

Antibiotic Resistance Gene Resource and Assay List

Understanding the relationships between drugs and the genes that pathogens use to evade or neutralize them is imperative for successfully treating a range of infectious diseases. This resource provides an overview of these relationships and information about Microbial DNA qPCR Assays and Assay Kits, which specifically detect microbial antibiotic resistance genes.

Overview

Resistance to drugs that target pathogens is a serious public health concern. Resistance is the result of specific genes harbored by microorganisms that reduce the impact of drug molecules. Mechanisms employed by these gene products include covalent modification of the drug or target, removal of the drug from the cells, or activation of an alternative pathway. To understand an organism's reaction to a drug or family of drugs, researchers must know which genes act on which set of drug compounds.

Scientists can detect the presence of a specific antibiotic resistance gene in a sample by using QIAGEN's Microbial DNA qPCR Assays and Assay Kits. These assays are highly sensitive and specific molecular analysis research tools, designed by a proprietary algorithm to test for the presence of microbial genes. The Microbial DNA qPCR Assays are a mix of two PCR primers and one 5'-hydrolysis probe that enables quantitative real-time PCR. They can screen for extremely small amounts of a target DNA sequence within a metagenomic sample.

Microbial DNA qPCR Assay Kits (BBXX#####A) are a complete solution for real-time PCR-based microbial detection. Microbial DNA qPCR Assay Kits contain a Microbial DNA qPCR Assay, Microbial DNA Positive Control, Positive PCR Control, Microbial DNA-Free Water, and Microbial qPCR Mastermix — everything required for a successful qPCR run. Each assay kit supplies enough material to perform 20 x 25 µl reactions.

Microbial DNA qPCR Assays (BPXX#####A) contain only the two PCR primers and hydrolysis probe and the accompanying mastermix that enables quantitative real-time PCR. However, each assay supplies enough material to perform 100 x 25 µl reactions.

Antibiotic and antibiotic resistance gene relationships

The following tables outline the relationships between antibiotic resistance genes and the drugs they target, including the generic and brand names of the drugs. Included in the right-hand column are Microbial DNA qPCR Assays and Assay Kits that specifically target these antibiotic resistance genes.



Aminoglycosides / Beta-lactams

The resistance genes for **aminoglycosides** (Table 1) encode for aminoglycoside acetyltransferases, adenylyltransferases, and phosphotransferases. The transferases and phosphatases act enzymatically on the drug compounds, leading to the inactivation of the drug.

Table 1. Aminoglycosides

Generic name	Brand names	Aminoglycoside resistance genes (cat. no. for Microbial DNA qPCR Assays; Assay Kits)
Amikacin	Amikin®	
Arbekacin	Decontasin, Blubatosine, Habekacin®	
Astromicin (Fortimicin A/B)		
Bekanamycin (Kanamycin B)		
Dibekacin		
Framycetin	Soframycin, Sofra-Tulle, Framycetin sulf	
Gentamicin	Garamycin®	aphA6 (BPAR00373A; BBAR00373A)
Hygromycin B		aadA1 (BPAR00370A; BBAR00370A)
Isepamicin (Isepamycin)		
Kanamycin (Kanamycin A)	Kantrex®	aacC4 (BPAR00369A; BBAR00369A)
Neomycin	Neo-Fradin	
Netilmicin	Netromycin	aacC2 (BPAR00368A; BBAR00368A)
Paromomycin (Monomycin, Aminosidine)	Humatin	aacC1 (BPAR00367A; BBAR00367A)
Ribostamycin		
Sisomicin (bactoCeaze/ Ensamycin)		
Spectinomycin	Trobicin®	
Streptomycin (Dihydrostreptomycin)		
Tobramycin	Tobrex®, TobraDex®, Nebcin®, Tobi®	
Verdamycin		

The **beta-lactam** resistance genes (Table 2) protect microorganisms by hydrolyzing the beta-lactam ring of various compounds, including penicillins, cephalosporins, and more. These genes are classified as groups based on function and classes based on sequence similarity.

Table 2. Beta-lactams

Generic name	Brand names	Beta-lactam resistance genes (cat. no. for Microbial DNA qPCR Assays; Assay Kits)
	Penicillins	
	Actimoxi, Alphamox, Amimox, AMK, Amocla, Amoksiklav, Amorion, Amoxibiotic, Amoxibos, Amoxicilina, Amoxiclav®, Amoxidal, Amoxidal, Amoxil®, Amoxin, Apo-Amoxi, Arsogil, Augmentin®, Bactox, Bioxidona, Cilamox, Clamoxyl, Clavamox®,	mecA (BPAR00374A; BBAR00374A) BES-1 (BPAR00375A; BBAR00375A) BIC-1 (BPAR00376A; BBAR00376A)
Amoxicillin (Amoxycillin)		

Beta-lactams

	Clonamox, Curam, Dedoxil, Defender, Dispermox, Duomox, E-Mox, Enhancin, Ezymox, Geramox, Gimalxina, Hiconcil, Isimoxin, Klavax, Klavocin, Klavox, Lamoxy, Largopen, MOX, Moxatag [®] , Moxilen, Moxypen, Moxyvit, Nobactam, Novamox, Novamoxin, Optamox, Ospamox, Pamoxicillin, Panklav, Pinamox, Polymox, Senox, Sinacilin, Skymox, Spektramox, Starmox, Tolodin, Tormoxin, Trimox [®] , Tyclav, Unimox, Wedemox, Wymox, Yucla, Zerrsox, Zimox, Zoxicillin	CTX-M-1 group (BPAR00377A; BBAR00377A) CTX-M-8 group (BPAR00378A; BBAR00378A) CTX-M-9 group (BPAR00379A; BBAR00379A) GES (BPAR00380A; BBAR00380A) IMI & NMC-A (BPAR00381A; BBAR00381A) KPC (BPAR00382A; BBAR00382A) Per-1 group (BPAR00383A; BBAR00383A) Per-2 group (BPAR00384A; BBAR00384A) SFC-1 (BPAR00385A; BBAR00385A) SFO-1 (BPAR00386A; BBAR00386A) SHV (BPAR00387A; BBAR00387A) SHV(156D) (BPAR00388A; BBAR00388A) SHV(156G) (BPAR00389A; BBAR00389A) SHV(238G240E) (BPAR00390A; BBAR00390A) SHV(238G240K) (BPAR00391A; BBAR00391A) SHV(238S240E) (BPAR00392A; BBAR00392A) SHV(238S240K) (BPAR00393A; BBAR00393A) SME (BPAR00394A; BBAR00394A) TLA-1 (BPAR00395A; BBAR00395A) VEB (BPAR00396A; BBAR00396A) ccrA (BPAR00397A; BBAR00397A) IMP-1 group (BPAR00398A; BBAR00398A) IMP-12 group (BPAR00399A; BBAR00399A) IMP-2 group (BPAR00400A; BBAR00400A) IMP-5 group (BPAR00401A; BBAR00401A) NDM (BPAR00402A; BBAR00402A) VIM-1 group (BPAR00403A; BBAR00403A)
Ampicillin	Principen [®]	
Azocillin		
Bacampicillin	Spectrobid, Penglobe	
Carbenicillin	Pyopen, Geocillin	
Carindacillin (Carbenicillin indanyl)	Geocillin	
Cloxacillin	Cloxapen, Cloxacap, Orbenin [®] , Tegopen	
Dicloxacillin	Diclocil, Dynapen	
Epicillin		
Flucloxacillin (Floxacillin)	Floxapen, Flopen, Staphylex, Softapen, Flubex	
Hetacillin	Hetacin [®]	
Mecillinam (Amdinocillin)	Coactin	
Metampicillin		
Methicillin (Methicillin)	Staphcillin	
Mezlocillin	Mezlin	
Nafcillin	Unipen	
Oxacillin	Bactocill, Prostaphlin	
Benzathine benzylpenicillin (benzathine penicillin)	Bicillin [®] L-A	
Benzylpenicillin (Penicillin G)	Pfizerpen [®] , Pentids	
Phenoxyethylpenicillin (Penicillin V)	Veetids [®] (Pen-Vee-K)	
Piperacillin	Pipracil [®]	
Pivampicillin		
Pivmecillinam (Amdinocillin Pivoxil)	Selexid, Penomax, Coactabs	
Sulbenicillin		
Temocillin	Negaban	
Ticarcillin	Ticar	
Amoxicillin/Clavulanate (Co-Amoxiclav)	Augmentin, Clavamox, Tyclav, Synulox, et al.	
Ampicillin/Sulbactam	Unasyn [®] , Ampictam	
Piperacillin/Tazobactam	Zosyn [®] , Tazocin, Brodactam, Piptaz, Maxitaz, Kilbac, Trezora, Biopiper TZ	
Ticarcillin/Clavulanate (Co-Ticarclav)	Timentin [®]	
Cephalosporins		
Cefacetile	Celospor, Celtol, Cristacef, Vetimast	
Cefaclor (Cefachlor, Cefaclorum)	Biocef, Ceclor [®] , Distaclor, Keflor, Raniclur	
Cefadroxil	Duricef [®]	
Cefalexin (Cephalexin)	Keflex [®]	

Beta-lactams

Cefaloglycin (Cephaloglycin)		VIM-13 (BPAR00404A; BBAR00404A)
Cefalonium		VIM-7 (BPAR00405A; BBAR00405A)
Cephaloridine (Cefaloridine)		ACC-1 group (BPAR00406A; BBAR00406A)
Cefalotin (Cefalothin)	Keflin	ACC-3 (BPAR00407A; BBAR00407A)
Cefamandole (Cephmandole)	Mandol	ACT 5/7 group (BPAR00408A; BBAR00408A)
Cefapirin		ACT-1 group (BPAR00409A; BBAR00409A)
Cefatrizine		CFE-1 (BPAR00410A; BBAR00410A)
Cefazedone		CMY-10 group (BPAR00411A; BBAR00411A)
Cefazolin (Cefazoline, Cephazolin)	Ancef [®] , Cefacidal, Cefamezin, Cefrina, Elzogram, Faxilen, Gramaxin, Kefazol, Kefol, Kefzolan, Kezolin, Novaporin, Reflin, Zinol [®] , Zolicef	DHA (BPAR00412A; BBAR00412A)
Cefbuperazone		FOX (BPAR00413A; BBAR00413A)
Cefcapene		LAT (BPAR00414A; BBAR00414A)
Cefdaloxime		MIR (BPAR00415A; BBAR00415A)
Cefdinir	Omnicef, Cefdiel, Cefzon, Cednir, Kefnir	MOX (BPAR00416A; BBAR00416A)
Cefditoren	Spectracef [®] , Meiact	OXA-10 group (BPAR00417A; BBAR00417A)
Cefepime	Neopime, Maxipime [®] , Maxcef, Cepimax, Cepimex, Axepim	OXA-18 (BPAR00418A; BBAR00418A)
Cefetamet		OXA-2 group (BPAR00419A; BBAR00419A)
Cefixime	Suprax [®] , Setic	OXA-23 group (BPAR00420A; BBAR00420A)
Cefmenoxime		OXA-24 group (BPAR00421A; BBAR00421A)
Cefmetazole		OXA-45 (BPAR00422A; BBAR00422A)
Cefminox		OXA-48 group (BPAR00423A; BBAR00423A)
Cefodizime		OXA-50 group (BPAR00424A; BBAR00424A)
Cefonidic (Cefonicid)		OXA-51 group (BPAR00425A; BBAR00425A)
Cefoperazone	Cefazone, Cefobid [®]	OXA-54 (BPAR00426A; BBAR00426A)
Ceforanide		OXA-55 (BPAR00427A; BBAR00427A)
Cefotaxime	Claforan [®]	OXA-58 group (BPAR00428A; BBAR00428A)
Cefotetan	Apatof, Cefotan	OXA-60 (BPAR00429A; BBAR00429A)
Cefotiam	Pansporin	OXA-62 (BPAR00430A; BBAR00430A)
Cefovecin	Convenia [®]	
Cefoxitin	Mefoxin [®]	
Cefozopran		
Cefpimizole		
Cefpiramide		
Cefpirome	Cefrom, Keiten, Broact, Cefir	
Cefpodoxime	Vantin [®] , C-Doxim, Simplicef [®] , Cefpo	
Cefprozil (cefproxil)	Cefzil [®] , Procef, Cronocef	

Beta-lactams

Cefquinome	
Cefradine (Cephadrine)	Velocef, Intracef, SEFRIL, REOCEF, Lebac
Cefroxadine	Oraspor, Cefthax-DS
Cefsulodin	
Ceftaroline fosamil	Teflaro [®] , Zinforo [®]
Ceftazidime	Cefzim, Fortum, Fortaz [®] , Cefidime
Cefteram	
Ceftezole	
Ceftibuten	Cedax [®]
Ceftiofur	Excenel [®]
Ceftiolene	
Ceftizoxime	Cefizox [‡] [®]
Ceftobiprole	Zeftera [®] , Zevtera [®]
Ceftriaxone	Rocephin [®]
Cefuroxime	Ceftin [®] , Zinnat, Zinacef [®] , Supacef, Xorimax, Turbocef
Cefuzonam	
Flomoxef	
Latamoxef	
Loracarbef	Lorabid [®]
Carbapenems	
Biapenem	
Doripenem	Doribax [®] , Finibax [®]
Ertapenem	Invanz [®]
Imipenem/Cilastatin	Primaxin [®] , CILASAFE
Meropenem	Merrem [®] , Merofit, Monan, Meronem
Panipenem	
Monobactams	
Aztreonam	Azactam [®] , Cayston [®]
Carumonam	
Nocardicin A	
Tigemonam	
Penems	
Faropenem	

Erythromycin / Quinolones and fluoroquinolones

The **erythromycin** resistance gene *ereB* (Table 3) encodes an erythromycin esterase, which hydrolyzes the macrolactone ring, thus enzymatically inactivating the drug compound.

Table 3. Erythromycin

Generic name	Brand names	Erythromycin resistance gene (cat. no. for Microbial DNA qPCR Assay; Assay Kit)
Erythromycin	Erythrocin®, Erythroped	<i>ereB</i> (BPAR00431A; BBAR00431A)

The genes conferring resistance to **quinolones and fluoroquinolones** (Table 4) have diverse molecular mechanisms, including altering DNA topology, performing enzymatic modifications, and acting as drug efflux pumps.

Table 4. Quinolones and fluoroquinolones

Generic name	Brand names	Quinolone and fluoroquinolone resistance genes (cat. no. for Microbial DNA qPCR Assays; Assay Kits)
Ciprofloxacin	Cipro®, Ciproxin, Ciprobay	QnrS (BPAR00441A; BBAR00441A)
Enoxacin	Almitil, Bactidan, Bactidron, Comprecin, Enoksetin, Enoxen, Enroxil, Enoxin, Enoxor, Flumark, Penetrex®, Gyramid, Vinone	QnrD (BPAR00440A; BBAR00440A)
Gatifloxacin	Gatiflo, Tequin, Zymar®, Zymaxid®	QnrC (BPAR00439A; BBAR00439A)
Gemifloxacin	Factive®	QnrB-8 group (BPAR00438A; BBAR00438A)
Levofloxacin	Levaquin®, Tavanic	
Lomefloxacin	Maxaquin, Okacyn, Uniquin	QnrB-5 group (BPAR00437A; BBAR00437A)
Moxifloxacin	Avelox®, Avalox, Avelon, Vigamox®, Moxeza®	QnrB-4 group (BPAR00436A; BBAR00436A)
Nalidixic acid	Nevigramon, NegGram®, Wintomylon, WIN 18,320	QnrB-31 group (BPAR00435A; BBAR00435A)
Norfloxacin	Noroxin®, Chibroxin®, Apiflox	
Ofloxacin (50:50 Levofloxacin:Dextrofloroxacin)	Floxin®, Ocuflor®, Floxin Otic, Optiflox, eylox	QnrB-1 group (BPAR00434A; BBAR00434A)
Trovafloroxacin	Turvel, Trovan	QnrA (BPAR00433A; BBAR00433A)
Grepafloxacin	Raxar‡	
Sparfloxacin	Spacin, Zagam, Zagam Respiripac	QepA (BPAR00432A; BBAR00432A)
Temafloroxacin	Omniflox‡	
Gatifloxacin	Gatiflo, Tequin, Zymar®, Zymaxid®	AAC(6)-Ib-cr (BPAR00366A; BBAR00366A)
Gemifloxacin	Factive®	
Levofloxacin	Levaquin®, Tavanic	oprm (BPAR00448A; BBAR00448A)
		oprj (BPAR00447A; BBAR00447A)

The molecular mechanisms of the genes conferring resistance to **macrolides, lincosamides, and streptogramins** (Table 5) include enzymatic modifications of the drug and their targets, as well as acting as drug efflux pumps.

Macrolides, lincosamides, and streptogramins / Tetracyclines

Table 5. Macrolides, lincosamides, and streptogramins

Generic name	Brand names	Macrolide, lincosamide, and streptogramin resistance genes (cat. no. for Microbial DNA qPCR Assays; Assay Kits)
Macrolides		
Azithromycin	Azithromycin	
Carbomycin	Carbomycin	
Clarithromycin	Clarithromycin	
Dirithromycin	Dirithromycin	
Erythromycin	Erythromycin	
Flurithromycin	Flurithromycin	
Josamycin	Josamycin	
Telithromycin	Telithromycin	
Cethromycin (ABT-773)	Cethromycin (ABT-773)	
Midecamycin	Midecamycin	msrA (BPAR00446A; BBAR00446A)
Miocamycin	Miocamycin	
Mitemcinal	Mitemcinal	mefA (BPAR00445A; BBAR00445A)
Oleandomycin	Oleandomycin	
Rokitamycin	Rokitamycin	
Roxithromycin	Roxithromycin	ermC (BPAR00444A; BBAR00444A)
Spiramycin	Rovamycine	
Troleandomycin	Triocetin, Tekmisin, Tao	ermB (BPAR00443A; BBAR00443A)
Tylosin		ermA (BPAR00442A; BBAR00442A)
Lincosamides		
Clindamycin	Cleocin [®] , Dalacin [®] , Lincocin [®] , Daclin	
Lincomycin	Lincocin	
Pirlimycin	Pirsue [®]	
Streptogramins		
Dalfopristin		
Pristinamycin (Pristinamycine)	Synercid [®] , Pyostacine	
Quinupristin		
Virginiamycin (Pristinamycin IIA / Virginiamycin M1 & Virginiamycin S1)		

The **tetracycline** resistance genes tetA and tetB (Table 6) encode for proteins that act as tetracycline efflux proteins. The efflux pump proteins prevent the accumulation of tetracycline in the microbial cell, resulting in sub-inhibitory concentrations.

Table 6. Tetracyclines

Generic name	Brand names	Tetracycline resistance genes (cat. no. for Microbial DNA qPCR Assays; Assay Kits)
Chlortetracycline	Aureomycin [®]	
Clomocycline		
Demeclocycline	Declomycin [®] , Declostatine, Ledermycin	tetA (BPAR00449A; BBAR00449A)
	Vibramycin [®] , Monodox [®] , Microdox, Periostat [®] , Vibra-Tabs [®] , Oracea [®] ,	tetB (BPAR00450A; BBAR00450A)
Doxycycline	Doryx [®] , Vibrox [®] , Adoxa [®] , Doxyhexal, Doxylin, Doxoral, Doxy-1, Atridox [®]	
Lymecycline		
Meclocycline		
Metacycline (Methacycline)		

Tetracyclines / Vancomycin

Minocycline	Minomycin, Akamin, Minocin [®] , Minoderm, Cyclimycin, Arestin [®] , Aknemin, Solodyn [®] , Dynacin [®] , Sebomin, Mino-Tabs, Acnamino, Minopen, Maracyn-Two [®] , Quatrocin, Minox [®] , Minoz, Divaine, Cleeravue-M
Oxytetracycline	Terramycin [®]
Penimepicycline (mepicycline penicillinate)	
Pipacycline	
Rolitetraacycline	
Tetracycline	Sumycin [®] , Achromycin V [®] , Steclin
Tigecycline	Tygacil [®]

The **vancomycin** resistance genes vanB and vanC encode for D-alanine-D-lactate ligases, which alter the terminal amino acid residues of the vancomycin targets, NAM/NAG-peptide subunits.

Table 7. Vancomycin

Generic name	Brand names	Erythromycin resistance gene (cat. no. for Microbial DNA qPCR Assay; Assay Kits)
Vancomycin	Vancocin	vanB (BPAR00451A; BBAR00451A)
		vanC (BPAR00452A; BBAR00452A)

Ordering Information

Product	Contents	Cat. no.
Microbial DNA qPCR Assays	One 100 µl tube Microbial DNA qPCR Assay, one 1.35 ml tube Microbial qPCR Mastermix	330025
Microbial DNA qPCR Assay Kits	One 20 µl tube Microbial DNA qPCR Assay, 1 tube Positive PCR Control (20 µl), 1 tube Microbial DNA Positive Control (50 µl), 1 tube Microbial DNA-Free Water (1.35 ml), 1 tube Microbial qPCR Mastermix (1.35 ml)	330033

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