Host Defense: Where the Rubber of Immunology Hits the Road of Life

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Disclosures of Financial Relationships with Relevant Commercial Interests

- List of disclosures or “None”

Concepts of Hell

Host Immune Defense

Humoral
- Complement
- Mannose binding lectin
- Antibody

Cellular
- Neutrophils
- Monocytes
- Eosinophils
- Lymphocytes (NK, T, B)
- Other (erythrocytes, platelets)

Basic Principles

Patients with impaired inflammation:

- May be unable to tell you they are sick (feel fine)
- Are often sicker than they look
- Often have more extensive disease than is apparent
- May require longer treatment than normals
- May have unusual infections

In vitro testing is tricky and variable, genetics is not

Who's Got a Problem?

Abnormal frequency of infections

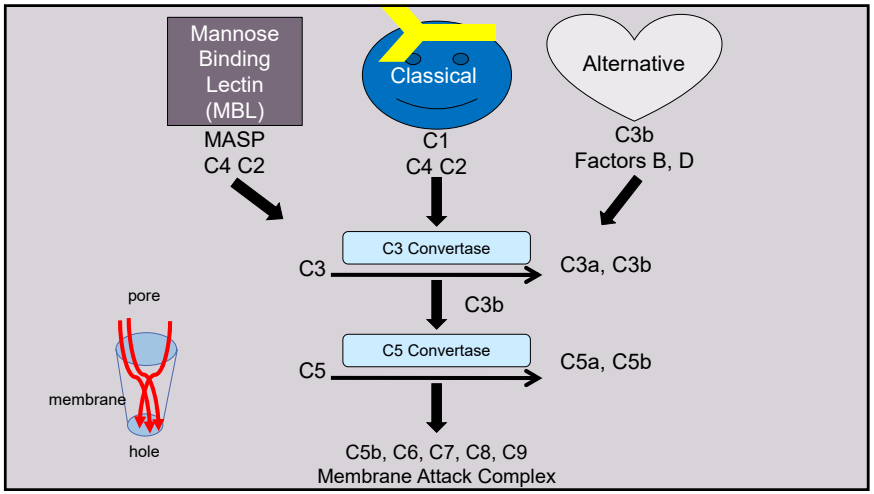
- *Recurrent Neisseria* bacteremia, pneumonia

Abnormal presentation of infections

- Necrotic cutaneous ulcers (not anthrax)
- *Aspergillus* pneumonia

Unusual infections

- *Pneumocystis jirovecii*
- *Burkholderia cepacia complex*
- *Nontuberculous mycobacteria*



Complement Deficiencies

Classical Pathway (C1-C9) (Recessive)

- Antibody *de*pendent bacterial lysis
- Deficiency leads to recurrent bacteremia and meningitis

Alternative Pathway (Factors I, H, Properdin, C3)
(Properdin X-linked, others AR)

- Antibody *in*dependent bacterial lysis
- More severe than classical defects

Mannose Binding Lectin (MBL) Pathway

- Very modest IF ANY defect, mild effect in infancy

Complement Defects

C5-C9 Defects
- Recurrent Neisseria bacteremia and meningitis
- Average age of onset 17 y, milder CNS sequelae
- High rates of relapse and reinfection

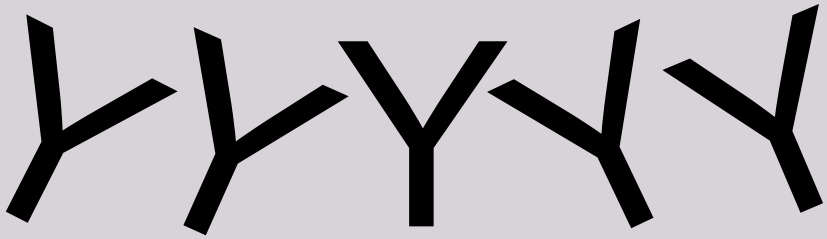
C1-C4 Defects
- Autoimmune disease (SLE, DLE) more common

Dx - CH_{50} (Classical), AH50 (Alternative)

Rx - treat infections, prophylaxis if needed, hypervaccination?

J Clin Immunol 2020 May;40(4):576-591

Let's Talk About Antibodies!!! Five Flavors



IgD IgM **IgG** IgA IgE

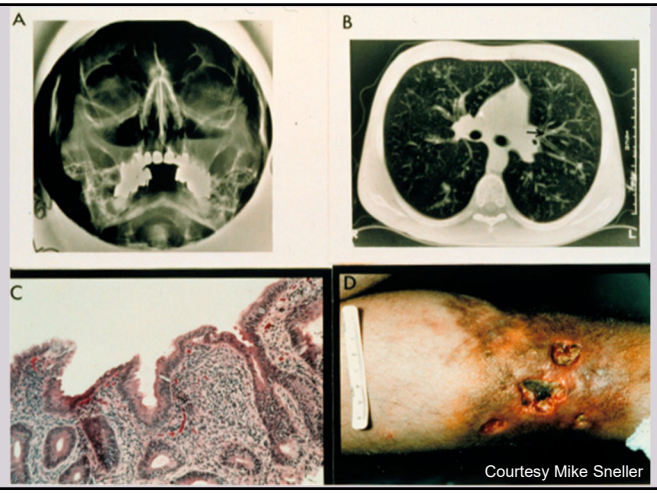
Antibody Deficiencies

IgA Deficiency (AR)
- Common (1/700 adults)
- Probably not a pathologic condition per se
- Frequently associated with other deficits, such as common variable immunodeficiency (CVID), Ig subclass deficiencies, allergies, etc.

Dx - Low IgA

Rx - None

J Transl Autoimmun 2019 Nov 23:2:100025



Common Variable Immunodeficiency (CVID)

Recurrent sino-pulmonary bacterial infections

Chronic enteric *Giardia, Campy, Salmonella, Shigella*

Severe enteroviral meningitis/encephalitis/myositis

Nodular regenerative hyperplasia of liver

Dx - IgG (total and subclasses 1,3 or 2,4),
IgA, IgM, isohemagglutinins, DTH,
Impaired response to new or recall immunization
Autoimmunity and cancer

Rx - Treat infections, Ig replacement

Cunningham-Rundles C. Immunol Rev. 2019 Jan;287(1):145-161.

Question #1

47-year-old woman

- Recurrent episodes of bronchitis, recently more exacerbations; tired
- One episode of documented bacterial pneumonia and sinusitis
- Immunoglobulin levels:
  - IgG 500 (normal 523-1482)
  - IgA <10 (normal 51-375)
  - IgM 165 (normal 37-200)

Question #1

What is the next step?

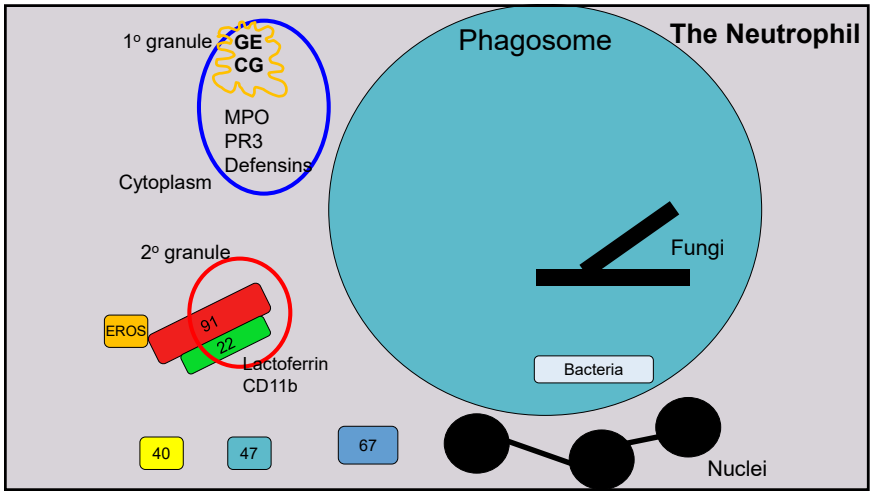
A. IgG subclasses and titers against tetanus and pneumococcus. If low, consider IVIG.

B. Repeat IgG levels. If low, consider IVIG.

C. Skin tests for DTH. If anergic, consider IVIG.

D. Titers against tetanus and pneumococcus, immunize, and repeat. If low, consider IVIG.

E. Check MBL levels. If low, consider IVIG.



Question #2

Neutrophils: Nobody cares until they are not around.

- Average count 5000/mcl
  - (5,000,000/ml)
  - (5,000,000,000/L)

So, how many do you make a day?

Question #2

How many neutrophils do you make a day?

A. 10e8; the half-life is 10 days
B. 10e9; the half-life is 5 days
C. 10e10; the half-life is 1 day
D. 10e11; the half-life is 7 hours
E. 10e6; they live until you use them up

Neutrophils: Always Fresh, Always Ready!

D. 10e11; the half-life is 7 hours*

- Make around 1011/day
- Most are in bone marrow
- Can go up 10-fold in emergency
- Circulating half life 7 hours
- About 50% marginated

Cyclic and Severe Chronic Neutropenias

Cyclic and SCN: *ELANE* mutations (AD)

Kostmann SCN: *HAX1* mutations (AR)

- Digital, oral, perineal infections, usually self-healing with recovery of counts, bacteremia uncommon
- Relatively low baseline PMN count with profound neutropenia, about every 3-4 weeks

Dx - Molecular; periodicity, family history, genetics

Rx - G-CSF, BMT

Hematol Oncol Clin North Am. 2019;33:533-551

Other Causes of Neutropenia

X-linked
WAS
GATA1
TAZ

Dominant
GFI1
ELA2
GATA2
DNM2
SRP54
CXCR4

Recessive
G6PC3
HAX1
JAGN
USB1
CSF3R
VPS45
GSD1B
SBDS

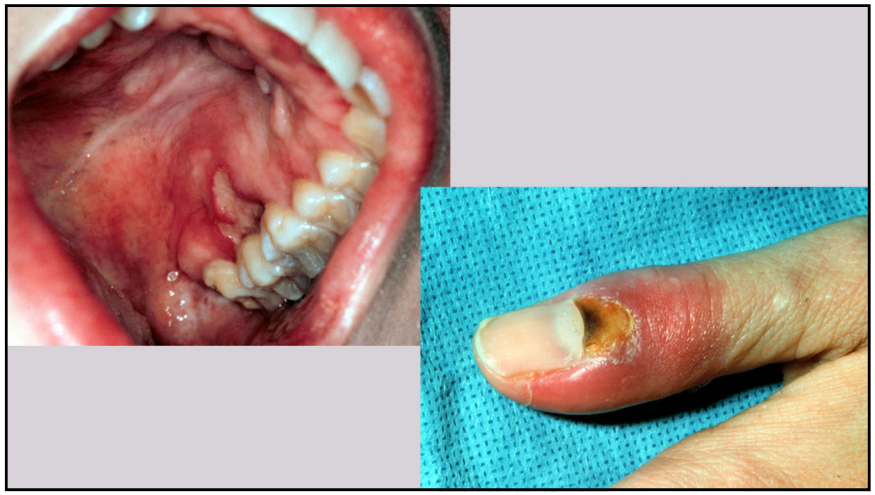
Big Causes
Drugs

Splenomegaly/ sequestration

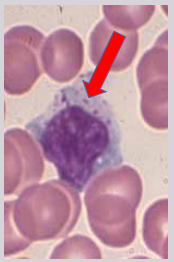
Autoimmunity

Case Study

52-year-old man
- Referred from his Family Practitioner
- Recurrent digital and oral ulcers occurring every month or so for the last 4 months
- One CBC showed an ANC of 100, but on repeat several days later was normal
- Previous health good
- Took “some antibiotic for a cold a few months ago”
- Spleen tip felt



Acquired Neutropenia in Adults



- Drugs, lupus, etc.
- Acquired cyclic neutropenia
  (Large Granular Lymphocytosis, LGL)
  Splenomegaly, often associated with
  Rheumatoid arthritis (Felty Syndrome)
- **Dx -** Clonal CD3+/8+/57+ lymphs (LGL)
  (Gain of Function mutations in STAT3)
- **Rx -** Treatment of the abnormal clone can be curative
  (Cyclosporine, MTX, steroids, alemtuzumab)
  G-CSF may lift both nadir and baseline

Hematol Malig Rep. 2020 Apr;15(2):103-112.

Myeloperoxidase (MPO) Deficiency (AR)

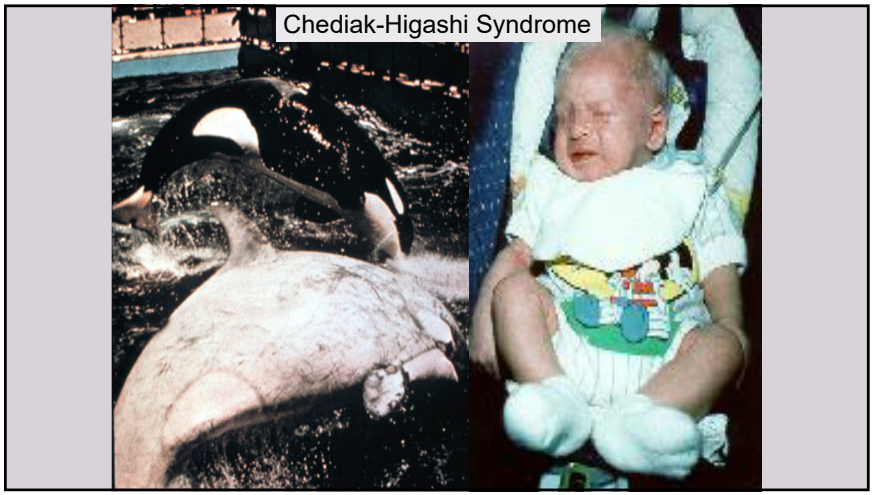
Most common neutrophil disorder (1/2000)

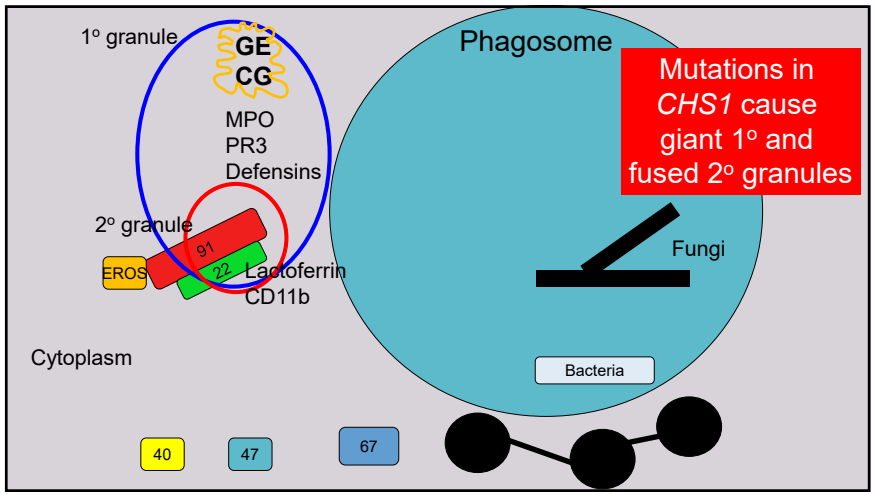
- Not a pathologic condition per se
- Failure of H_2O_2 -----MPO-----> HOCl
- Compensated by increased H_2O_2 production
- Appears to need another condition to potentiate, such as diabetes

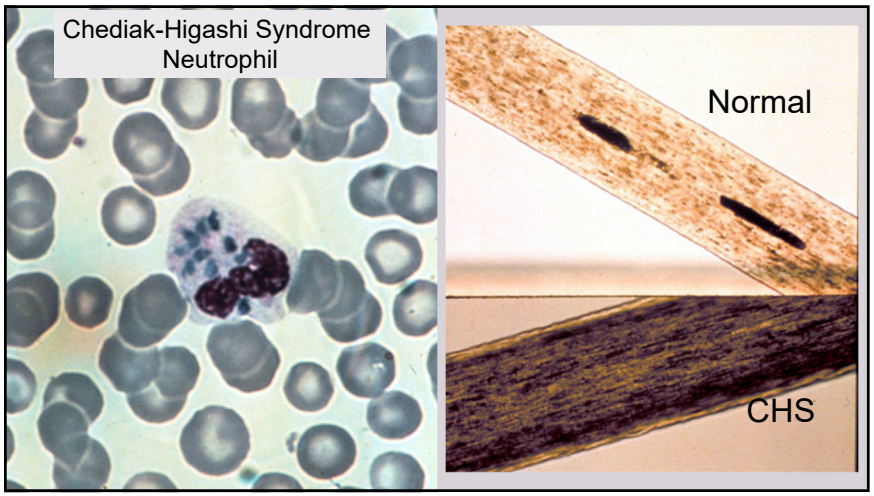
Dx - Absence of peroxidase positive granules due to mutations in *MPO* gene

Rx - Treat invasive infections (*Candida*), no specific therapy

J Leukoc Biol. 2013 Feb;93(2):185-98







Chediak-Higashi Syndrome (Recessive)

Recurrent cutaneous, sino-pulmonary infections
- GNR, staph, strep, no fungi
- Mild neutropenia (intramedullary destruction)

Partial oculocutaneous albinism,

Mental retardation, neuropathy (late)

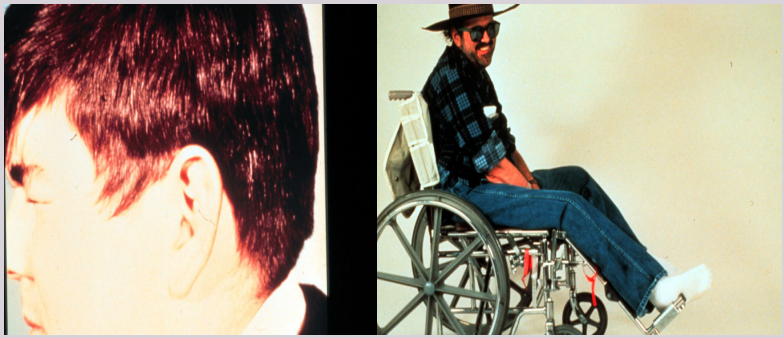
Lymphoma or HLH-like “accelerated phase” (late)

Dx - Giant blue PMN granules or chaotic hair granules due to mutations in CHS1, encodes LYST

Rx - Prophylaxis, treatment of infections, BMT

Drug Discov Today Dis Models. 2020;31:31-36

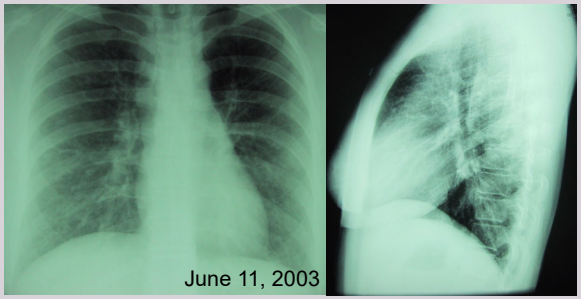
Silvery Sheen **Peripheral Neuropathy**



Case Study

23-year-old woman; athletic coach

Previously healthy; short of breath 4 hours after 3-mile run



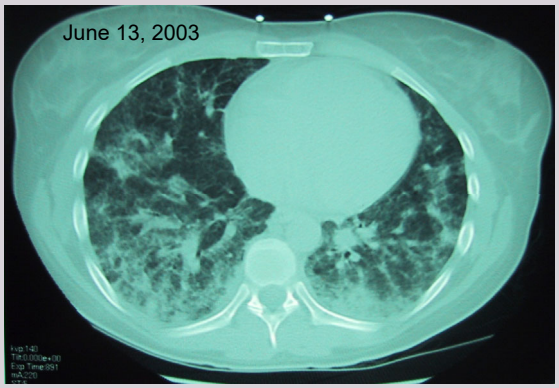
ER Presentation

- Recent weekend with friends in NYC
- Anxious, chest pressure, febrile
- Acute mononucleosis?

PMH
- Respiratory infections in infancy
- Cat scratch disease 8-year-old: resolved with antibiotics

Family History
- 1 brother with two episodes Cat scratch cervical nodes
- 2 sibs well

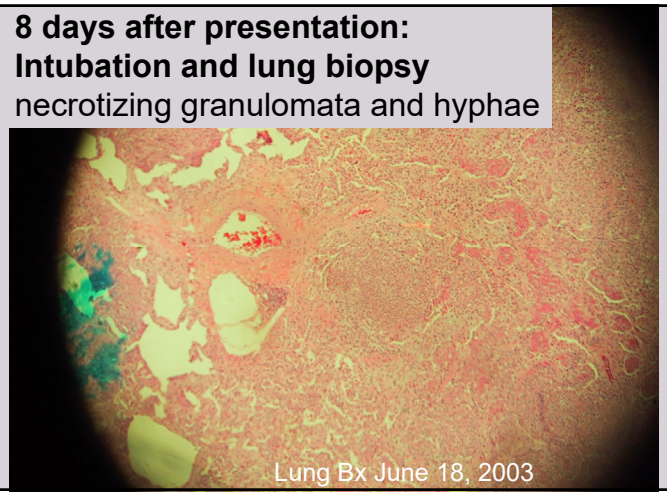
2 Days Later, Hypoxia And Fever



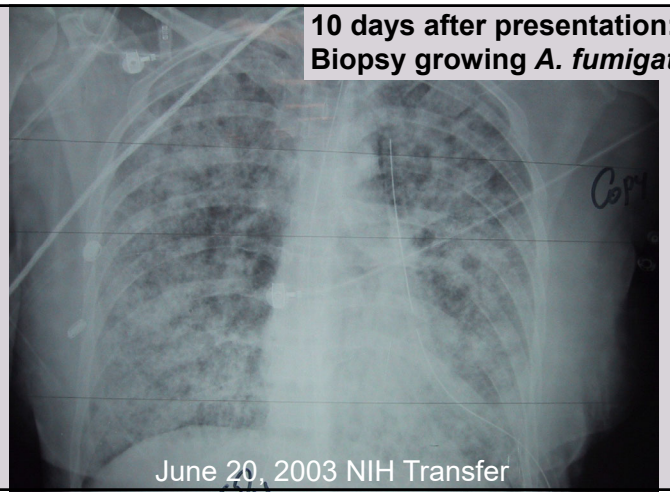
Hospital Course

- Progressive dyspnea, fever, leukocytosis
- Refractory to antibiotics and steroids
- Bronchoscopy uninformative
- Visually Assisted Thoracoscopic Surgery (VATS)

8 days after presentation:
Intubation and lung biopsy
necrotizing granulomata and hyphae



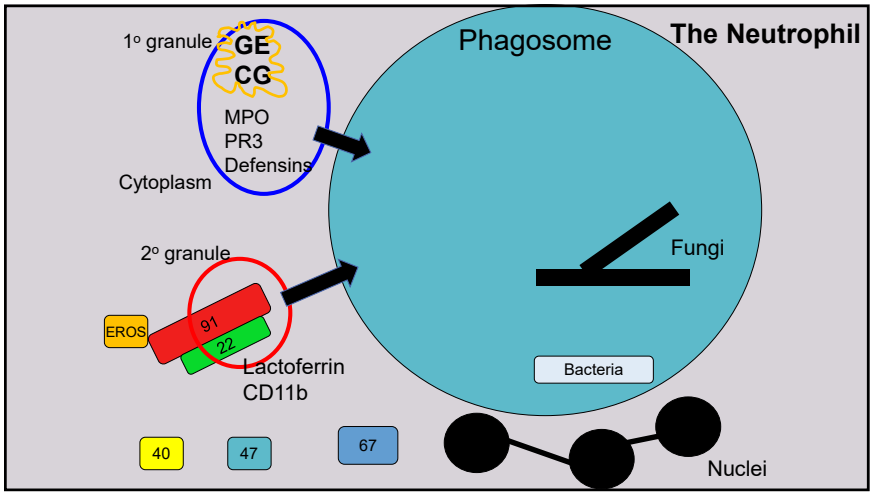
10 days after presentation:
Biopsy growing *A. fumigatus*

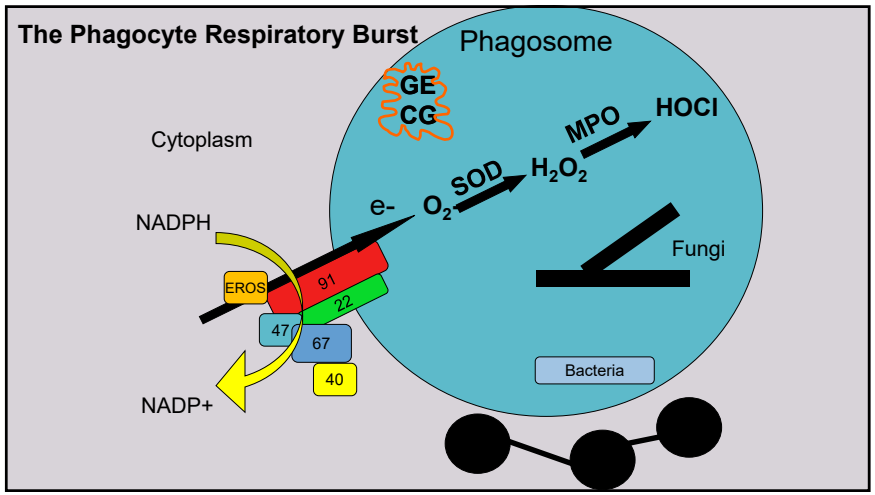


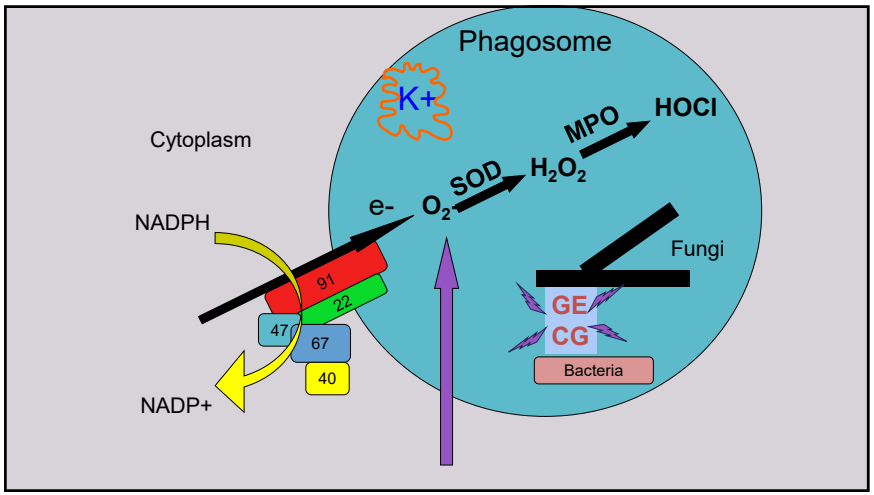
Question #3

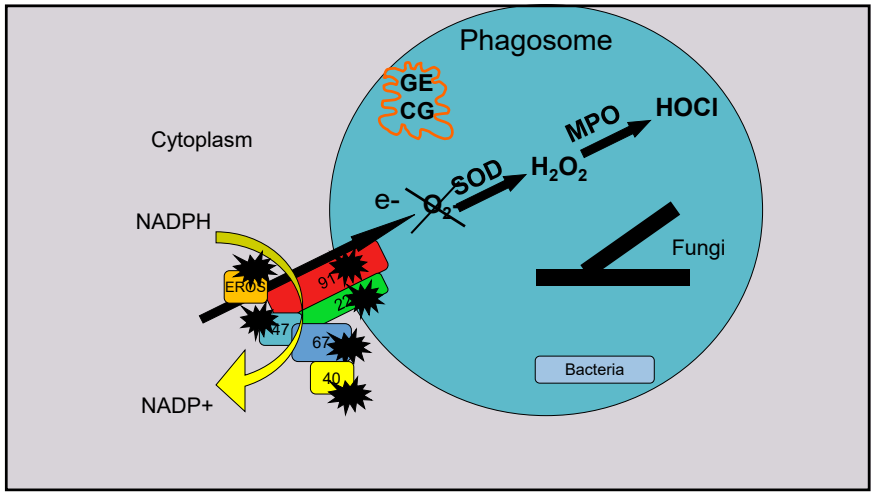
Which of the following is a cause of invasive aspergillosis in an otherwise normal host?

A. Allergic bronchopulmonary aspergillosis
B. Cystic fibrosis
C. Lymphocyte dysfunction (SCID)
D. Phagocyte defect
E. Acute HIV









Chronic Granulomatous Disease (X, AR)

Failure to make the phagocyte respiratory burst

Frequency 1/100,000 - 1/200,000 live births

- Presentation usually in childhood; more adults recognized

Recurrent life-threatening infections

- Catalase-positive bacteria, fungi (this is nuanced)
- Tissue granuloma formation

  Infections: Lung, liver, lymph nodes, skin, bone

  Bacteremia: Uncommon but bad

Infections in CGD

S. aureus	(liver, lymph nodes, osteo)
S. marsescens	(skin, lung, lymph nodes)
B. cepacia	(pneumonia, bacteremia)
Nocardia spp.	(pneumonia, brain, liver)
Aspergillus spp.	(lung, esp. miliary, spine)
Salmonella	(enteric, bacteremia)
BCG	(local/regional infections)

Chromobacterium violaceum (warm brackish water, soil, e.g., Disney World)

Francisella philomiragia (brackish water, Chesapeake Bay, Sounds)

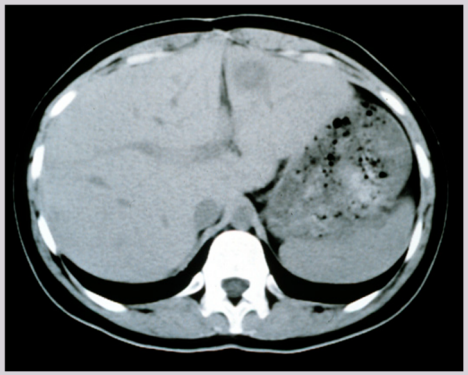
Burkholderia gladioli (causes onion rot)

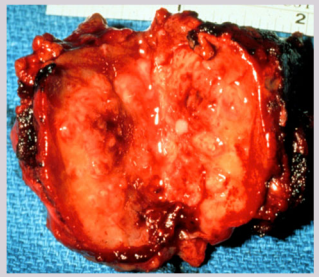
Granulibacter bethesdensis (necrotizing LN, hard to grow, likes CYE)

Paecilomyces spp.

Pediatric Health Med Ther 2020 Jul 22;11:257-268.

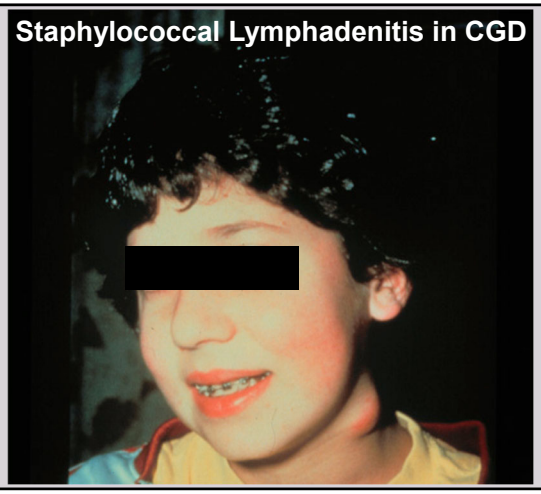
Staphylococcal Liver Abscess in CGD



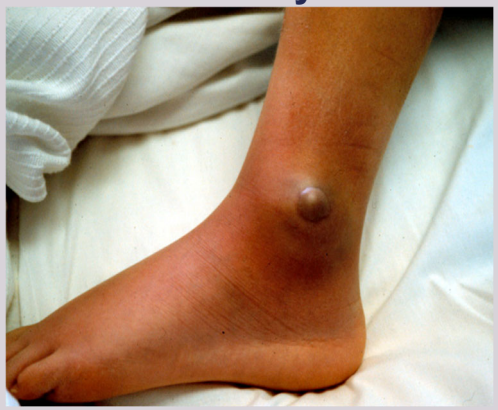


CID 2018;66:1427-1434

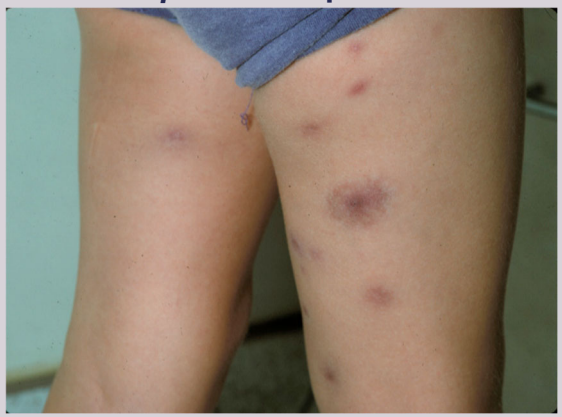
Staphylococcal Lymphadenitis in CGD

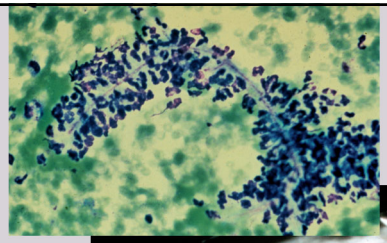


Staph aureus Osteomyelitis in CGD

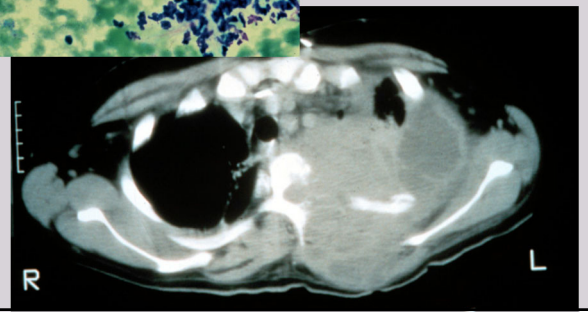


Burkholderia cepacia Complex Bacteremia in CGD

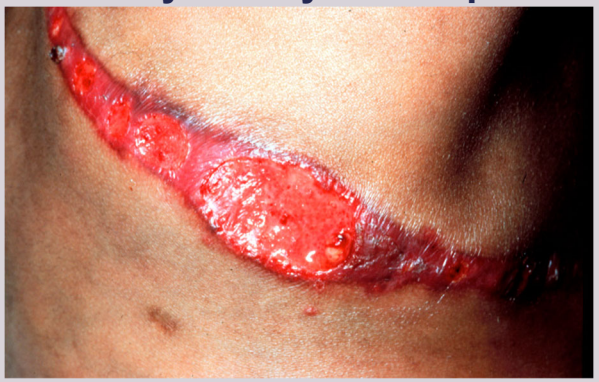




CGD
Aspergillus nidulans
Pneumonia



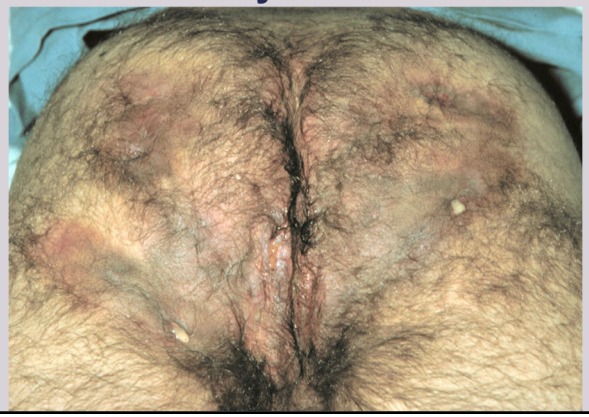
Thoracotomy 10 Days Postop



CGD Granulomatous Wound Dehiscence

CGD Granulomatous Esophageal Obstruction

CGD Inflammatory Bowel Disease



Chronic Granulomatous Disease

- X-linked, chr. Xp21 (70% of US cases)
  - Carrier females are mosaic (Lyonization)
  - 1/2 of offspring of carrier Mom will receive the gene
    - ~1/3 of carriers are sporadic, from sperm
  - X-linked male: all daughters carriers, no sons affected
- Autosomal recessive (30% of cases)

Dx - PMN dihydrorhodamine 123 oxidation (DHR)
[PMN nitroblue tetrazolium reduction (NBT) is the old test]
(MPO Deficiency gives a FALSE ABNORMAL DHR)

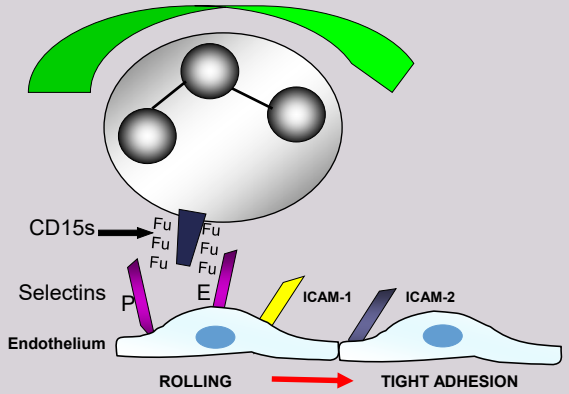
BE CAREFUL ABOUT THE LAB AND HOW YOU DISCUSS IT!

CGD Management and Treatment

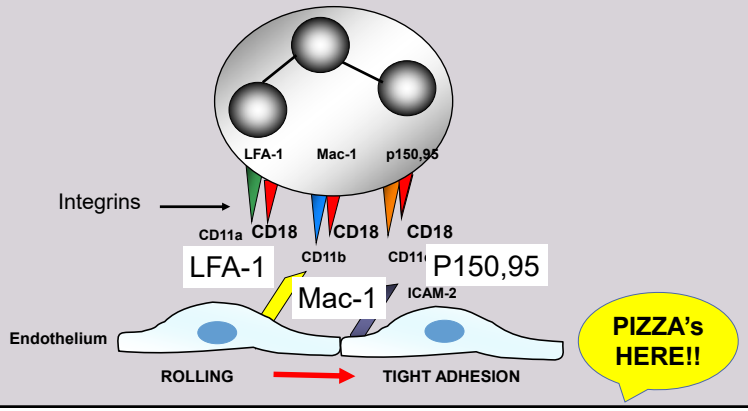
- 90% overall long-term survival
- Follow CRP, radiographs
- Prophylactic antibiotics and antifungals
  - TMP/SMX, itraconazole
- Prophylactic interferon gamma
  - 50 µg/m2 subcutaneously three times weekly
- Aggressive search for and treatment of infections
- BMT (gene therapy)

Hematol Oncol Clin North Am. 2013 Feb;27(1):89-99

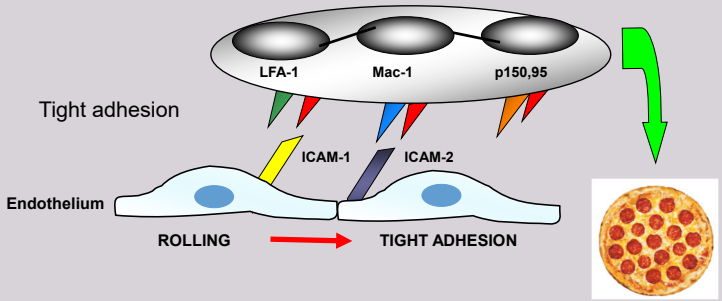
Neutrophil Rolling



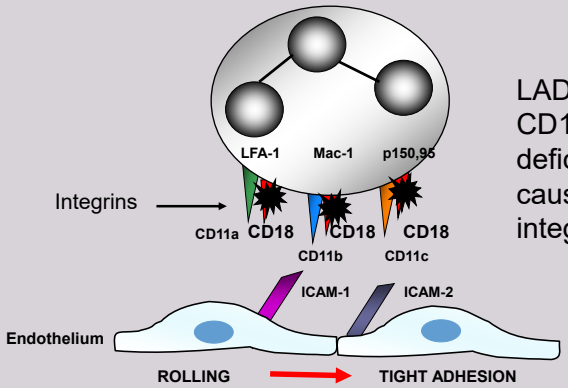
Neutrophil Adhesion



Neutrophil Tissue Entry (Diapedesis)



Leukocyte Adhesion Deficiency Type 1



LAD1 is due to CD18 deficiency, causing loss of integrins

Leukocyte Adhesion Deficiency Type 1 (AR)

- Failure to attach to the endothelium due to mutations CD18
- Recurrent necrotizing infections: skin, perineum, lung, gut
- Enteric GNR, GPC, NOT fungi or Candida
- Baseline leukocytosis, further WBC increase to infection
- Rare, consanguinity common

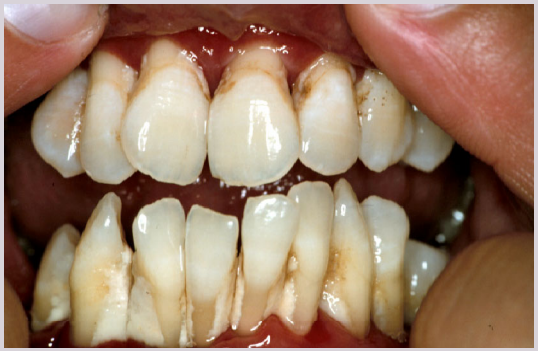
Dx - FACS for CD18, genetics

Rx - Treatment of infections, BMT

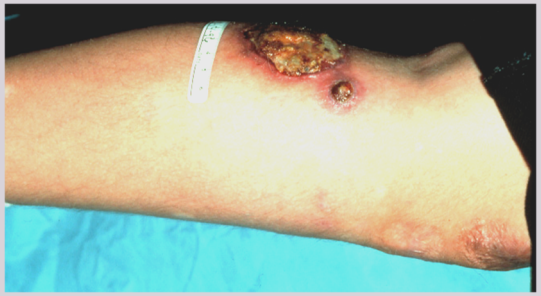
Leukocyte Adhesion Deficiency I

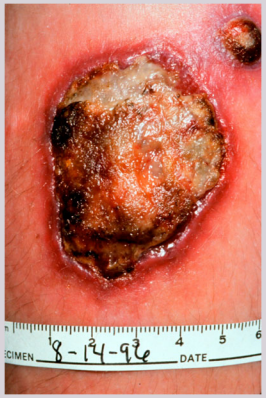
- Delayed umbilical stump separation
- Dystrophic, “cigarette paper” scars
- Gingivitis with tooth loss, alveolar ridge resorption
- Biopsies show no neutrophils at sites of infection, rare monocytes and eosinophils
- Severe and moderate forms of disease

Almost Universal Tooth Loss in LAD1 By Adulthood

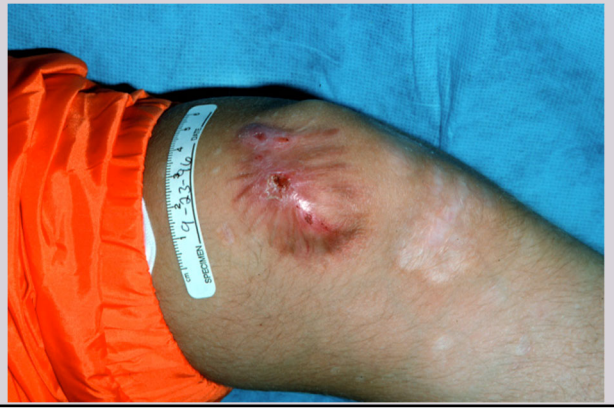


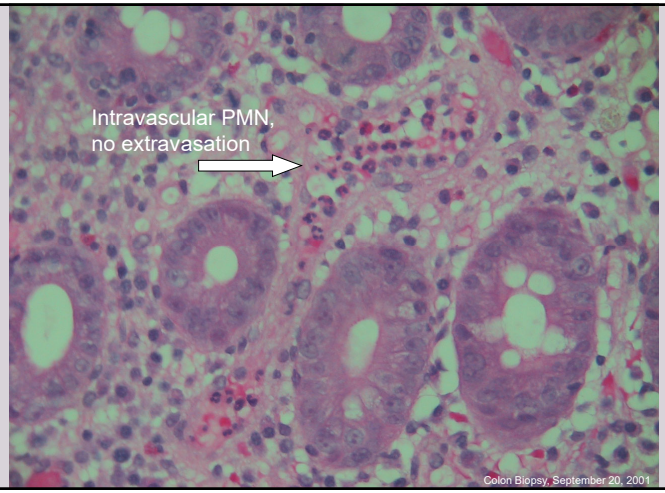
Impaired Wound Healing in LAD1





Cigarette Paper Scarring





Question #4

19-year-old boy with Pneumonia

- Admission WBC 43,000, looked OK
- Ceftriaxone, good response
- Medical student: WBC never <11,000/mcl
- Left shin ulcer not inflamed
- Not healed in > 2 mos
- She raises the possibility of Leukocyte Adhesion Deficiency (LAD1)

Question #4

Which of the following would rule <u>against</u> LAD1?

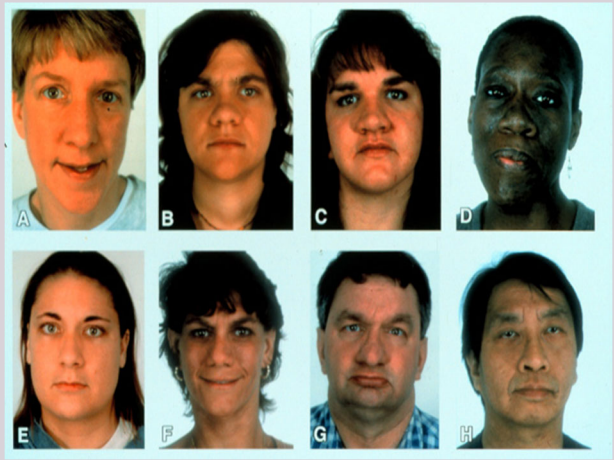
A. Gingivitis, tooth loss, and alveolar ridge resorption
B. FACS showing 5% of normal expression of CD18 and CD11a-c on granulocytes
C. He is the product of a first cousin union
D. Extensive neutrophil infiltration in the left shin ulcer
E. Multiple dystrophic scars over the legs from previous ulcers

27-year-old Woman with Boils

Referred for recurrent boils with *S. aureus*

- IgE of 12,376 IU
- "Bronchitis and sinusitis at least once a year"
- Persistent eczema requiring topical steroids
- Never hospitalized but having "more trouble" lately

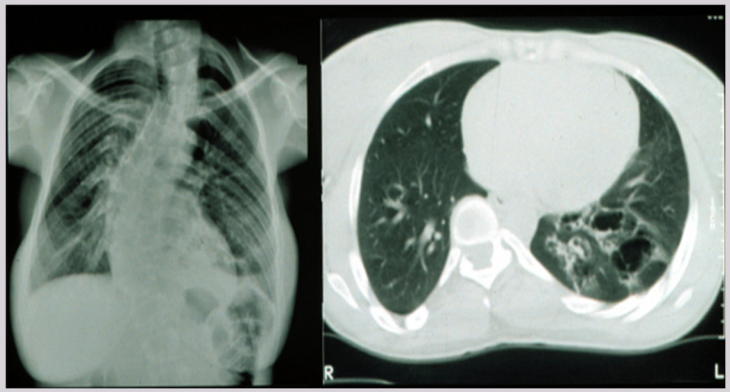
Job's Syndrome



N Engl J Med. 1999;340:692-702

HIE (Job's) Syndrome History and Exam

Eczema	100%
Facies	100% (>16y)
Boils	87%
Pneumonia	87%
Mucocutaneous Candidiasis	83%
Pulmonary Cysts	77%
Scoliosis	76% (> 16y)
Delayed dental deciduation	72%
Coronary artery aneurysms	65%
Pathologic fractures	57%



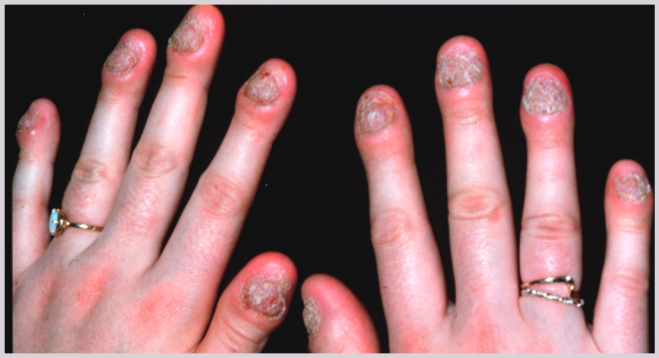
Pulmonary Pathogens in HIE

Primary Pathogens:
- *Staphylococcus aureus*
- *Streptococcus pneumoniae*
- *Hemophilus influenzae*

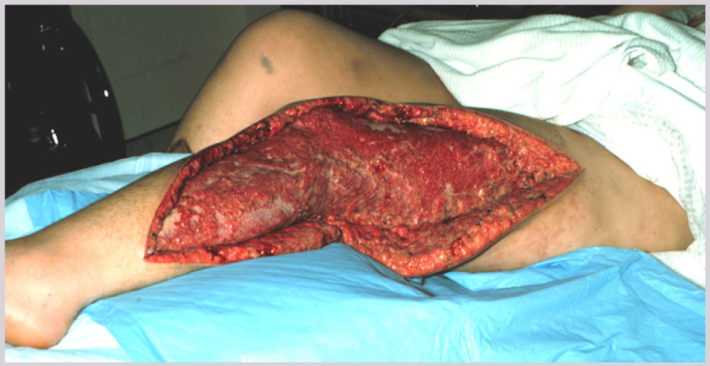
Secondary Pathogens:
- *Pseudomonas aeruginosa*
- *Aspergillus fumigatus*

Others:
- *Pneumocystis jirovecii, M. avium* complex

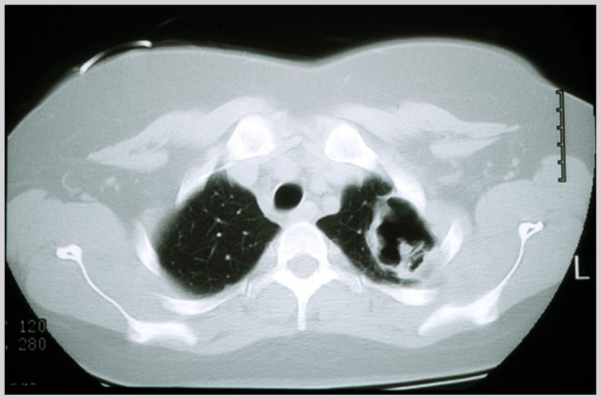
Candida



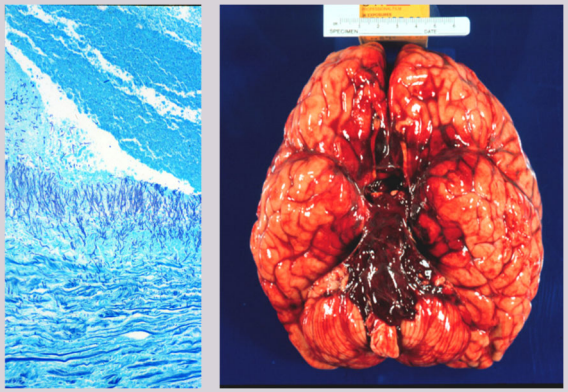
Group A Strep



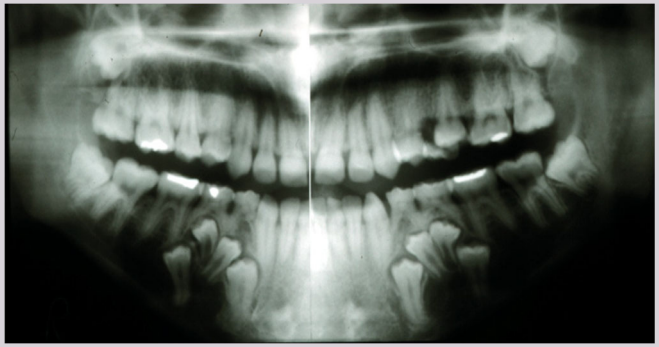
Aspergillus Lung Infection



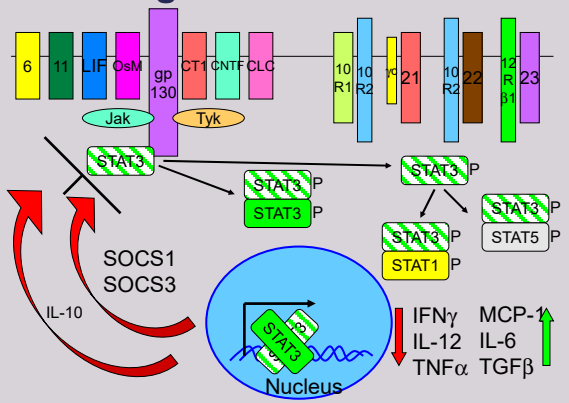
Metastatic *Aspergillus* Brain Infection



Failure Of Primary Dental Deciduation



Dominant Negative Mutant STAT3



Hyper IgE Recurrent Infection (Job's)

- Recurrent sinopulmonary *S. aureus, S. pneumo, H. flu*
- Post-infectious pulmonary cyst formation
- Recurrent S. aureus skin abscesses
- Characteristic facies, eczema, scoliosis, fractures
- Very elevated IgE (>2000 IU), modest eosinophilia

DDx - Atopic dermatitis is a close mimic
Job's: pneumonia, lung cysts, skeletal, mutations in STAT3

Rx - Treatment of infections, prophylactic antibiotics, antifungals increasingly BMT

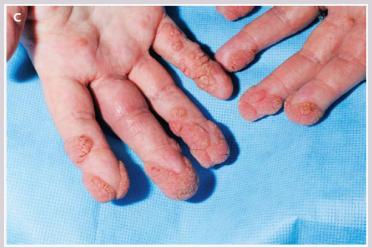
J Clin Immunol. 2021;41:864-880

Close Mimic: DOCK8 Deficiency

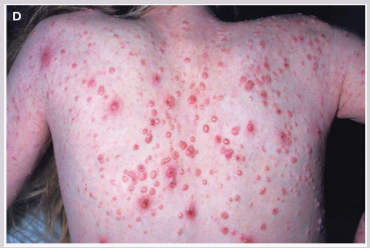
Autosomal Recessive hyper IgE syndrome
Eczema, allergies, asthma, high IgE
Staph, Strep, H. flu, Acinetobacter, Pseudomonas
Candida, Cryptococcus, Histoplasma
HPV, HSV, molluscum
Squamous cell carcinomas, lymphoma

J Clin Immunol 2021 May 1. doi: 10.1007/s10875-021-01051-1.

DOCK8 Deficiency



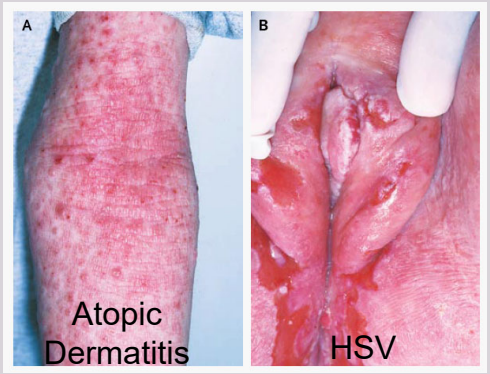
HPV



Molluscum contagiosum

N Engl J Med. 2009;361:2046-55

DOCK8 Deficiency



DOCK8 vs. STAT3 Hyper IgEs

	DOCK8 (Recessive)	STAT3 (Dominant)
Pneumonia	+	+++
Pneumatoceles	-	+++
Retained teeth	-	+++
Fractures	-	+++
Viral infections	+++	-
Fungal infections	+	++
Allergies	+++	-
IgM	Low	Normal
Eosinophils	+ to ++	+

Question #5

15-year-old girl with recurrent infections

- Infancy: eczema, recurrent pneumonias, skin infections
- IgE 14,574 IU/ml
- Allergist: use bed covers to avoid dust mites

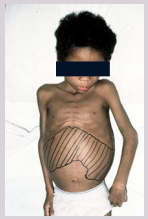
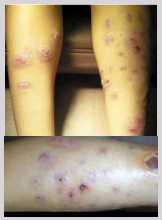
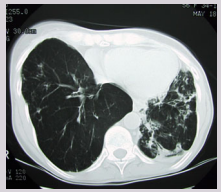
Going over the allotted 15 minutes, you elicit points trying to establish whether she has hyper-IgE recurrent infection syndrome (Job's).

Question #5

Which one of the following is not supportive of the diagnosis of Job's (STAT3DN)?

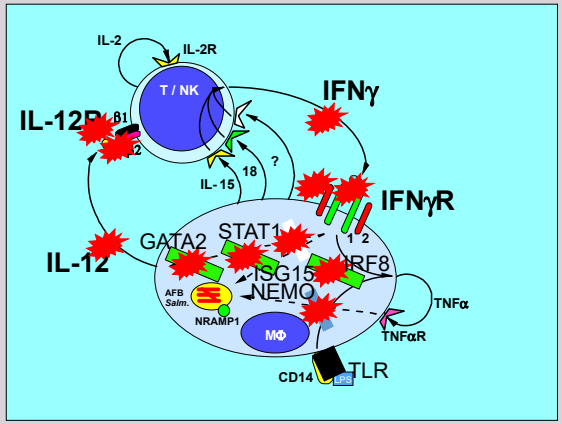
A. Pneumatoceles
B. Scoliosis
C. Severe warts
D. Retained baby teeth
E. Recurrent fractures

Clinical Spectrum of NTM Infections

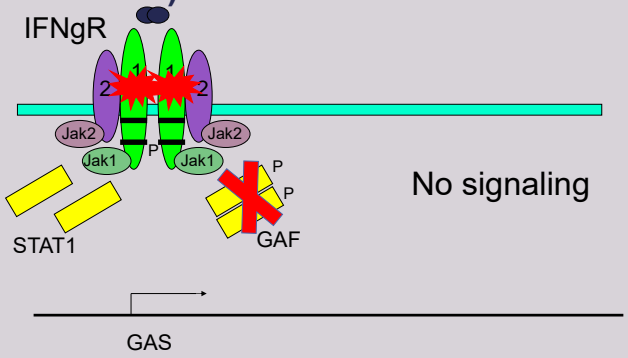
Disseminated	Skin	Pulmonary
Severe, Young	Exposure	Chronic, Older
IFNγ/IL-12 defects	Inoculation	Bronchiectasis
NEMO, STAT1		Cystic fibrosis (CF)
		Ciliary dyskinesia (PCD)
		
IMMUNE	EXPOSURE	EPITHELIAL

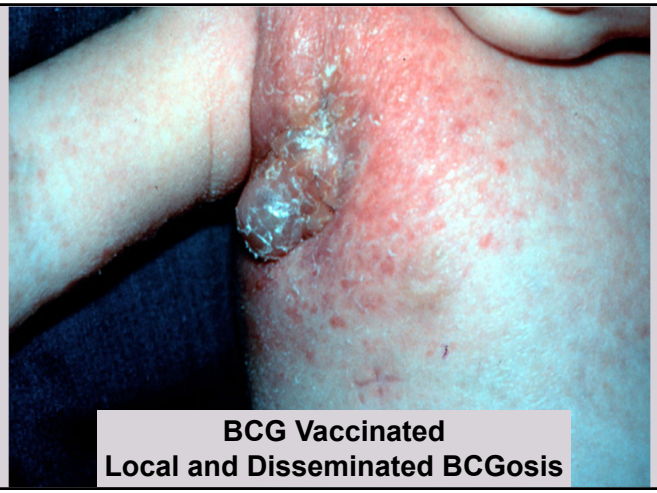
Lancet Infect Dis. 2015;15:968-80

Disseminated NTM Only



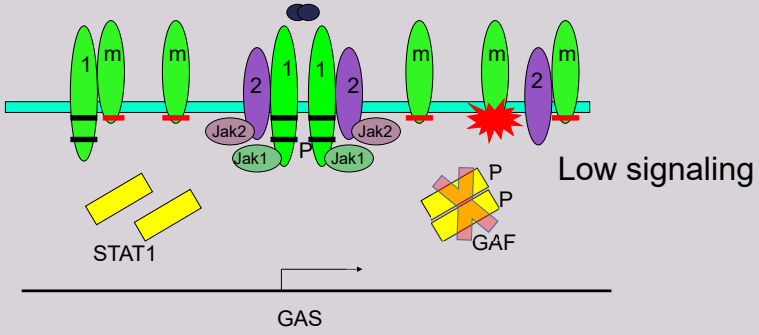
Autosomal Recessive IFNGR1 (Both Alleles)



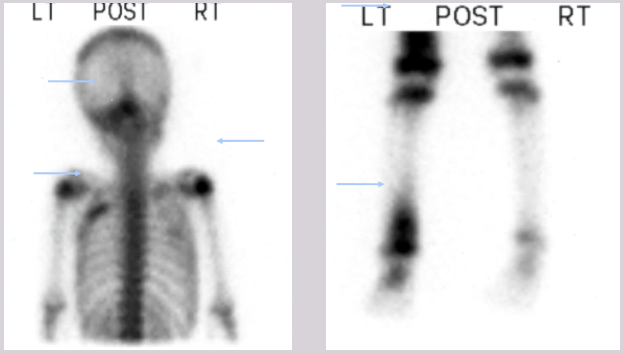


BCG Vaccinated
Local and Disseminated BCGosis

Autosomal Dominant IFNGR1 (One Allele)



Mycobacterial Osteomyelitis in Dominant IFNγR1 Deficiency



Ann Allergy Asthma Immunol 2002;89:239-43.

Pathogens in Human IFNγR Deficiencies

M. avium	Salmonella
M. intracellulare	Listeria
M. chelonae	
M. abscessus	CMV
M. smegmatis	HSV
M. fortuitum	VZV
M. tuberculosis	RSV
Bacille Calmette Guerin	HHV-8
Coccidioides	
Histoplasma	

NOT JUST MYCOBACTERIA!!

IFNGR1: Dominant vs. Recessive

Characteristic	AD	AR
IFNγR1 display	High	None
IFNγR1 responsiveness	Low	None
Clinical presentation	Local	Disseminated
Granulomata	Present	Absent
Osteomyelitis	100%	Rare
Survival	Excellent	Most die

Lancet. 2004;364:2113-21.

Interferon γ Receptor Deficiencies

Absent or defective IFNγR1

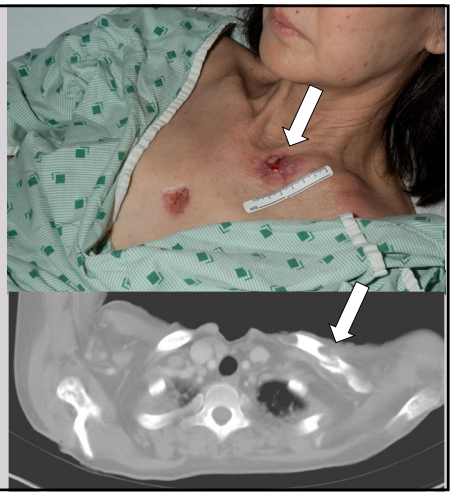
- MAC and other NTM, *Salmonella*, TB, viruses
- Complete defects present in childhood
- Partial defects present later in life
- May be misdiagnosed as malignancy!
- NOT a cause of isolated lung disease in adults

- **Dx -** genetics, flow cytometry for IFNγR1
- **Rx -** antimycobacterials, BMT

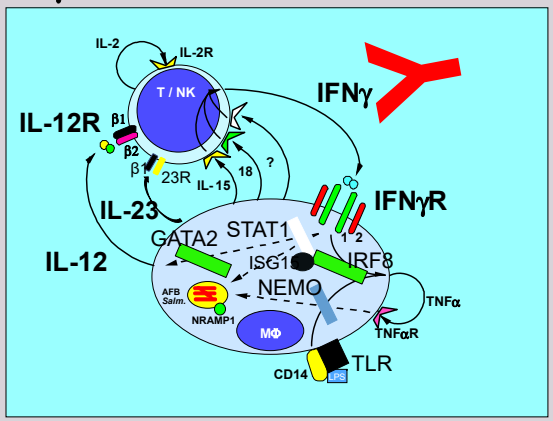
N Engl J Med. 2017;377:1077-1091.

60-year-old Vietnamese Woman

- USA 1970s
- 1 year recurring disseminated *M. avium* complex
- Numerous fistulae



Anti-IFNγ Autoantibodies

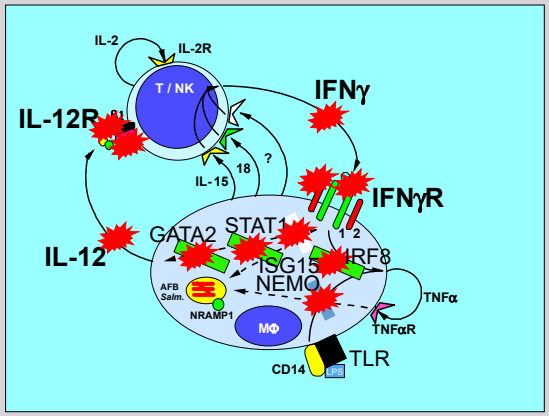


Anti-IFNγ Autoantibody Syndrome

- *Disseminated* NTM later in life also TB, *Talaromyces*, *Burkholderia*, VZV
- Predominantly female, mostly East Asian
- **Dx -** anti-IFNγ autoantibody detection
  Quantiferon is often INDETERMINATE
- **Rx -** antimycobacterials, possibly rituximab

NEJM 2012;367:725

NOT the Pathway for Lung Disease



Question #6

30-year-old Thai Woman with Back Pain

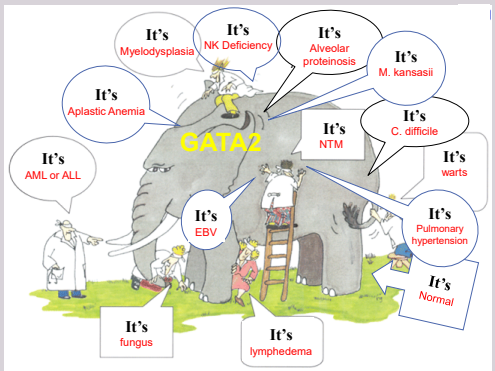
- 2 months pain and weight loss
- HIV-, normal CBC and chemistries, normal CD4
- Biopsy: osteomyelitis, MAC growing
- Quantiferon indeterminate
- You suspect that she has the anti-interferon gamma autoantibody syndrome

Question #6

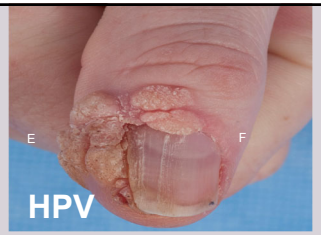
Supporting this diagnosis, what should you do?

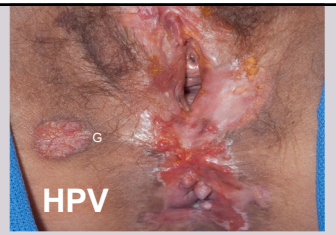
A. Check complements and total IgG
B. Determine anti-IFNγ antibody levels
C. Determine anti-GM-CSF autoantibody levels
D. Determine anti-IFNα autoantibody levels
E. Determine her cellular response to IFNγ

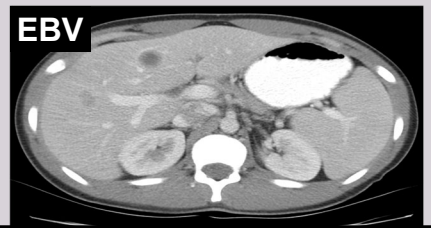
The Blind

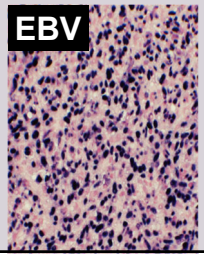


The Elephant









GATA2 Deficiency

- Mutations in GATA2, a critical hematopoietic gene
- Adolescent to adult onset
  - HPV (hands, genitals, cervical, vulvar)
  - Disseminated NTM (mediastinal *M. kansasii*)
  - Pancytopenia
- Labs: profound monocytopenia, low B, low NK
- CT: subpleural blebs
- Autosomal dominant
- Dx: genetics, hypocellular marrow, abnormal megakaryocytes
- Rx: antibiotics, BMT

Blood 2014; 123:809-21

Idiopathic CD4+ T-lymphocytopenia

- Idiopathic CD4+ T-lymphocytopenia (ICL)
  - ≤ 300 CD4+/µl
  - Associated with AIDS-like infections (crypto, PCP, MAC)
    - Exclude HIV infection (PCR, bDNA, p24, culture)
    - Often older onset than HIV associated OI
    - Surprisingly stable, consider incident cancers
- **Dx -** Determination of CD4 and CD8 number
  Often due to an underlying defect, so LOOK
- **Rx -** Treat infections (follow CD4+, ?cytokines)

N Engl J Med. 2023;388:1680-1691

Screening Laboratories

- For Lymphocytes
  - Ig levels
  - Immunization status (tetanus, pneumovax)
  - CD4+ number
  - *Genetics* (exome studies, panels)

Screening Laboratories

- Phagocytes
  - DHR for CGD
  - Genetics for everything else
- Complement
  - CH_{50} (classical pathway)
  - AH_{50} (alternative pathway)
  - Think about the gene involved!
  - Use Pubmed OMIM
  - Sequence is faster and cheaper than you think