HIGH RETURN

PFK-I

- Rate limiting enzyme of glycolysis
- 1st committed step of glycolysis
- Most important control point
- Bottle neck of glycolysis

HIGH RETURN

- Nature of Pathway: Catabolic
- Occurs in Fed state
- Activated by hormone: Insulin (usually anabolic Pathways are activated by Insulin. But this catabolic Pathway is activated by Insulin)
- Organelle: Cytoplasm (Any anabolic Pathway occurs in cytoplasm. **But this catabolic pathway occurs in cytoplasm)**
- Organ/cell: In all the cells of the body
- Only Pathway which occurs in both aerobic and anaerobic conditions
- Glucose is the only molecule which can produce ATP without O_2

Flux generating step	Rate limiting step
Example: Hexokinase in glycolysis	**Example:** PFK-I in glycolysis
Usually have low Km	Usually have high Km
Speed of reaction is high	Very slow speed of reaction
All substrates get converted to products	Not all substrates are converted to products

Remember: Aldolase B (the hepatic isoform) is in fructose Metabolism

Remember: DHAP can also be used for TG synthesis.

Irreversible/Regulatory steps	Substrate level Phosphorylation (SLP) steps
1. HexoKinase/Glucokinase 2. Phosphofructokinase-1 3. Pyruvate Kinase	1. Phosphoglycerate Kinase 2. Pyruvate Kinase

G-6-PD deficiency
First most common human enzyme deficiency
This is enzyme of HMP pathway
Hemolysis occurs due to oxidative stress. (No NADPH and Reduced Glutathione to scavenge H_2O_2) (See HMP)
Heinz bodies present

Q. Number of ATP produced in RBC in Fed state?

Q. Number of ATP produced in RBC in aerobic state?

Answer to both questions is = 2 ATPs

Because in RBCs there is no mitochondria. NADH can give ATPs after entering ETC, which occurs in mitochondria. So, NADH can never give ATPs in RBCs. So in RBC energetics is 4 (ATPs from Substrate Level Phosphorylation) – 2 ATPs (used by Hexokinase and PFK-1) = 2 ATPs

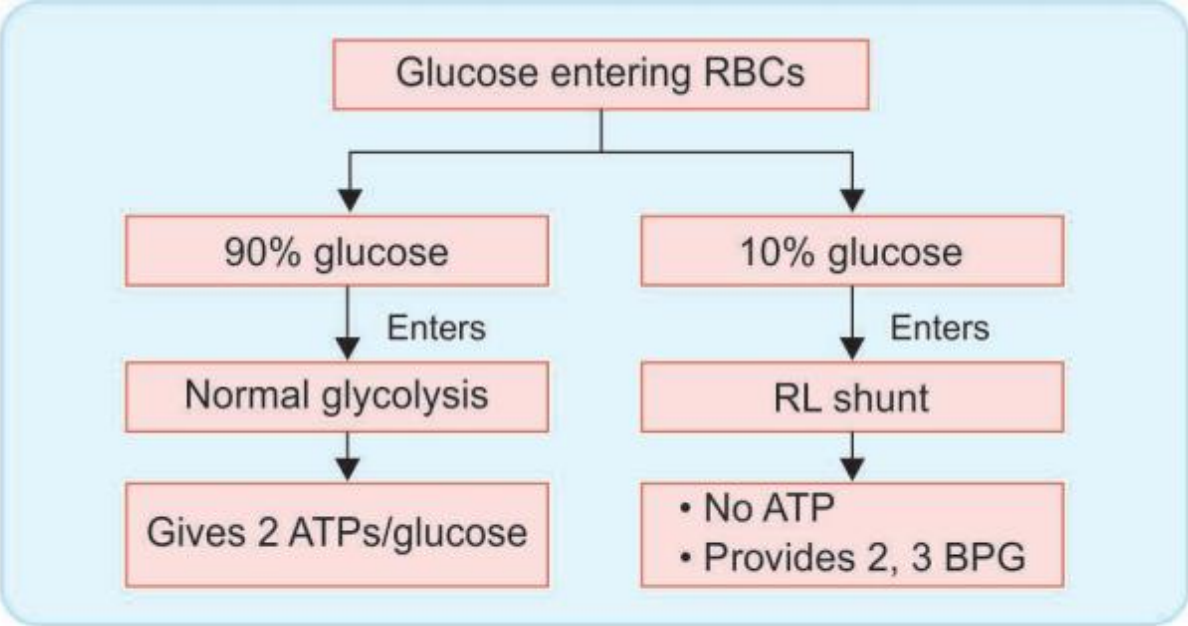

Fig. 3.5: Number of ATPs in RBCs can never be more than two, but it can be less than two if it is RL shunt

RL: RAPAPORT LEUBERING SHUNT (RL-SHUNT) RL shunt occurs only in RBCs

HIGH RETURN

Link between Glycolysis and TCA

- Activated by hormone – Insulin
- Occurs in mitochondria
- Occurs in fed state

PFK-I	PFK-II
• Converts fructose-6-phosphate to fructose 1, 6–Bis phosphate	• Converts fructose-6-phosphate to fructose 2, 6–Bis phosphate
• Not a bifunctional enzyme	• A bifunctional enzyme i.e. having both enzymatic activities– PFK-II and fructose 2, 6-bisphosphatase

High Return

- Nature of Pathway: catabolic and anabolic (Amphibolic)
- Neither activated by Insulin nor Glucagon
- Organelle: Mitochondria
- Organ/cell: In all the cells of the body (where mitochondria is present)
- A Vital Pathway for cells (vital pathways occur in mitochondria)
- Occurs only in aerobic conditions
- Occurs both in Fed and Fasting state
- TCA is called a cycle, not a pathway because it begins and ends with oxaloacetate

High Return

- **Intermediates of TCA are:** Oxaloacetate, Citrate, Isocitrate, Alpha-Ketoglutarate, Succinyl CoA, Succinate, Fumarate, Malate
- Acetyl CoA is not the intermediate of TCA

HIGH RETURN

Irreversible Steps of TCA

1. Citrate Synthase
2. Alpha-Ketoglutarate Dehydrogenase

If both given in question, then Citrate Synthase is best option to be marked.

HIGH RETURN

- Acetyl CoA is not the carrier of TCA cycle
- Acetyl CoA is not the 1st substrate of TCA cycle
- Acetyl CoA is not the intermediate of TCA cycle
- Acetyl CoA is never Glucogenic

HIGH RETURN

Protons (H^+)

- Complex I $\rightarrow$ 4 H^+ $\rightarrow$ 1 ATP produced
- Complex III $\rightarrow$ 4 H^+ $\rightarrow$ 1 ATP produced
- Complex IV $\rightarrow$ 2 H^+ $\rightarrow$ 0.5 ATP produced

HIGH RETURN

- **Non-Shivering Thermogenesis:** Thermogenin acts as uncoupler. This is a protein present in brown fat (in Neonates and Hibernating animals), which is like a H^+ channel. So when themogenin is present, then protons move through this thermogenin channel. Complex V is not used for proton

transfer in such a case. So, ATP formation (phosphorylation) does not occur. But there is no problem in oxidation i.e. electron flow. So energy is not used for ATP formation, instead it is diverted for heat generation. This is known as Non-shivering thermogenesis.

- ADP to ATP **conversion** is inhibited by - Oligomycin
- ADP to ATP **transfer** is inhibited by – Atractyloside
- ATP formation is also inhibited by uncouplers but uncouplers indirectly inhibit this. Oligomycin directly inhibit Complex V and inhibit ADP to ATP conversion

- Fructose 1, 6-Bisphosphate – Glycolysis
- Fructose 1, 6-Bisphosphatase – Gluconeogenesis
- Fructose 2, 6-Bisphosphate – Reciprocal Regulator (produced in fed state)
- Fructose 2, 6-Bisphosphatase – Active in cancerous mutation

HIGH RETURN

- Compartment: Both glycogenesis and glycogenolysis occurs in cytoplasm
- Both rate limiting enzymes of glycogen metabolism are transferases

GLYCOGEN SYNTHESIS

HIGH RETURN

- Also known as Glycogenesis
- Nature of Pathway: Anabolic
- Occurs in Fed state
- Activated by hormone: Insulin (all Anabolic pathways are activated by Insulin)
- Organelle: Cytoplasm (any Anabolic pathway occurs in cytoplasm)
- Organ/cell: Liver and Muscle

Glycogen Breakdown

HIGH RETURN

- Also known as Glycogenolysis
- Nature of pathway: Catabolic
- Occurs in fasting or in between meals
- Activated by hormone: Glucagon (all Catabolic pathways are activated by Glucagon)
- Organelle: Cytoplasm (both glycogen synthesis and breakdown occurs in cytoplasm)
- Organ/cell: Liver and Muscle

HMP

High Return

- Nature of pathway: Anabolic
- Occurs in fed state
- Activated by hormone: Insulin (usually anabolic pathways are activated by Insulin)
- Organelle: Cytoplasm (any anabolic pathway occurs in cytoplasm)
- Organ/cell: Liver, Adipose tissue, Lactating Mammary glands, Adrenal Cortex, Gonads and RBCs
- Alternate pathway for oxidation of glucose
- Major source for NADPH
- No ATP generated but CO_2 is produced

High Return

Similarities with HMP:

- Minor pathway for Oxidation of glucose
- Starts from glucose-6-phosphate
- No ATP produced
- **Site** – Cytoplasm
- **Organ** – Liver

High Return

- Transketolase → requires TPP (derivative of Vit B1) and Mg
- Transketolase transfers 2 carbon units
- Transaldolase transfers 3 carbon units

- Epinephrine acts in Muscle and Liver but Glucagon acts only in Liver

Multiple Choice Questions

Glycolysis

1. **The major metabolic product produced under normal circumstances by erythrocytes and by muscle cells during intense exercise is recycled through liver in Cori's cycle. The metabolite is:** *(Recent Question 2018)*
   a. Oxaloacetate b. Alanine
   c. Glycerol d. lactate
2. **Rate limiting enzyme (RLE) in Glycolysis is PFK-I. Which among the following is the most potent allosteric activator of PFK-I?** FAQ *(PGMEE 2013, 14)*
   a. Low pH
   b. Citrate
   c. ATP
   d. fructose 2, 6 Bisphosphate
3. **Which of the following decreases affinity of oxygen with hemoglobin?** FAQ *(JIPMER May 2018)*
   a. Decreased H^+ ions
   b. 2,3 BPG
   c. Increase in temperature
   d. Decreased sorbitol
4. **How many ATPs are used in energy investment phase of glycolysis?** *(Recent Question 2017)*
   a. 2 b. 3
   c. 4 d. ZERO
5. **In anaerobic glycolysis, end product is-** FAQ
   a. 2 ATP + 2 NAD b. 2 ATP
   c. 2 ATP + 2 NADH d. 4 ATP + 2 $FADH_2$
6. **In anaerobic glycolysis, there is gain of –** FAQ
   a. 2 ATP + 2 NAD b. 2 ATP
   c. 2 ATP + 2 NADH d. 4 ATP + 2 $FADH_2$
7. **All tissues convert glucose to predominantly lactate EXCEPT:** *(Recent Question 2017)*
   a. Brain b. Cornea
   c. Lens d. RBCs
8. **Which is a negative heterotropic allosteric modulator of glycolysis?** *(Recent Question 2017)*
   a. Citrate b. ATP
   c. ADP d. AMP
9. **Which of the following is TRUE about glycolysis?**
   a. Occurs in mitochondria
   b. Complete breakdown of glucose
   c. Conversion of glucose to 3 C pyruvate
   d. 3 ATPs produced in anaerobic glycolysis
10. **What activate Kinase of glycolysis?** *(PGMEE 2015)*
    a. ATP b. cAMP
    c. Insulin d. Glucagon
11. **In glycolysis which of the ion is most important?** FAQ *(PGMEE 2009)*
    a. Zn b. Mg
    c. Cu d. Ca
12. **The number of ATPs produced by Rapaport Leubering cycle in RBC from glucose?** *(PGMEE 2015)*
    a. 1 b. 2
    c. 3 d. 4
13. **ATP yield via substrate level phosphorylation in glycolysis:** *(PGMEE 2013)*
    a. 5 b. 6
    c. 4 d. 3
14. **Post prandial utilization of glucose is by which enzyme?** FAQ *(PGMEE 2012)*
    a. Fructokinase b. Glucokinase
    c. Hexokinase d. All of above
15. **Inhibition of glycolysis by increase supply of O_2 is called –** *(PGMEE 2013)*
    a. Carbtree effect
    b. Pasteur effect
    c. Lewis effect
    d. None
16. **Immediate metabolic products during conversion of fructose 1-6 bisphosphate to 2 molecules of pyruvate:** *(PGMEE 2015)*
    a. 3-Phosphoglycerate and 1,3-Bisphosglycerate
    b. Glyceraldehyde -3-phosphate and 1, 3 Bisphosphoglycerate
    c. Dihydroxyacetone phosphate and Dihydroxyacetone phosphate
    d. Glyceraldehyde-3-phosphate and Dihydroxyacetone phosphate
17. **The purpose of extra step of anaerobic glycolysis is :**
    a. Production of 2 lactate *(JIPMER 2016)*
    b. Production of one lactate
    c. Replenishment of NAD
    d. Replenishment of NADH
18. **Zero ATP in RBC in glycolysis occurs in:** FAQ
    a. Arsenic poisoning b. RL shunt
    c. Both a and b d. None
19. **How many ATPs are produced in glycolysis :**
    a. 7 b. 9
    c. 3 d. 0
20. **2, 3-BPG binds to ___ site(s) of hemoglobin and ____ the affinity for oxygen?** *(AIIMS May 2014)*
    a. 4, decreases b. 1, decreases
    c. 4, increases d. 1, increases
21. **Which of the following enzymes catalyze the irreversible step of glycolysis?** *(AIIMS May 2013)*
    a. Glucokinase, Phosphofructokinase, pyruvate Carboxylase
    b. Hexokinase, fructose 1, 6 Bisphosphatase, pyruvate Kinase
    c. Glucokinase, Phosphofructokinase, pyruvate Kinase
    d. Enolase, fructose 1, 6 Biphospahatase, Phosphofructokinase

MCQs Ans.

1. d
2. d
3. b
4. a
5. a
6. b
7. c
8. a
9. c
10. c
11. b
12. b
13. c
14. b
15. b
16. d
17. c
18. c
19. a
20. b
21. c

22. Glycolytic enzyme (s) inhibited by Fluoride is/are: ***(PGI Nov 2008)***

a. Hexokinase b. Aldolase
c. Enolase d. Pyruvate Kinase
e. Phosphofructokinase

23. Which of the following is INCORRECT about RBCs? ***(PGI Nov 2017)***

a. RBCs cannot use fatty acids, amino acids and ketone bodies for energy
b. RBCs does not contain enzyme Isocitrate Dehydrogenase
c. Lactate dehydrogenase is absent in RBCs
d. Production of 2,3 BPG does not yield any ATP
e. ATP Synthase is present in RBCs

24. In traumatic brain injury, changes in brain metabolism are seen. All are true EXCEPT: FAQ ***(AIIMS November 2014)***

a. There is shut down of pyruvate Dehydrogenase activity
b. There is accumulation of lactate in brain
c. There is increased lactate uptake from circulation
d. Increased CSF lactate is associated with good prognosis

Link Reaction

25. Which of the following statement about link reaction is CORRECT? ***(Recent Question 2016)***

a. This is a link between TCA and ETC
b. This is oxidative deamination of pyruvate
c. This is oxidative decarboxylation of acetyl CoA
d. This reaction requires lipoic acid and four B-complex vitamins

26. Major source of acetyl CoA is/are: FAQ

a. Triglycerides b. Fatty acids
c. Pyruvate d. Alanine

27. Thiamine deficiency results in decrease energy production, because TPP: ***(AIIMS May 2017)***

a. Interferes with alcohol metabolism
b. Interferes with transketolase activity
c. Is cofactor for pyruvate dehydrogenase and Alpha Ketoglutarate dehydrogenase
d. Interferes with energy production from amino acids

28. Which of the following is reversible enzyme?

a. Pyruvate Kinase
b. Pyruvate Dehydrogenase
c. Lactate Dehydrogenase
d. Hexokinase

29. Congenital lactic acidosis may occur due to defect in FAQ

a. Pyruvate Carboxylase
b. Pyruvate Decarboxylase
c. Pyruvate Dehydrogenase
d. Transketolase

30. A baby is hypotonic and shows that pyruvate cannot form acetyl CoA in fibroblasts. Also lactic acidosis is found. Administration of which of the following can revert this situation? FAQ ***(JIPMER May 2018)***

a. Biotin b. Pyridoxal phosphate
c. Thiamine d. Pyruvate

31. Which of the following is/are INCORRECT? ***(PGI Nov 2017)***

a. Fats can be converted to carbohydrates
b. Carbohydrates can be converted to fats
c. Glycerol can be converted to glucose
d. Beri-Beri leads to lactic acidosis
e. Link reaction is irreversible

32. Pyruvate Dehydrogenase complex has all enzyme components EXCEPT: ***(PGI Nov 2017)***

a. Decarboxylase b. Dehydrogenase
c. Carboxylase d. Transacetylase
e. Phosphatase

33. True about acetyl CoA: ***(PGI Nov 2011)***

a. Precursor for synthesis of cholesterol and other steroids.
b. Form ketone bodies
c. Starting material for synthesis of fatty acid
d. Arise from glycolysis
e. Can never be converted to glucose

TCA Cycle

34. Which is not the intermediate of TCA cycle? FAQ

a. Acetyl CoA b. Oxaloacetate
c. Alpha- Ketoglutarate d. Succinyl CoA

35. Cyanide taken up by child. First one to be affected in Kreb's cycle is:

a. Aconitase b. NAD
c. Citrate d. Acetyl CoA

36. Thiokinase of TCA produces:

a. ATP b. GTP
c. Both a and b d. NADH

37. Which among the following controls is an allosteric inhibitor of TCA cycle?

a. Isocitrate Dehydrogenase
b. Malate Dehydrogenase
c. Ketoglutarate Dehydrogenase
d. Pyruvate Dehydrogenase

38. Which of the following is anaplerotic reaction? FAQ ***(AIIMS May 2017)***

a. Conversion of pyruvate to Lactic acid
b. Conversion of pyruvate to Oxaloacetate
c. Conversion of pyruvate to Acetyl CoA
d. Conversion of pyruvate to Acetaldehyde

39. Why TCA cycle is called amphibolic cycle?

a. It can proceed both in forward and backward direction
b. It is both endothermic and exothermic
c. Metabolites are used in both amino acid and ketone body synthesis
d. Same enzyme can be used in reverse direction

40. Succinate Dehydrogenase is inhibited by: FAQ ***(PGMEE 2013)***

a. Fluoroacetate b. Arsenite
c. Cyanide d. Malonate

41. What is liberated when citrate converted to cis-aconitate? ***(PGMEE 2015)***

a. H_2O b. CO_2
c. H_2O_2 d. H_2

MCQs Ans.

22. c
23. c,e
24. d
25. d
26. c
27. c
28. c
29. c
30. c
31. a
32. a,c,e
33. a,b, c,d,e
34. a
35. b
36. c
37. a
38. b
39. b
40. d
41. a

42. In TCA cycle, which is first formed? ***(PGMEE 2009)***
a. Succinate b. Citrate
c. Isocitrate d. None

43. The net ATP yield when one molecule of pyruvate is completely oxidized to CO_2 and H_2O is: ***(PGMEE 2013)***
a. 12.5 b. 12
c. 15 d. 30

44. All of the following are correct EXCEPT:
a. Fluorocitrate is competitive inhibitor of Aconitase
b. Fluoroacetate is non-competitive inhibitor of Aconitase
c. Malonate is competitive inhibitor of Succinate Dehydrogenase
d. Iodoacetate inhibits Glycerol-3-phosphate Dehydrogenase

45. Enzyme responsible for complete oxidation of glucose to CO_2 and H_2O is present in :
a. Cytosol b. Lysosomes
c. Mitochondria d. Endoplasmic reticulum

46. Two carbon atoms which leave in the form of CO_2 in TCA, are derived from: ***(PGI May 2017)***
a. Acetyl CoA b. Oxaloacetate
c. CO_2 d. Citrate
e. Pyruvate

47. Source of energy in TCA is:
a. NAD b. NADH
c. FAD d. NADPH

48. Which of the following is not the dehydrogenase of TCA :
a. Succinate Dehydrogenase
b. Pyruvate Dehydrogenase
c. Malate Dehydrogenase
d. Isocitrate Dehydrogenase

49. Rate limiting step of TCA is/are: F A Q
a. Citrate synthase
b. Isocitrate dehydrogenase
c. Alpha-ketoglutarate dehydrogenase
d. All

50. Which enzyme of TCA is present in Inner Mitochondrial Membrane (IMM)? F A Q
a. Alpha-Ketoglutarate Dehydrogenase
b. Malate Dehydrogenase
c. Fumarate Dehydrogenase
d. Succinate Dehydrogenase

51. TCA cycle depends on:
a. Availability of acetyl CoA
b. Availability of Oxaloacetate
c. Availability of Insulin
d. Availability of Glucagon

52. Oxalo-acetate + Acetyl-Co-A → Citrate + Co-ASH this reaction is:
a. Reversible b. Irreversible
c. Endergonic d. None

53. Thiamine requirement increases in excessive intake of: ***(AIIMS May 2009)***
a. Carbohydrates b. Fats
c. Proteins d. None

54. The type of enzyme inhibition in which Succinate Dehydrogenase reaction is inhibited by malonate is an example of:
a. Noncompetitive b. Uncompetitive
c. Competitive d. Allosteric

55. TRUE statement regarding Lactate Dehydrogenase deficiency: ***(PGI Nov 2014)***
a. Fumarate level increases
b. Exercise intolerance
c. Muscle cramps may occur
d. It operate in anaerobic condition
e. It is key enzyme of Kreb cycle

56. NAD acts as a cofactor for: ***(PGI Nov 2011)***
a. Citrate Synthase
b. Isocitrate Dehydrogenase
c. a-Ketoglutarate Dehydrogenase
d. Malate Dehydrogenase
e. Succinyl Thiokinase

57. In TCA, CO_2 is released by: ***(PGI May 2017)***
a. Citrate Synthase
b. Alpha-Ketoglutarate Dehydrogenase
c. Citrate Dehydrogenase
d. Isocitrate Dehydrogenase
e. Succinate Thiokinase

58. First substrate of Kreb's cycle is: F A Q ***(PGI Nov 2017)***
a. Glucose b. Glycine
c. Citrate d. Acetyl CoA

59. Unaltered final product of TCA is: F A Q ***(PGI May 2017)***
a. Acetyl CoA b. Oxaloacetate
c. CO_2 d. Pyruvate

60. Fluoroacetate inhibits which metabolic pathway? ***(AIIMS May 2018)***
a. TCA cycle
b. Glycolytic pathway
c. Oxidative phosphorylation
d. ETC

Shuttles

61. Malate shuttle is required for:
a. Glycolysis ***(Recent Question 2018)***
b. Pyruvate Dehydrogenase complex
c. TCA
d. All

62. If aerobic glycolysis uses Glycerol-3-phosphate shuttle, how many ATPs are produced? F A Q ***(Recent Question 2018)***
a. 2 ATP b. 5 ATP
c. 7 ATP d. 3 ATP

63. NADPH via Glycerol phosphate shuttle gives how many ATPs? ***(Recent Question 2018)***
a. 2.5 b. 1.5
c. 3 d. Zero

64. Reason of presence of less ATP forming glycerol-P-shuttle in brain are all EXCEPT:
a. This is a shorter shuttle ***(Recent Question 2017)***
b. It is a quick source of ATP
c. After going in brain in ETC, it gives high energy
d. Brain needs a quick source of ATP

MCQs Ans.

42. b
43. a
44. d
45. c
46. b
47. b
48. b
49. all
50. d
51. b
52. b
53. a
54. c
55. b,c,d
56. b,c,d
57. b,d
58. d
59. b
60. a
61. a
62. b
63. d
64. c

ETC

65. Which is the only non-protein member of ETC? F A Q *(Recent Question 2017)*
a. Cytochrome c b. Coenzyme Q
c. Complex V d. Complex II

66. Cytochrome c Oxidase requires: *(Recent Question 2016)*
a. Cu b. Mg
c. Ca d. Zn

67. ATPs given by complex IV of ETC are: F A Q *(Recent Question 2016)*
a. 1 b. 2
c. 3 d. 0.5

68. ETC is located in: *(Recent Question 2015)*
a. Inner mitochondrial Membrane
b. Outer mitochondrial Membrane
c. Mitochondrial matrix
d. Inter membrane space

69. Which of the following is NOT TRUE regarding ETC? *(Recent Question 2015)*
a. Coupling of oxidation and phosphorylation occurs
b. Occurs in mitochondrial matrix
c. Known as chemiosmotic theory
d. ADP + Pi → ATP

70. Mitochondrial membrane contains a protein which is transporter of: *(Recent Question 2015)*
a. Oxaloacetate b. Acetyl CoA
c. NADH d. ATP

71. Which couple has minimum redox potential F A Q *(PGMEE 2012)*
a. $NADP^+$/NADPH b. CoQ-CoQ H_2
c. FAD/$FADH_2$ d. NAD^+/NADH

72. Most important source of ATP?
a. Oxidative phosphorylation
b. Substrate level phosphorylation
c. Aerobic glycolysis
d. TCA

73. Mechanism of action of uncouplers: *(PGMEE 2015)*
a. Inhibition of ATP synthesis only not ETC
b. Inhibition of both ATP synthesis and ETC
c. Inhibition of only ETC not ATP synthesis
d. None of the above

74. Barbiturates act on which step of mitochondrial respiratory chain? *(PGMEE 2013)*
a. Complex I to Coenzyme Q
b. Coenzyme Q to Complex III
c. Complex II to Coenzyme Q
d. Cytochrome C to Complex IV

75. CO binds with which complex of the electron transport chain? *(PGMEE 2013)*
a. Complex I b. Complex III
c. Complex II d. Complex IV

76. ATP is generated in ETC by- *(PGMEE 2013)*
a. ADP kinase
b. Na^+ Cl ATPase
c. F_o–F_1 ATPase
d. Na^+ K^+ ATPase

77. Enzyme involved in oxidative phosphorylation *(PGMEE 2012)*
a. Succinyl CoA Thiokinase
b. Pyruvate Kinase
c. NADH Dehydrogenase
d. Pyruvate Dehydrogenase

78. Which of the component of respiratory chain reacts directly with molecular oxygen? *(PGMEE 2013)*
a. Cyt b b. CoQ
c. Cyt c d. Cyt aa_3

79. Last electron acceptor in ETC is *(PGMEE 2014)*
a. Oxygen
b. Tetrachloroethylene
c. Nitrate
d. Iron

80. Atractyloside act as- F A Q *(PGMEE 2013)*
a. Inhibitor of complex III of ETC
b. Inhibitor of oxidative phosphorylation
c. Uncoupler
d. Inhibitor of glycolysis

81. Creatinine is the breakdown product of- *(PGMEE 2015)*
a. Adenosine triphosphate
b. Purine nucleotides
c. Pyrimidine nucleotides
d. Creatine phosphate

82. Cyanide affects respiratory chain by: *(PGMEE 2013)*
a. Non-competitive reversible inhibition
b. Competitive reversible inhibition
c. Suicide irreversible inhibition
d. Non-competitive irreversible inhibition

83. True about 2, 4- Dinitrophenol is? *(PGMEE 2012)*
a. Prevents ATP synthesis and electron transport chain
b. Prevents ATP synthesis and electron transport chain is increased
c. Blocks electron transport chain but ATP synthesis is normal
d. Blocks ATP synthesis but electron transport chain is normal

84. Uncouplers of oxidative phosphorylation include: F A Q *(PGI May 2018)*
a. 2,4 – DNP b. H_2S
c. Cyanide d. Thermogenin
e. Carboxin

85. Electrons in electron transport chain travel from: *(PGMEE 2013)*
a. One way irrespective of the potential
b. Low to high potential
c. Two way
d. High to low potential

86. Which vitamin is used in ETC?
a. Thiamine b. Biotin
c. Nicotinic acid d. Pyridoxal phosphate

87. Which of the following vitamin is a component of ETC? *(PGMEE 2009, 2007)*
a. Vitamin B12
b. Riboflavin
c. Nicotinic acid
d. Thiamine

MCQs Ans.

65. b
66. a
67. d
68. a
69. b
70. d
71. d
72. a
73. a
74. a
75. d
76. c
77. c
78. d
79. a
80. b
81. d
82. d
83. b
84. a,d
85. b
86. c
87. b

88. Oxidative phosphorylation is inhibited by all EXCEPT: *(FMGE Nov 2018)*
a. CO b. Antimycin A
c. Malonate d. Thermogenin

89. MELAS inhibit all ETC Complexes EXCEPT: F A Q *(PGMEE 2015)*
a. I b. II
c. III d. IV

90. Oxidative phosphorylation is NOT inhibited by: F A Q *(PGI May 2016)*
a. Fluoride
b. 2, 4-dinitrophenol (DNP)
c. Oligomycin
d. Carboxin
e. Ouabain

91. ETC is regulated by: *(PGI Nov 2011)*
a. NADH Co-Q Reductase
b. Cytochrome C Oxidase
c. Glutathione Reductase
d. Isocitrate Dehydrogenase
e. Co-Q Cytochrome C Reductase

92. Which of the following is high energy phosphate bond (produce ATP on hydrolysis): *(PGI Nov 2011)*
a. Fructose-6-phosphate
b. Creatine phosphate
c. Carbamoyl phosphate
d. Glucose-1-phosphate
e. Glucose-6-phosphate

93. Number of ATPs produced in adipose tissue from 1 NADH (NAD^+/NADH) through respiratory chain: *(PGI Nov 2011)*
a. 0 ATP b. 1 ATP
c. 2 ATP d. 2.6 ATP
e. 3 ATP

94. Which component transfers four protons : *(PGI Nov 2011)*
a. NADH-CoQ Oxidoreductase
b. Cytochrome c Oxidase
c. CoQ Cytochrome c Reductase
d. Isocitrate Dehydrogenase
e. Succinate CoQ Reductase

95. Which of the following releases/provide energy :
a. Conversion of ADP to ATP
b. Breaking of high energy bond to low energy bond
c. Conversion of pyruvate to lactate
d. Electrical gradient across inner and outer side of mitochondrial membrane
e. Passage of electron through $FADH_2$ in ETC

Gluconeogenesis

96. All are substrates of gluconeogenesis EXCEPT: F A Q *(Recent Question 2018)*
a. Lactate b. Alanine
c. Leucine d. Lysine

97. Glucose can be synthesized from all EXCEPT: *(FMGE June, 2018)*
a. Amino acids b. Glycerol
c. Acetoacetate d. Lactic acid

98. Which is NOT glucogenic? *(Recent Question 2018)*
a. Acetyl CoA b. OAA
c. Pyruvate d. Lactate

99. Which of the following substrates CANNOT contribute to gluconeogenesis in mammalian liver? F A Q *(PGI May 2017)*
a. Alanine b. Glutamate
c. Palmitate d. Pyruvate
e. Odd chain fatty acids

100. A 15-year-old male presents with increased thirst, hunger, urination, and weight loss. His fasting blood glucose level is 400 mg/dl and is diagnosed with type 1 diabetes mellitus. What is the reason for this patient's inability to maintain a normal blood glucose level? *(Recent Question 2017)*
a. Increased ketone body production
b. Abnormal response to glucagon
c. Decreased glucagon to insulin ratio
d. Decreased uptake of glucose by peripheral cells

101. Which of the following is the sequence of compartments of gluconeogenesis? *(Recent Question 2017)*
a. Mitochondria → Cytoplasm → ER
b. Cytoplasm → ER → mitochondria
c. ER → mitochondria → Cytoplasm
d. Only in mitochondria and Cytoplasm

102. Which of the following is most effective for gluconeogenesis: *(Recent Question 2017)*
a. Fructose 2,6 bisphosphate inhibits fructose 1,6 Bisphosphatase
b. Acetyl CoA activates Pyruvate Carboxylase
c. Citrate stimulates Acetyl CoA Carboxylase
d. Citrate inhibit.s acetyl CoA Carboxylase

103. A child having hypoglycemia is unable to use both glycogenolysis and gluconeogenesis pathways. Which of the following enzyme is affected? *(Recent Question 2016)*
a. Glucokinase
b. Phospho-Fructo Kinase -1
c. Glucose-6-Phosphatase
d. Transketolase

104. Which of the following is/are substrate (s) for gluconeogenesis? F A Q *(PGI May 2018)*
a. Glycerol b. Fatty acids
c. Alanine d. Lysine
e. Leucine

105. Pyruvate can be converted directly into all of the following EXCEPT: *(Recent Question 2016)*
a. Phosphoenol pyruvate
b. Alanine
c. Acetyl CoA
d. Lactate

106. Which pathway can use propionic acid? *(Recent Question 2016)*
a. Glycolysis b. Gluconeogenesis
c. Glycogenolysis d. Glycogenesis

107. Glucose may be synthesized from: *(Recent Question 2016)*
a. Glycerol b. Adenine
c. Palmitic acid d. Guanosine

MCQs Ans.

88. d
89. b
90. a,d,e
91. a,b,e
92. b,c
93. d
94. a,c
95. b,d,e
96. c
97. c
98. a
99. c
100. d
101. a
102. b
103. c
104. c
105. a
106. b
107. a

108. Amino acid which cannot be used for glycogen synthesis: F A Q *(PGI May 2017)*
a. Alanine b. Threonine
c. Phenylalanine d. Leucine

109. Gluconeogenesis occurs in: *(Recent Question 2015)*
a. Muscles b. Kidney
c. Liver d. Intestine

110. Conversion of lactate to glucose requires all EXCEPT:
a. Pyruvate Carboxylase
b. PFK-1
c. Enolase
d. Glucose-6-Phosphatase

111. Regulatory enzymes in gluconeogenesis are all EXCEPT: F A Q *(Recent Question 2014)*
a. Pyruvate Carboxylase
b. Aldolase B
c. PEP carboxykinase
d. Glucose-6-Phosphatase

112. Enzymes involved in gluconeogenesis are all EXCEPT: *(Recent Question 2014)*
a. Phosphoglycerate Kinase
b. Fructose 1,6 bisphosphatase
c. Phosphoglucomutase
d. Pyruvate Carboxylase

113. Glyconeogenesis is: *(Recent Question 2013)*
a. Synthesis of galactose from non-carbohydrate sources
b. Synthesis of glycogen from glucose
c. Synthesis of glucose from glycerol
d. Synthesis of glycogen from non-carbohydrate sources

114. A genetic disorder renders fructose 1,6 bisphosphatase in liver less sensitive to regulation by fructose 2,6- bisphosphate. All of the following metabolic changes occur EXCEPT: *(Recent Question 2014)*
a. Level of fructose 1,6 bisphosphate is higher than normal
b. Level of fructose 1,6 bisphosphate is lower than normal
c. Less pyruvate formed
d. Less ATP formed

115. During gluconeogenesis, oxaloacetate is transported from mitochondria to cytoplasm by: F A Q *(Recent Question 2013)*
a. Malate b. Pyruvate
c. Glutamate d. Phosphoenol pyruvate

116. Malate shuttle is important in:
a. Glycogenesis b. Glycolysis
c. Gluconeogenesis d. Glycogenolysis

117. During prolonged starvation, rate of gluconeogenesis depends on: *(Recent Question 2013)*
a. Increased alanine levels in liver
b. Decreased cGMP levels in liver
c. ADP in liver
d. Decreased essential fatty acids in liver

118. All of the following amino acids forms Acetyl CoA via pyruvate Dehydrogenase EXCEPT:
a. Glycine b. Hydroxyproline
c. Tyrosine d. Alanine

119. Which of the following reactions takes place in two compartments? *(PGMEE 2015)*
a. Glycogenesis b. Gluconeogenesis
c. Glycolysis d. Glycogenolysis

120. Step of Gluconeogenesis is: *(PGMEE 2015)*
a. Fructose 6 phosphate to glucose 6 phosphate
b. Pyruvate to lactate
c. Phosphoenol pyruvate to Oxaloacetate
d. Pyruvate to acetyl CoA

121. Which of the following metabolites is involoved in glycogenolysis, glycolysis and gluconeogenesis?
a. Fructose – 6- phosphate *(PGMEE 2016, 17)*
b. Glucose – 6 – phosphate
c. Uridine diphospho glucose
d. Galactose- 1- phosphate

122. Substrate for gluconeogenesis- F A Q *(PGMEE 2015)*
a. Fatty acid
b. Acetyl-CoA
c. Pyruvic acid (pyruvate)
d. All of the above

123. Which of the following hormones can cause hyperglycemia without known effects on glycogen? *(PGMEE 2016, 17)*
a. Epinephrine b. Nor epinephrine
c. Thyroxine d. Glucagon

124. Gluconeogenesis is favoured in fasting state by: *(PGI-May 2017)*
a. Activation of pyruvate Carboxylase by acetyl CoA
b. Increased conversion of phosphoenol pyruvate to pyruvate by activation of pyruvate Kinase
c. Increased fatty acid oxidation in liver
d. Inhibition of PFK-II
e. Increase release of alanine from muscles to liver

Glycogen

125. Which vitamin is required for Glycogen Phosphorylase? F A Q *(AIIMS Nov 2017, PGMEE 2015, 2018)*
a. TPP (Thiamine Pyrophosphate)
b. PLP (Pyridoxal phosphate)
c. Riboflavin
d. Lipoic acid

126. Glycogen Phosphorylase is regulated by all EXCEPT:
a. Protein Kinase b. Calmodulin
c. cAMP d. Glycogenin

127. Allosteric stimulator of glycogen synthase:
a. Insulin
b. Glucose 6 phosphate
c. Glucagon
d. Fructose 1,6 bisphosphate

128. A 28-year-old professional cyclist has been training for an opportunity to go for a long race. His coach strongly suggests the intake of carbohydrates after the work out to ensure muscle glycogen storage. The activity of muscle glycogen synthase in resting muscles is increased by the action of which of the following? *(Recent Question 2017)*
a. Epinephrine b. Glucagon
c. Insulin d. Phosphorylation

MCQs Ans.

108. d
109. c
110. b
111. b
112. c
113. d
114. a
115. a
116. a
117. a
118. c
119. b
120. a
121. b
122. c
123. c
124. a,c, d,e
125. b
126. d
127. b
128. c

129. Muscle CANNOT maintain blood glucose because of deficiency of : FAQ ***(Recent Question 2017)***
a. Glucose-6-phosphatase
b. Glycogen Phosphorylase
c. Hexokinase
d. Phospho-gluco-mutase

130. Muscle CANNOT make use of glycogen because of deficiency of : ***(Recent Question 2017)***
a. Glucose-6-Phosphatase
b. Glycogen Phosphorylase
c. Hexokinase
d. Phospho-gluco-Mutase

131. Major carbohydrate store in the body is- ***(PGMEE 2015)***
a. Hepatic Glycogen
b. Blood glucose
c. Glycogen in adipose tissue
d. None of the above

132. A 15-year-old type I diabetic patient faints after injecting himself with insulin. He is administered glucagon and rapidly recovers consciousness. Glucagon induces activity of: ***(Recent Question 2017)***
a. Glycogen synthase b. Glycogen phosphorylase
c. Glucokinase d. Hexokinase

133. Glycogenin is a: ***(Recent Question 2016)***
a. Lipid
b. Polypeptide
c. Polysaccharide
d. Glycosa amino glycans (GAGs)

134. If muscle glycogen is used for anaerobic glycolysis, how many ATPs are formed? FAQ
a. 2 b. 7
c. 3 d. ZERO

135. Which of the following yields 3 molecules of ATP under anaerboic metabolism? ***(AIIMS May 2017)***
a. Glucose b. Galactose
c. Glycogen d. Amino Acid

136. All are sources of glucose EXCEPT: FAQ
a. Liver Glycogen b. Gluconoegenesis
c. Muscle Glycogen d. Alanine

137. A 30-year-old presents with intractable vomiting and inability to eat or drink for the past 3 days. His blood glucose level is normal. Which of the following is most important for maintenance of Blood glucose?
a. Liver b. Heart
c. Skeletal Muscle d. Lysosome

138. Glycogen phosphorylase degrades glycogen to produce: ***(Recent Question 2015)***
a. Glucose b. Glucose-1-P
c. Glucose-6-P d. UDP glucose

139. Glycogenolysis is best described by which of the following statements? ***(Recent Question 2015)***
a. It involves enzymes cleaving beta (1-4) glycosidic linkage
b. Requires activation of glycogen synthase
c. Requires a bifunctional enzyme (debranching and transferase)
e. Requires inactivation of phosphorylase kinase

140. During the breakdown of glycogen, free glucose is formed from which of the following?
a. Glucose residues in α-1,4 glycosidic linkages
b. The reducing end
c. The non reducing end
d. Glucose residues in α -1,6 glycosidic linkages

141. Glycogen catabolism is best described by which of the following statements- ***(Recent Question 2015)***
a. In brain, it yields glucose for skeletal muscle consumption
b. It requires a debranching enzyme in the erythrocytes
c. It is not a major pathway in brain
d. It uses Phosphorylase for glucose residue cleavage from the reducing end of glycogen in liver

142. The degradation of glycogen normally produces which of the following: ***(Recent Question 2015)***
a. More glucose than glucose-1-P
b. More glucose-1-P than glucose
c. Equal amount of glucose and glucose-1-P
d. Neither glucose nor glucose-1-P

143. The energy for glycogenesis is derived from :
a. GTP b. ATP
c. UDP d. UTP

144. UDP-glucose is not used in: ***(Recent Question 2015)***
a. HMP
b. Galactose metabolism
c. Glycogen synthesis
d. Uronic acid pathway

145. Which is branching enzyme? **(FMGE June 2018)**
a. Glycogen Synthetase
b. glucose-6 Phosphatase
c. Amylo $(1 \rightarrow 4)$, $(1 \rightarrow 6)$ Transglycosylase
d. Glycogen Phosphorylase

146. In starvation how many hours needed for depletion of Glycogen: FAQ ***(PGMEE 2015)***
a. 9 b. 18
c. 24 d. 48

147. Glycogen is released from muscle because of increased cAMP due to:
a. Glucagon b. Insulin
c. Epinephrine d. Growth hormone

148. Alpha amylase secreted by pancreas digest starch into which of the following major products?
a. Amylose, Amylopectin, and Maltose
b. Glucose, Galactose, and fructose
c. Glucose, Sucrose, and Maltotriose
d. Limit Dextrins, Maltose, and Maltotriose

149. Glycogen synthesis and breakdown takes place in the same cell, having enzymes necessary for both pathways. Why is glucose-6-phosphate produced during glycogenesis in the cytoplasm of liver cells, not acted upon by glucose-6-phosphatase enzyme? ***(AIIMS Nov 2015)***
a. Steric inhibition of phosphatase by albumin
b. Glucose-6-phosphatase is present in endoplasmic reticulum while Glycogen is in cytoplasm
c. It is thermodynamically viable only when Gluconoegenesis has stated
d. Require protein kinase for activation

MCQs Ans.

129. a
130. a
131. a
132. b
133. b
134. c
135. c
136. c
137. a
138. b
139. c
140. d
141. c
142. b
143. d
144. a
145. c
146. b
147. c
148. d
149. b

150. Enzyme involved in both glycogenesis and glycogenolysis is? F A Q *(AIIMS May 2015, 2014)*
a. Glycogen synthase b. Phosphoglucomutase
c. Phosphorylase d. Glycogen Transferase

151. In glycogen metabolism, some metabolically active important enzymes found in the liver are converted from their inactive dephosphorylated state to active phosphorylated state. Which of the following is true? *(AIIMS November 2012)*
a. Always activates the enzyme
b. Catecholamines directly stimulate it
c. More commonly seen in fasting state than in fed state
d. Always activated by cAMP dependent protein kinase

Glycogen Storage Diseases

152. A 10 year old boy rapidly develops hypoglycemia after moderate activity. Blood examination reveals raised levels of ketone bodies, lactic acid and triglycerides. On examination, liver and kidneys were enlarged. Histopathology of liver shows deposits of glycogen in excess amount. What is the diagnosis? *(AIIMS Nov 2017)*
a. Von Gierke's disease b. Cori's disease
c. Mc Ardle's disease d. Pompe's disease

153. An adolescent male patient came with pain in calf muscles on exercise. On biopsy excessive amount of glycogen present was found to be present in the muscle. What is the most likely enzyme deficiency? F A Q *(AIIMS May 2018)*
a. Muscle debranching enzyme
b. Phosphofructokinase I
c. Glucose 6 phosphatase
d. Phosphorylase enzyme

154. A 3-month-old infant presents with hepatosplenomegaly and failure to thrive. A liver biopsy reveals glycogen with an abnormal, amylopectin like structure with long outer chains and missing branches. Which of the following enzymes would most likely be deficient?
a. Alpha Amylase b. Branching enzyme
c. Debranching enzyme d. Glycogen Phosphorylase

155. A 30-year-old male presents with severe muscle cramps. His blood lactate levels did not increase after exercise. His blood glucose by GOD-POD levels was found to be normal. He has :
a. Mc Ardle's disease
b. Glycogen storage disease type III
c. Von Gierke's disease
d. Glycogen storage disease type VI

156. All of the following are associated with non-ketotic hypoglycemia, EXCEPT:
a. Von Gierke's disease b. Insulinoma
c. Carnitine deficiency d. MCAD deficiency

157. Increased uric acid levels are seen in which glycogen storage disease? *(Recent Question)*
a. Type I b. Type II
c. Type III d. Type IV

158. Enzyme deficient in Her's disease- *(PGMEE 2015)*
a. Muscle Phosphorylase
b. Acid maltase
c. Liver Phosphorylase
d. Debranching enzyme

159. Glycogen storage disease which presents as lysosomal storage disease: F A Q
a. Andersen's disease *(PGMEE 2012, 2013, 2015)*
b. Pompe's disease
c. Mc Ardle's disease
d. Von gierke's disease

160. Hypoglycemia is more severe in Type I Glycogen Storage Disease as compared to Type VI Glycogen Storage Disease because: *(AIIMS May 2014)*
a. No Gluconoegenesis in type I disease
b. No Gluconoegenesis in type VI disease
c. Both
d. Type I disease affects muscles and liver both

161. Baby has hypoglycemia, specially early morning hypoglycemia. Glucagon given. It raises blood glucose if given after meals But does not raises blood glucose if given during fasting. Liver biopsy shows increased glycogen deposits. Enzyme defect is?
a. Muscle Phosphorylase *(AIIMS May 2016)*
b. Glucose-6-phosphatase
c. Branching enzyme
d. Debranching enzyme

162. In Von Gierke's disease, the levels of ketone bodies are increased due to all EXCEPT: F A Q *(AIIMS May 2015)*
a. The patients have hypoglycaemia
b. The patients have low blood glucose
c. Less mobilization of fats
d. OAA is required for Gluconoegenesis

163. Glycogen storage disorder (s) is/are: F A Q
a. Niemann-Pick disease *(PGI Nov 2014)*
b. Gaucher disease
c. Tay-Sachs Disease
d. Pompe's disease
e. McArdles disease

HMP Pathway, Uronic Acid Pathway and Sorbitol Pathway

164. Products of HMP shunt are all EXCEPT: F A Q *(Recent Question 2018)*
a. Glyceraldehyde-3-P b. Glycerol-3- P
c. 2 NADPH d. 3 NADPH

165. HMP is the only source for : *(Recent Question 2018)*
a. NADPH b. NADH
c. Ribose-5-P d. CO_2

166. Which vitamin is required for glucose -6- phosphate Dehydrogenase? F A Q *(Recent Pattern June 2018)*
a. Riboflavin b. Thiamine
c. Niacin d. Biotin

167. NADPH is produced from: F A Q *(Recent Pattern 2018)*
a. HMP
b. Malic enzyme
c. Cytoplasmic isocitrate dehydrogenase
d. All

MCQs Ans.

150. b
151. c
152. a
153. d
154. b
155. a
156. a
157. a
158. c
159. b
160. a
161. d
162. d
163. d,e
164. b
165. c
166. c
167. d

168. Which pathway DOES NOT generate ATP? ***(Recent Question 2017)***

a. Glycolysis b. HMP
c. TCA d. Fatty acid oxidation

169. Severe thiamine deficiency is associated with : ***(Recent Question 2017)***

a. Increased clotting time
b. Decreased RBC transketolase activity
c. Decreased RBC Glutathione activity
d. Increased Xanthic acid excretion

170. Which of the following metabolic pathway in carbohydrate metabolism is required for nucleic acid synthesis? ***(Recent Question 2017)***

a. Glycolysis b. Glycogenesis
c. HMP d. Gluconeogenesis

171. HMP shunt occurs in all organs EXCEPT : ***(Recent Question 2016)***

a. Liver
b. Non lactating mammary glands
c. Adipose tissues
d. RBCs

172. Glutathione is a: F A Q ***(PGMEE 2006)***

a. Dipeptide b. Polypeptide
c. Tripeptide d. Oligopeptide

173. Reduced NADPH is produced by: F A Q ***(PGMEE 2016-17, 2015)***

a. Krebs cycle
b. Hexose monophosphate pathway (HMP shunt)
c. Uronic acid pathway
d. Anerobic glycolysis

174. Dehydrogenases of HMP shunt are specific for ***(PGMEE 2009)***

a. TPP b. $NADP^+$
c. FMN d. FAD

175. NADPH is generated in the reaction catalysed by: ***(PGMEE 2013, 2005)***

a. LDH b. G6PD
c. G3PD d. Alcohol Dehydrogenase

176. NADPH in extra mitochondrial site helps in the production of: F A Q ***(PGMEE 2013, 2012)***

a. Ketone bodies b. Steroids
c. Glycogen d. None

177. Products of uronic acid pathway in human beings are all EXCEPT: ***(PGMEE 2015)***

a. Vitamin C b. Pentoses
c. NADH d. Glucuronic acid

178. Glucose is converted to glucuronic acid by-

a. Oxidation of aldehyde group ***(PGMEE 2013-12)***
b. Oxidation of terminal alcohol
c. Oxidation of both
d. None

179. Due to which of the following enzyme deficiency, vitamin C CANNOT be synthesised in humans? F A Q ***(AIIMS May 2018)***

a. L-Glucuronic acid oxidase
b. L-Gulonic acid reductase
c. L-Gulonolactone oxidase
d. L-Gulonolactone reductase

https://drive.google.com/file/d/1B9Fm1WXtX9-hob-CBr-EPIfzCcW4Ssng/view?usp=sharing