.
- Prefers sandy soils
- Survives in fallow soil for up to 6 months
- Fairly long life cycle of about 100 days



SHEATH NEMATODE

- ***Hemicycliophora* spp.**

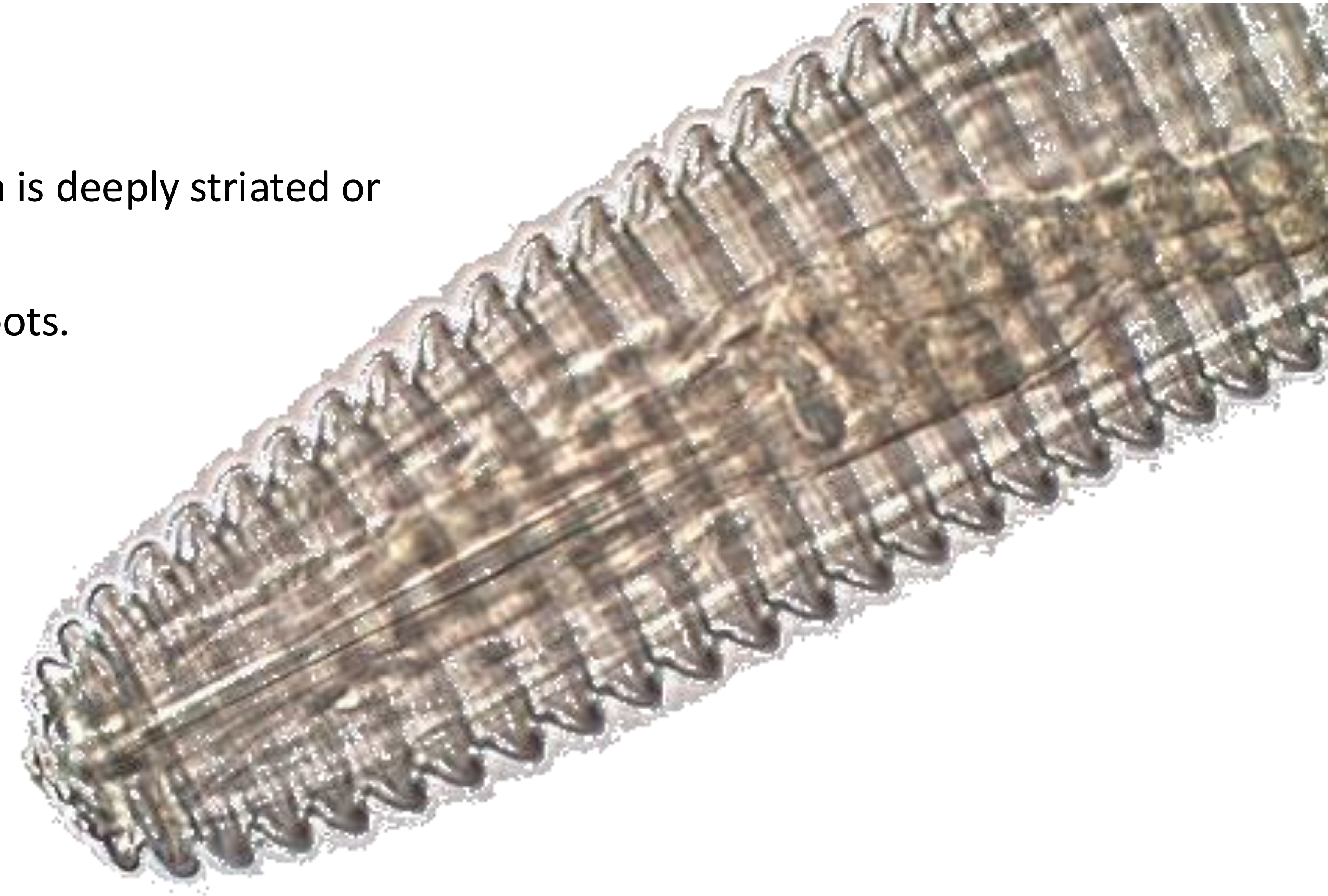


- Many species not considered economically important
- *H. sueri* identified casual pathogen poor carrot yields in SA.
- Cucurbitaceae, Leguminosae, Rutaceae, Solanaceae, and Umbelliferae.
- Feed usually near root tip causing root-tip swelling and stunted root/plant growth.
- Characterized by a sheath - an extra cuticular layer that surrounds, sometimes quite loosely, each life stage.
- Common in sandy soils

RING NEMATODE

- ***Criconemoides***

- Derive their name from their cuticle which is deeply striated or annulated.
- Feed on root tips or along more mature roots.



Sampling

- Timing is important because nematode populations fluctuate
    - Before planting (after cultivation/fumigation)
    - At harvest to determine the likely carry-over to help plan rotations
    - Highest in the root zone towards the end of the growing season or in late summer to mid-winter
- Nematode distribution is always patchy
- Sampling depth may differ for different crops
- In fallow field, samples should be taken from the depth of the root zone of the future crop
- For in season diagnostics
    - soil and plant samples from areas showing nematode damage (symptoms) and from healthy areas for comparison

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