What is claimed is:

1. A recombinant hemoglobin protein, with or without heme, comprising recombinant hemoglobin tetramer, dimer, and/or subunit as an oxygen carrier and supply replacing natural or native hemoglobin molecule isolated and/or purified from an animal or human source.

2. The recombinant hemoglobin protein of claim 1, wherein

(a) said recombinant hemoglobin subunit is a recombinant hemoglobin monomer being constructed and expressed based on a sequence of 141-146 amino acids originated from *Homo sapiens*; or

(b) said recombinant hemoglobin dimer comprises any two of the recombinant hemoglobin subunits, each of said recombinant hemoglobin subunits being a recombinant hemoglobin monomer and having a sequence of 141-146 amino acids originated from *Homo sapiens*; or

(c) said recombinant hemoglobin tetramer comprises any four of the recombinant hemoglobin subunits, each of said recombinant hemoglobin subunits being a recombinant hemoglobin monomer and having a sequence of 141-146 amino acids originated from *Homo sapiens*.

3. The recombinant hemoglobin protein of claim 2, wherein said recombinant hemoglobin subunit in (a) comprises alpha subunit, beta subunit, gamma-1 subunit, and gamma-2 subunit having SEQ ID Nos. 1 to 4, respectively; or

wherein said recombinant hemoglobin dimer in (b) comprises alpha-beta heterodimer, alpha-gamma-1 heterodimer, alpha-gamma-2 heterodimer, beta-gamma-1 heterodimer, and beta-gamma-2 heterodimer, each of said recombinant hemoglobin subunits having an amino acid sequence of any of SEQ ID Nos. 1 to 4; or

wherein said recombinant hemoglobin tetramer in (c) comprises $2\alpha\beta_2$, $2\alpha\gamma 1_2$, $2\alpha\gamma 2_2$, $2\beta\gamma 1_2$, and $2\beta\gamma 2_2$ tetramer, each of said recombinant hemoglobin subunits having an amino acid sequence of any of SEQ ID Nos. 1 to 4.

4. The recombinant hemoglobin protein of claim 1, wherein said recombinant hemoglobin subunit comprises with at least one of or without a Poly-N or a His tag.

5. A method of making the recombinant hemoglobin molecule of claim 1 comprising constructing a fusion gene coding for the recombinant hemoglobin protein, tetramer, dimer and/or subunit, inserting the fusion gene into a vector, inserting the vector into a host organism and expressing said protein, tetramer, dimer or subunit of claim 1.

6. A pharmaceutical composition comprising the recombinant hemoglobin protein of claim 1 in a pharmaceutically-acceptable carrier.

7. A recombinant hemoglobin protein, tetramer, dimer or subunit-based therapeutic agent comprising the recombinant hemoglobin protein, tetramer, dimer, and/or subunit of claim 1 and an active agent, the active agent selected from one or more of a chemotherapeutic agent, a radiotherapeutic agent, a cell labeling agent, or a fluorescent labeling agent, the recombinant hemoglobin protein, tetramer, dimer and/or subunit being either directly conjugated to the active agent or indirectly conjugated to the active agent through a cleavable or non-cleavable linker.

8. The therapeutic agent of claim 7, wherein

(a) said recombinant hemoglobin subunit is a recombinant hemoglobin monomer being constructed and expressed based on a sequence of 141-146 amino acids originated from *Homo sapiens*; or

(b) said recombinant hemoglobin dimer comprises any two of the recombinant hemoglobin subunits, each of said recombinant hemoglobin subunits being a recombinant hemoglobin monomer and having a sequence of 141-146 amino acids originated from *Homo sapiens*; or

(c) said recombinant hemoglobin tetramer comprises any four of the recombinant hemoglobin subunits, each of said recombinant hemoglobin subunits being a recombinant hemoglobin monomer and having a sequence of 141-146 amino acids originated from *Homo sapiens*; or

(d) said recombinant hemoglobin protein is linked with one or more of said linker molecule(s) at one or more subunits of said recombinant hemoglobin protein; or

(e) said recombinant hemoglobin protein comprises with at least one of or without a Poly-N or a His tag.

9. The therapeutic agent of claim 8, wherein said recombinant hemoglobin subunit in (a) comprises alpha subunit, beta subunit, gamma-1 subunit, and gamma-2 subunit having SEQ ID Nos. 1 to 4, respectively; or

wherein said recombinant hemoglobin dimer in (b) comprises alpha-beta heterodimer, alpha-gamma-1 heterodimer, alpha-gamma-2 heterodimer, beta-gamma-1 heterodimer, and beta-gamma-2 heterodimer, each of said recombinant hemoglobin subunits having an amino acid sequence of any of SEQ ID Nos. 1 to 4; or

wherein said recombinant hemoglobin tetramer in (c) comprises $2\alpha\beta_2$, $2\alpha\gamma 1_2$, $2\alpha\gamma 2_2$, $2\beta\gamma 1_2$, and $2\beta\gamma 2_2$ tetramer, each of said recombinant hemoglobin subunits having an amino acid sequence of any of SEQ ID Nos. 1 to 4.

10. The therapeutic agent of claim 7, wherein said recombinant hemoglobin protein, tetramer, dimer, or subunit is chemically modified by one or more functional groups before being conjugated to said active agent, said chemical modification comprising reacting the recombinant hemoglobin molecule with one or more of the following compound(s) in respect of different chemical reactions for said chemical modification:

a) for amine reactions, the compounds involved comprising anhydride, ketene, NHS ester, isothiocyanates, isocyanates, activated esters which include fluorophenyl esters and carbonyl azides, sulfonyl chlorides, carbonyls followed by reductive amination, epoxides, carbonates, fluorobenzenes, imidoesters, hydroxymethyl phosphine derivatives, mannich condensation,

diazonium derivatives, 4-sulfo-2,3,5,6-tetrafluorophenol, carbonyl diimidazole, sulfo-NHS, and N-terminal modification by pyridoxal-5-phoshpate-based biomimetic transamination;

b) for thiol reactions, the compounds involved comprising maleimides, alkyl halides, haloacetamides, disulfides, thiosulfates, aziridine-containing reagents, acryloyl derivatives, arylating agents, and vinylsulfone derivatives;

c) for carboxylate reactions, the compounds involved comprising diazoalkanes and diazoacetyl compounds, carbonyldiimidazoles, and carbodiimides;

d) for hydroxyl reactions, the compounds involved comprising epoxides and oxiranes, carbonyldiimidazoles, carbonates, chloroformates, chemical and enzymatic oxidations, alkyl halogens, and isocyanates;

e) for native chemical ligations, the compounds involved comprising thioesters;

f) for N-terminal modification, the compounds involved comprising N-terminal serine or threonine using periodate oxidation thereof to generate aldehydes for coupling with hydroxylamines, hydrazines, or hydrazides, carbodiimides;

g) for incorporation of bioorthogonal functionalities, the compounds involved comprising alkynes and azides with subsequent bioorthogonal conjugation reactions which include dipolar addition Huisgen 1,3-dipolar additions of alkynes and azides, Staudinger ligation of azides and triarylphosphines, Diels-alder reaction of alkenes and tetrazines, and coupling of alkenes and tetrazoles;

h) for photochemical reactions, the compounds involved comprising photoaffinity labeling agents, diazirine derivatives, benzophenones and anthraquinones;

i) for metal-mediated reactions, the compounds involved comprising metal carbenoids and palladium-activated allyl reagents, optionally wherein said cleavable linker comprises carbinolamine, disulfide, carbamide, aminal, carbonate, ester, carbamate, phosphate, amide,

acetal, imine, oxime, ether and sulfonamide group linker; optionally wherein said non-cleavable linker comprises alkyl and aryl group linker; optionally wherein said chemotherapeutic agent comprises 5-Fluorouracil, temozolomide, cisplatin and other anti-cancer drugs; optionally wherein said radiotherapeutic agent comprises Rhodium-105 complex, Samarium-153 complex and other related complexes; optionally wherein said cell or fluorescent labeling agent comprises one or more fluorescent proteins, non-protein organic fluorophores, fluorescent nano-particles and metal-based luminescent dyes; optionally wherein said cancer comprises pancreatic cancer, leukemia, head and neck cancer, colorectal cancer, lung cancer, breast cancer, liver cancer, nasopharyngeal cancer, esophageal cancer, prostate cancer, stomach cancer and brain cancer.

11. A pharmaceutical composition comprising a therapeutically effective amount of the recombinant hemoglobin protein, tetramer, dimer or subunit-based therapeutic agent of claim 7, said composition to be administered to a subject in need thereof who suffers from cancer.

12. The composition of claim 11, wherein the therapeutically effective amount of said therapeutic agent is at $\leqslant$ 0.0024 g/kg of said subject and said subject is human, or

wherein the therapeutically effective amount of said therapeutic agent is at $\leqslant$ 0.03 g/kg of said subject and said subject is animal.

13. The composition of claim 11 further comprising a pharmaceutically acceptable carrier, salt, buffer, water, or a combination thereof,

optionally wherein route of said administration comprises intravenous injection, intraperitoneal injection, and subcutaneous injection, and said administering of the composition can be in single dose or in multiple doses for once a week,

optionally wherein said cancer comprises pancreatic cancer, leukemia, head and neck cancer, colorectal cancer, lung cancer, breast cancer, liver cancer, nasopharyngeal cancer, esophageal cancer or brain cancer,

optionally wherein said cancer is tumor comprising hepatocellular carcinoma, liver cancer progenitor cells-induced tumor, glioblastoma, or triple negative progenitor cells-induced tumor.

14. The pharmaceutical composition of claim 11 wherein (a) the composition has a pH in a range of 5.5 to 9.5, or (b) the composition has a pH of 7.2 to 8.0.

15. A method for preparing the therapeutic agent of claim 7, said method comprising:

a) providing a recombinant hemoglobin protein, tetramer, dimer or subunit;

b) purifying the recombinant hemoglobin protein, tetramer, dimer or subunit using different column chromatography methods;

c) stabilizing the recombinant hemoglobin protein or tetramer by a cross-linker to form a cross-linked recombinant hemoglobin protein or tetramer;

d) chemically modifying the recombinant hemoglobin protein, tetramer, dimer or subunit comprising reacting with one or more functional groups followed by conjugating said recombinant hemoglobin protein, tetramer, dimer or subunit with an active agent, or conjugating an active agent with a cleavable or non-cleavable linker to form a linker-active agent conjugate prior to linking said conjugate to said recombinant hemoglobin protein, tetramer, dimer or subunit.

16. The method of claim 15, wherein said chemically modifying comprises one or more of the following reactions or modifications:

a) amine reactions, wherein the compounds involved comprises anhydride, ketene, NHS ester, isothiocyanates, isocyanates, activated esters which include fluorophenyl esters and carbonyl azides, sulfonyl chlorides, carbonyls followed by reductive amination, epoxides, carbonates, fluorobenzenes, imidoesters, hydroxymethyl phosphine derivatives, mannich condensation, diazonium derivatives, 4-sulfo-2,3,5,6-tetrafluorophenol, carbonyl diimidazole,

sulfo-NHS, and N-terminal modification by pyridoxal-5-phoshpate-based biomimetic transamination;

b) thiol reactions, wherein the compounds involved comprises maleimides, alkyl halides, haloacetamides, disulfides, thiosulfates, aziridine-containing reagents, acryloyl derivatives, arylating agents, and vinylsulfone derivatives;

c) carboxylate reactions, wherein the compounds involved comprises diazoalkanes and diazoacetyl compounds, carbonyldiimidazoles, and carbodiimides;

d) hydroxyl reactions, wherein the compounds involved comprises epoxides and oxiranes, carbonyldiimidazoles, carbonates, chloroformates, chemical and enzymatic oxidations, alkyl halogens, and isocyanates;

e) native chemical ligations, wherein the compounds involved comprises thioesters;

f) N-terminal modification, wherein the compounds involved comprises N-terminal serine or threonine using periodate oxidation thereof to generate aldehydes for coupling with hydroxylamines, hydrazines, or hydrazides, carbodiimides;

g) incorporation of bioorthogonal functionalities, wherein the compounds involved comprises alkynes and azides with subsequent bioorthogonal conjugation reactions which include dipolar addition Huisgen 1,3-dipolar additions of alkynes and azides, Staudinger ligation of azides and triarylphosphines, Diels-alder reaction of alkenes and tetrazines, and coupling of alkenes and tetrazoles;

h) photochemical reactions, wherein the compounds involved comprises photoaffinity labeling agents, diazirine derivatives, benzophenones and anthraquinones;

i) metal-mediated reactions, wherein the compounds involved comprises metal carbenoids and palladium-activated allyl reagents, optionallywherein said cleavable linker comprises carbinolamine, disulfide, carbamide, aminal, carbonate, ester, carbamate, phosphate, amide,

acetal, imine, oxime, ether or sulfonamide group linker, optionally wherein said non-cleavable linker comprises alkyl or aryl group linker, optionally wherein said active agent is a chemotherapeutic agent comprising 5-Fluorouracil, temozolomide, cisplatin and other anti-cancer drug, optionally wherein said active agent is a cell/fluorescent labeling agent comprising one or more fluorescent proteins, non-protein organic fluorophores, fluorescent nano-particles and metal-based luminescent dye.

17. The composition of claim 6 for locally oxygenating tissue from or in an animal or human subject

18. The method of claim 17, wherein the tissue is (a) cancerous tumor tissue, or (b) hypoxic, or (c) *ex vivo*, or (d) normal organ tissue.

19. Use of the composition of claim 6 in manufacturing a medicament for treating oxygen-deprivation disorder or hemorrhagic shock in an animal or human subject in needs thereof.

20. Use of the therapeutic agent of claim 7 in manufacturing a medicament for (a) targeting and inducing apoptosis of cancer cells in a subject in needs thereof or (b) inhibiting tumor metastasis and reducing recurrence in a subject in needs thereof, wherein said medicament comprises a therapeutically effective amount of the therapeutic agent of claim 7.

21. The therapeutic agent of claim 11 for live-cell imaging and diagnostic imaging of cancer cells or tumor cells or progenitor cells or cancer stem cells.