

# Ultrasound of Peripheral Nerves

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## Disclosures

- Consultant: Bioclinica
- Advisor: Philips
- Book Royalties: Elsevier
- Not relevant to this lecture

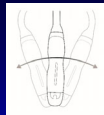
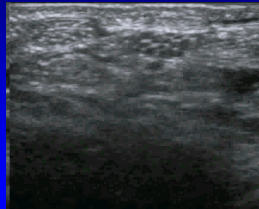
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## Normal Peripheral Nerve

- Ultrasound appearance:
  - Hypoechoic nerve fascicles
  - Hyperechoic connective tissue
- Transverse:
  - Honeycomb appearance



Silvestri et al. Radiology 1995; 197:291

Median Nerve

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## Nerve Compression

- Experimental model (rat, sciatic nv):
  - Compression causes ischemia
  - First pathologic change: edema
    - Correlated with severity of axonal injury
  - Mild compression: demyelination
  - Severe compression: axonal damage

Powell, Laboratory Investigation 1986; 55:91

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## Nerve Entrapment

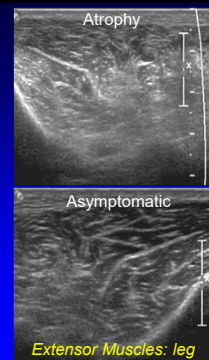
- US findings:
  - Nerve enlargement proximal to entrapment
    - Best appreciated transverse to nerve
  - Abnormally hypoechoic
    - Especially the connective tissue layers
  - Variable enlargement or flattening at entrapment site

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## Denervation

- Edema: hyperechoic
- Fatty degeneration:
  - Hyperechoic
  - Echogenic interfaces
- Atrophy:
  - Hyperechoic with decreased muscle size
- Compare to other side!

J Ultrasound Med 1993; 2:73



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## Nerve Entrapment Syndromes

- Median:
  - Carpal tunnel syndrome
  - Pronator teres syndrome
- Ulnar:
  - Ulnar tunnel syndrome
  - Cubital tunnel syndrome

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## Carpal Tunnel Syndrome:

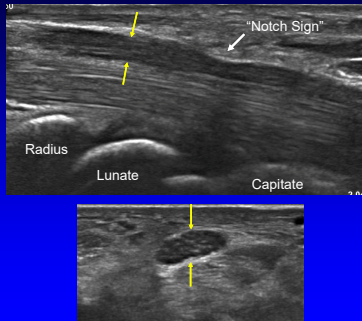
- Proximal median nerve swelling
  - Area: circumferential trace
  - Normal:  $< 9 \text{ mm}^2$
  - Borderline:  $9 - 12 \text{ mm}^2$
  - Abnormal:  $> 12 \text{ mm}^2$ 
    - $12.8 \text{ mm}^2$  = moderate (83% sens, 95% spec)
    - $14.0 \text{ mm}^2$  = severe (77% sens, 100% spec)



Klauser AS et al. Sem Musculoskel Rad 2010; 14:487  
Ooi et al. Skeletal Radiol 2014; 43:1387

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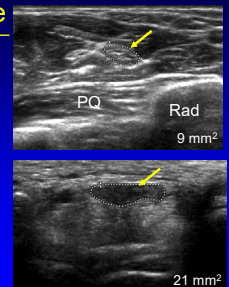
## Carpal Tunnel Syndrome



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## Carpal Tunnel Syndrome

- Compare areas:
  - Proximal: pronator quadratus
  - Distal: carpal tunnel
- $\geq 2 \text{ mm}^2$  = carpal tunnel syndrome
- 99% sensitivity
- 100% specificity



Klauser AS. Radiology 2009; 250:171

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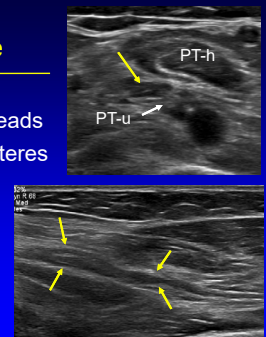
## Nerve Entrapment Syndromes

- Median:
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  - Pronator teres syndrome
- Ulnar:
  - Ulnar tunnel syndrome
  - Cubital tunnel syndrome

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## Pronator Teres Syndrome

- Median nerve compression between humeral and ulnar heads
- Trauma, congenital, pronator teres hypertrophy
- Rare
- Forearm pain, numbness, weakness



Jacobson JA, et al. Semin Musculoskeletal Rad 2010; 14:473

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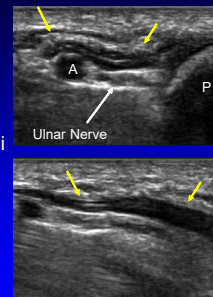
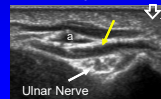
## Nerve Entrapment Syndromes

- Median:
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- Ulnar:
  - Ulnar tunnel syndrome
  - Cubital tunnel syndrome

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## Accessory Abductor Digiti Minimi

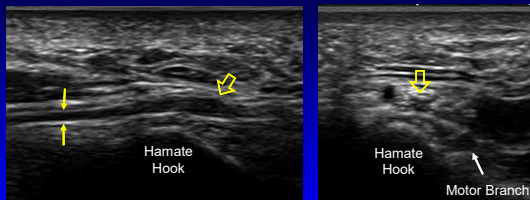
- Normal variant: 24%
- Origin: palmaris longus, flexor retinaculum, fascia
- Insertion: abductor digiti minimi
- Superficial to ulnar nerve:
  - Nerve compression
  - Uncommonly interposed



Timins et al. AJR 1999; 172:1397

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## Ulnar Nerve: cyclist wrist



Longitudinal

Transverse

Sensory branch impingement between hook of hamate and bicycle handlebar

Courtesy of EFW Radiology, Calgary, Alberta, Canada

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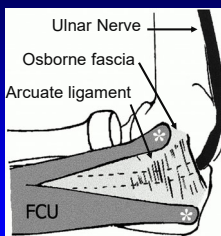
## Nerve Entrapment Syndromes

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  - Ulnar tunnel syndrome
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## Ulnar Nerve: anatomy

- Behind medial epicondyle of humerus:
  - Cubital tunnel retinaculum or Osborne fascia
- Distal to epicondyle:
  - True cubital tunnel
  - Between ulnar and humeral heads: flexor carpi ulnaris
  - Under arcuate ligament

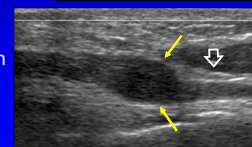
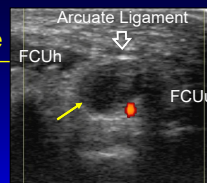


Martinoli, C. et al. Radiographics 2000;20:S199-S217 **RadioGraphics**

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## Ulnar Nerve: cubital tunnel syndrome

- Hypoechoic and enlarged
  - $> 9 \text{ mm}^2$  area<sup>1</sup>
  - 2.8x area compared to proximal<sup>2</sup>
- Mild hypoechoogenicity alone: may be normal
- Causes:
  - Idiopathic, overuse, joint process
  - Anconeus epitrochlearis: compression
    - Normal variant accessory muscle



<sup>1</sup>Thoirs K et al. J Ultrasound Med 2008; 27:737  
<sup>2</sup>Yoon JS et al. Muscle Nerve 2008; 38:1231

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### Anconeus Epitrochlearis

- Normal variant: 34% of population
- Roof of cubital tunnel:
  - Residual muscle
  - In absence of normal attrition forming Osborn fascia
- Secondary ulnar nerve entrapment
- **Diagnose in elbow extension!**

Sem Musculoskel Radiol 2000; 14:814:473

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### Isolated Ulnar Nerve Dislocation

Okamoto, J Hand Surg 2000; 25B:85

\*Asymptomatic finding in 20%

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### Snapping Triceps Syndrome

- Ulnar nerve and medial triceps dislocate over apex of medial epicondyle
- Ulnar nerve and medial triceps remain in contact with each other
- Palpable snap felt through transducer

Jacobson JA et al. Radiology 2001; 220:601

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### Nerve Entrapment Syndromes

- Radial:
  - Posterior interosseous nerve syndrome
  - Wartenberg syndrome
    - Superficial sensory branch radial nerve

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### Radial tunnel

- Radial nerve: deep branch
  - Originates from radial nerve between brachioradialis and brachialis
  - Passes between deep and superficial layers of supinator muscle
  - Exits as posterior interosseous nerve

Jacobson JA, et al. Sem Musculoskel Rad 2010; 14:473

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### Radial Nerve: deep branch

- Supinator syndrome:
  - Motor deficits (wrist, finger extension)
  - Abnormal electrodiagnostic studies
  - Nerve enlargement: entrapment
- Radial tunnel syndrome:
  - Pain, no motor deficits, normal EMG
  - Muscle denervation on MRI
  - No nerve enlargement

Ferdinand BD et al. Radiology 2006; 240:161

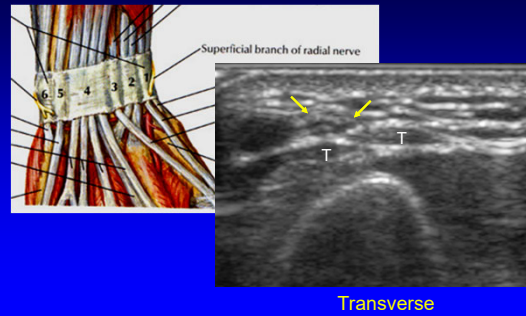
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## Nerve Entrapment Syndromes

- Radial:
  - Posterior interosseous nerve syndrome
  - Wartenberg syndrome
    - Superficial sensory branch radial nerve

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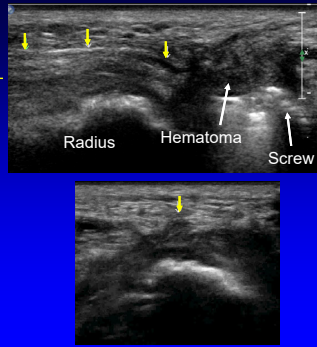
## Wartenberg Syndrome



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## Wartenberg Syndrome

- Superficial branch of radial nerve
  - Sensory branch
  - Crosses over distal radius and first wrist compartment
- Entrapment
- Injury: direct trauma, iatrogenic



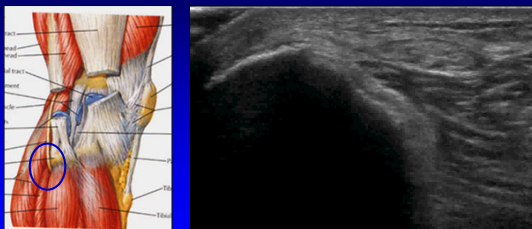
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## Nerve Entrapment Syndromes

- Peroneal (fibular):
  - Common peroneal
  - Superficial peroneal
- Tibial
- Intermetatarsal neuroma

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## Common Peroneal Nerve: entrapment



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## Peroneal Intraneural Ganglion

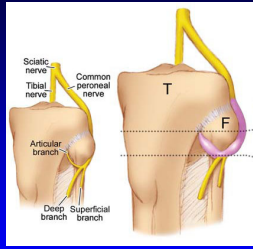
- Pain: knee or peroneal nerve distribution
  - Possible palpable mass, fluctuating course
- 18% of those with foot drop<sup>1</sup>
- No identifiable etiology
  - Weight loss, trauma, leg crossing
- High body mass index<sup>2</sup>
  - Unlike other causes for peroneal neuropathy

<sup>1</sup>Visser et al. Neurology 2006; 67:1473  
<sup>2</sup>Young et al. Neurology 2009; 72:447

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### Peroneal Intra-neural Ganglion

- Joint fluid from proximal tibiofibular joint
  - Enters peroneal nerve via articular nerve branches
  - Shown at MR arthrography after exercise
  - Extends proximal via epineurial sheath<sup>1</sup>

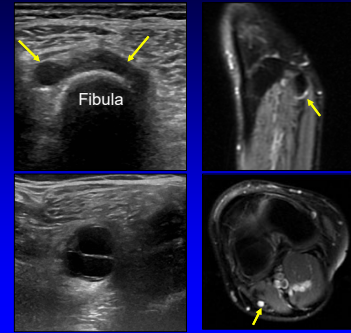


From: Spinner et al. Skeletal Radiol 2008;37:1091

Spinner et al. Clin Anatomy 2007; 20:826

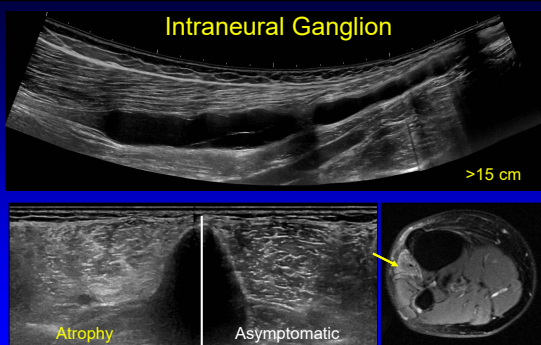
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### Peroneal Intra-neural Ganglion



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### Intra-neural Ganglion



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### Nerve Entrapment Syndromes

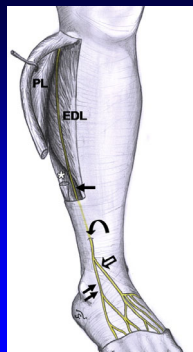
- Peroneal:
  - Common peroneal
  - Superficial peroneal
- Tibial
- Intermetatarsal neuroma

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### Superficial Peroneal Nerve

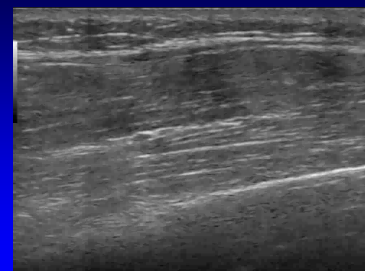
- Pierces crural fascia of leg:
  - 9.2 cm proximal to fibular tip
  - Range: 6 to 16 cm proximal
  - Potential entrapment site
- Terminal branches: 6 cm proximal to fibular tip
  - Superficial to inferior extensor retinaculum

Canella, AJR 2009; 193:174



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### Muscle Hernia (extensor digitorum): superficial peroneal nerve entrapment



Longitudinal

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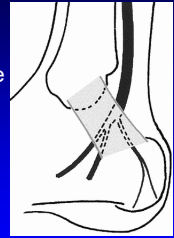
## Nerve Entrapment Syndromes

- Peroneal:
  - Common peroneal
  - Superficial peroneal
- **Tibial**
- Intermetatarsal neuroma

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## Tarsal Tunnel:

- Osteofibrous tunnel: medial ankle
- Tibial nerve
- Tendons: tibialis posterior, flexor digitorum longus, flexor hallucis longus
- Entrapment: mass, ganglion

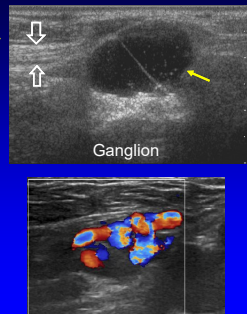


From: Martinoli, RadioGraphics 2000; 20:S199

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## Tarsal Tunnel Syndrome

- Entrapment of tibial nerve
  - Ganglion cyst: most common
  - Varicose veins, tenosynovitis
  - Trauma, deformity, coalition, idiopathic
- Tibial nerve:
  - May appear normal
  - May be hypoechoic and swollen



Nagaoka, J Ultrasound Med 2005;24:1035

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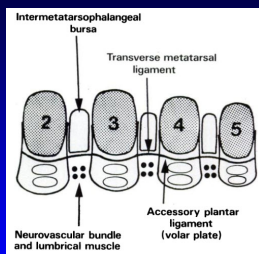
## Nerve Entrapment Syndromes

- Peroneal:
  - Common peroneal
  - Superficial peroneal
- Tibial
- Intermetatarsal neuroma

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## Anatomy

- At level of metatarsal heads:
  - Transverse metatarsal ligament
    - Attaches to plantar plates
  - Intermetatarsal bursa: dorsal
  - Neurovascular bundle: plantar



Zanetti M et al. Radiology 2014; 203:516

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## Intermetatarsal Neuroma

- Interdigital nerve entrapment
- Edema, fibrosis, necrosis
- 3<sup>rd</sup> intermetatarsal space > 2<sup>nd</sup>
- Sharp, burning pain to toes
- Females: pliable foot, high-heeled, narrow-toed shoes
- Asymptomatic neuromas in up to 33%
- Neuromas < 5 mm mediolateral: **often asymptomatic**



Zanetti M et al. Radiology 1997; 203:516

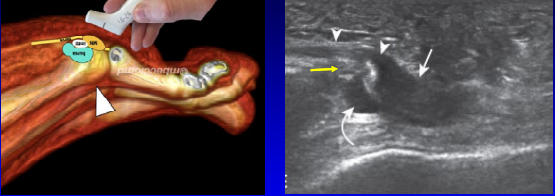
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### Neuromas: eponyms

- Medial to first metatarsal: Joplin
- 1<sup>st</sup> webspace: Heuter
- 2<sup>nd</sup> webspace: Hauser
- 3<sup>rd</sup> webspace: Morton
- 4<sup>th</sup> webspace: Iselin

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### Intermetatarsal Neuroma




**Note:** neuroma is at distal edge of intermetatarsal ligament  
 White arrow: neuroma  
 Arrowheads: interdigital nerve  
 Curved arrow: intermetatarsal bursa  
 Yellow arrow: intermetatarsal ligament

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### Ultrasound Evaluation

- #1: plantar, short axis
  - With dorsal compression
- #2: plantar, long axis
  - With dorsal compression
- #3: Mulder maneuver
  - With side-to-side compression

\*Neuroma of 5 mm or larger: 100% sensitivity, 83% specificity

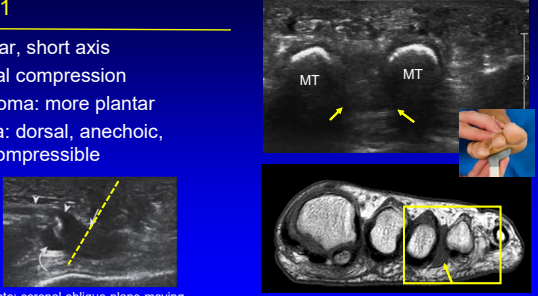


Redd et al. Radiology 1989; 171:415  
 Quinn et al. AJR 2000; 174:1723

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### Step #1

- Plantar, short axis
- Dorsal compression
- Neuroma: more plantar
- Bursa: dorsal, anechoic, compressible

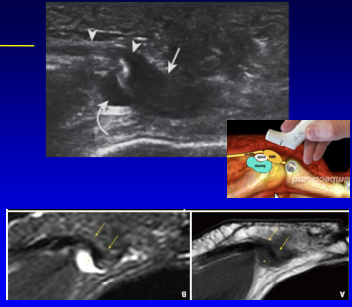


Note: coronal-oblique plane moving distal to metatarsal heads

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### Step #2

- Plantar, long axis
  - Follow MT head curvature
- Dorsal compression
  - Move finger distal, proximal
  - See neuroma sliding over intermetatarsal ligament
- Neuroma: plantar, distal
- Bursa: curved arrow
  - Dorsal, proximal
  - Anechoic, compressible




MRI flipped upside down to simulate US

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### Step #3: Mulder's maneuver

- Transducer: plantar, short axis
- Squeeze foot side-to-side
- Neuroma moves plantar
  - Palpable click, elicits symptoms
  - Important to document
  - Improved accuracy, measurements
- Make sure to perform distal to intermetatarsal ligament
- Bursa: remains dorsal




Torriani M et al. AJR 2003; 180:1121

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### Differential Diagnosis

- Pericapsular fibrosis
- Associated with capsule injury
- Hypoechoic
- Eccentric
- Not truly intermetatarsal
- Negative Mulder's maneuver



Umans H et al. Skeletal Radiol 2014

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### Summary: peripheral nerve US

- Evaluate entire limb efficiently
- Easy comparison to contralateral side
- Direct correlation: signs and symptoms
- Complements electrodiagnostic testing
- Dynamic imaging

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Thank you!



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Syllabus on line and other educational material:  
[www.jacobsonmskus.com](http://www.jacobsonmskus.com)



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